SEASONS OUT OF BALANCE: CLIMATE CHANGE IMPACTS, VULNERABILITY, AND SUSTAINABLE ADAPTATION IN INTERIOR ALASKA

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SEASONS OUT OF BALANCE: CLIMATE CHANGE IMPACTS, VULNERABILITY, AND SUSTAINABLE ADAPTATION IN INTERIOR ALASKA

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Abstract

Koyukon Elders of Alaska's Interior observe that "cold weather is growing old" and recent warming is contributing to a world out of balance. Alaska is among the most rapidly warming places globally, with the Interior experiencing the most pronounced warming statewide, and with significant regional-scale ecosystem services disruptions affecting subsistence hunting and harvest success. Vulnerability of individuals, households, and communities to climate change is exacerbated by rising energy costs and a regulatory system that constrains the adaptive flexibility needed to cope with impacts on livelihoods. Socioeconomic and cultural change notwithstanding, the well-being of rural native communities is still dependant on access and ability to harvest wild foods, with moose the example explored in this study.

Over the last decade communities in the Koyukuk-Middle Yukon (KMY) region report an inability to satisfy their needs for harvesting moose before the hunting season closes, citing warmer falls, changing water levels, and the regulatory framework as primary causes. A combination of factors, including the complicated dual state/federal management system for wildlife and subsistence, creates uncertainties about the sustainability of moose populations and subsistence livelihoods in the region. By combining indigenous observations and understanding of climate and western social-natural sciences, this study examines the complex, multi-scaled interaction of climate change and subsistence livelihoods, with the goal of understanding vulnerability and adaptive capacity in the KMY region.

This research demonstrates that a recent trend during early fall results in seasonality shifts, where September is getting warmer and wetter and, most recently, temperatures during 2005-2007 were outside the normal, expected range of variability. The regulatory system lacks the flexibility needed to provide local hunters with sufficient opportunity to harvest moose. This complex interplay of climate, agency intervention, and rural community needs, increases vulnerability because of a "closing window" during the critical fall harvest. Sustainable adaptation requires collective, strategic action such as "in-season" management. It is argued that this approach will more effectively respond to

climate variability, and provide the necessary venue wherein wildlife management includes climate science with the human dimensions of subsistence. It is further argued that new research initiatives will build social and institutional capital between the local hunters and agency managers.

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DEDICATION

To My Mom

Michele Howard McNeeley

“used to be”

June 26, 1942 – February 1, 1991

And to Taz

“used to be”

December 1, 1990 – February 17, 2008

and Dakota

September 8, 2008 –

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Preface

My first visit to a remote Alaska Native village was in the spring of 2003 when I arrived to the Koyukon Athabascan village of Huslia (population 277) on the Koyukuk River. I had already been working in Alaska as an associate scientist for the National Center for Atmospheric Research exploring the feasibility of an "Alaska Climate Affairs" higher education program. My interest was to develop a program that integrated social and natural sciences along with indigenous and scientific ways of knowing (adapted from the Climate Affairs model developed by Dr. Michael Glantz). Through this exploration I realized that there was still a lot of work to be done – both personally and within academia – in Alaska to even establish a critical mass of baseline research on the topic before this kind of program could be developed. So I decided instead to turn my focus toward doing research myself, working in collaboration with Alaska Native communities. It was during this transition that I received the invitation to Huslia to attend the workshop on Changes in Weather, which would catalyze me to write a proposal for a community-based research project documenting Alaska Native Elders' observations on climate change in the Interior of Alaska.

In the winter of 2004 I began traveling to various villages in the Koyukuk-Middle Yukon (KMY) region to present my ideas to the tribal councils and ask for their support and partnership in the project. The timing was impeccable as the village Elders were increasingly voicing their concerns about the changes they were witnessing and a series of workshops between scientists and Koyukon communities were taking place in Huslia on changes in weather and fires. This was also the time when warming impacts on the fall moose hunt were increasingly problematic in the region, and a topic of interest for not just people in the villages, but for government agencies as well since the issue was surfacing in the wildlife and subsistence regulatory setting.

In the fall of 2004 there was a convergence during the moose hunting season of warming climatic conditions with social, political, and ecological events and conditions that affected the ability of subsistence hunters in the region to successfully harvest moose. Warmer falls continued for the next three years from 2005 through 2007, so the issue became increasingly urgent as communities had difficulties harvesting this most critical subsistence food. Conflict arose over how to devise solutions for this problem, and this became the focus of this research as the reader will see in chapters five and six. So, exactly at the time I was interested in this topic, it was on the minds of many people in the region, and growing in importance with each passing year with many unanswered questions about climate trends.

When I first started working in the KMY region I went with a lens to investigate climate change observations, impacts, vulnerability, and adaptation. Yet I came away after many periods of village work from 2003 through 2008 with a new understanding of social-ecological relationships based on the wisdom learned from the Elders about life, love, human relations to each other and to the natural world, and about what has sustained the Koyukon for millennia. It is the Koyukon worldview based on a deep respect and close relationship with Nature that sustains them today despite contemporary health problems, periodic food shortages, and the sometimes overwhelming social, political and economic problems that threaten their livelihoods in modern times. The Koyukon are a society that depends directly on harvesting natural resources in a region where warming effects are already tangible; and I came to find out early on that they are among the best teachers in the world for understanding how climate change is affecting our planet. They taught me the importance of looking outside the traditional academic boundaries of science for understanding, while at the same time being able to integrate and reconcile very different ways of seeing the world.

As I look back over the entire six years of this project from 2003-2009, my confidence to finally tell this story is found in the advice, guidance, and enduring support of my teachers and collaborators, Koyukon and non-Koyukon alike. One of the things that makes this research special is the widespread collaboration with stakeholders across the spectrum. I collaborated with tribal councils and communities, Koyukon Elders and youth; with state and federal agency biologists, subsistence specialists, and refuge mangers; as well as with ecologists, anthropologists, and climatologists. It was only thanks to these collaborations that this work was made possible. I must give special credit, though, to the Koyukon Elders who let me into their lives and hearts, and who shared with me their stories and highly sophisticated and wise understanding of the world that will stay with me forever, and I hope that in turn I will be able to give something back to them through this work. They taught me what it means to live in harmony with the natural world by watching and listening to the enduring wisdom of the Earth and its wild inhabitants. It was the Koyukon Elders who taught me to pay attention to the signs in Nature that speak to how humans are now creating a world that is out of balance. To me, after having had this experience, it is clear that there is possibly no more subtle, yet profound warning of this imbalance than the seasonality shifts and environmental changes happening in the Interior of Alaska from recent decades of a warming planet.

Chapter 1: When the Cold Weather Grows Old

Old timers, I used to listen to old timers lots, you know, and they tell us that the weather is going to get old; it's going to stay warm all the time in years to come. And that's what's happening now. Right now it's happening. Winter - like in the fall time it stays warm until way in November sometimes. Hardly go out anymore. Long time ago it used to get cold right away, freeze up, and we would go out with dog team. – Tony Sam, Huslia Elder (Sam 2004)

Chief Henry used to say k'ukkʉtl ełeyonh *meaning 'the cold weather has aged'* – *because they could remember when they were children when it was so super cold. But even in their time it wasn't as cold as it used to be or the stories that they used to hear. That the weather was so cold that there were times that people were traveling, and when they were traveling it was so cold the dog's tail would freeze off. And they'd pick up the dog tail and put the dog tail around their neck to keep warm.* – Eliza Jones, Koyukuk Elder (Jones 2005)

Introduction

As one travels by bush plane over the remote northwest Interior of Alaska it appears to be untouched by humans. Vast expanses of boreal forest, meandering rivers and sloughs, lakes, mountains, and wetlands stretch to the horizon in every direction. The valleys and flatlands of the Koyukuk-Middle Yukon region of the Interior are comprised of wetlands that provide excellent habitat for waterfowl, fish, and water mammals such as beavers and muskrats. Forests are mostly spruce, willow, and birch trees, where moose, bears, and wolves roam. The uplands of tundra and mountain ranges are where the caribou herds pass by seasonally on their annual migrations. Occasionally from above one will spot a tiny village along the riverbank, villages with anywhere from 30 to 600 people.

This is Koyukon Athabascan country where the small, remote, rural villages in the region are still populated with mostly Koyukon Athabascans and a minority of Iñupiaq Eskimos and non-Alaska Natives.

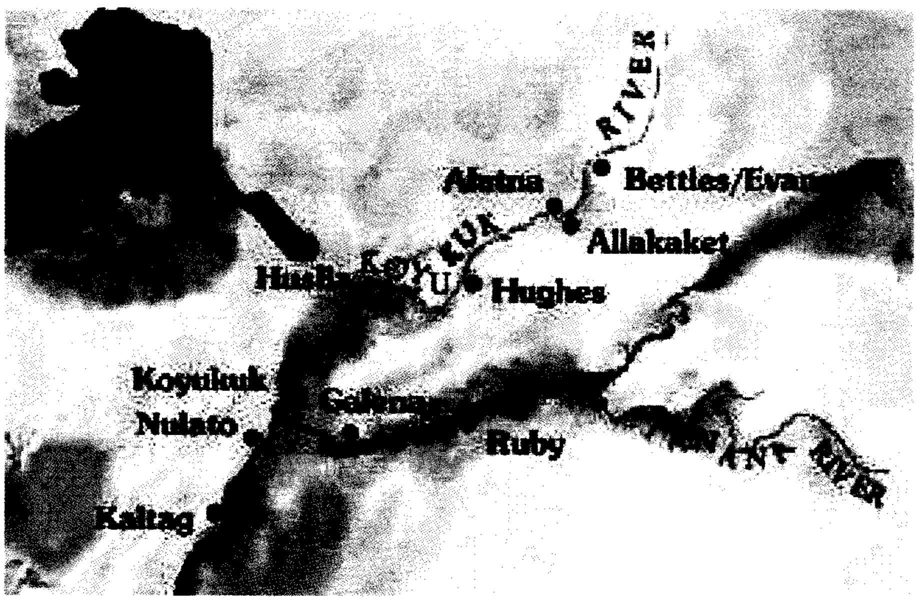

Figure 1 Map of the Koyukuk-Middle Yukon Region courtesy of the Yukon-Koyukuk School District

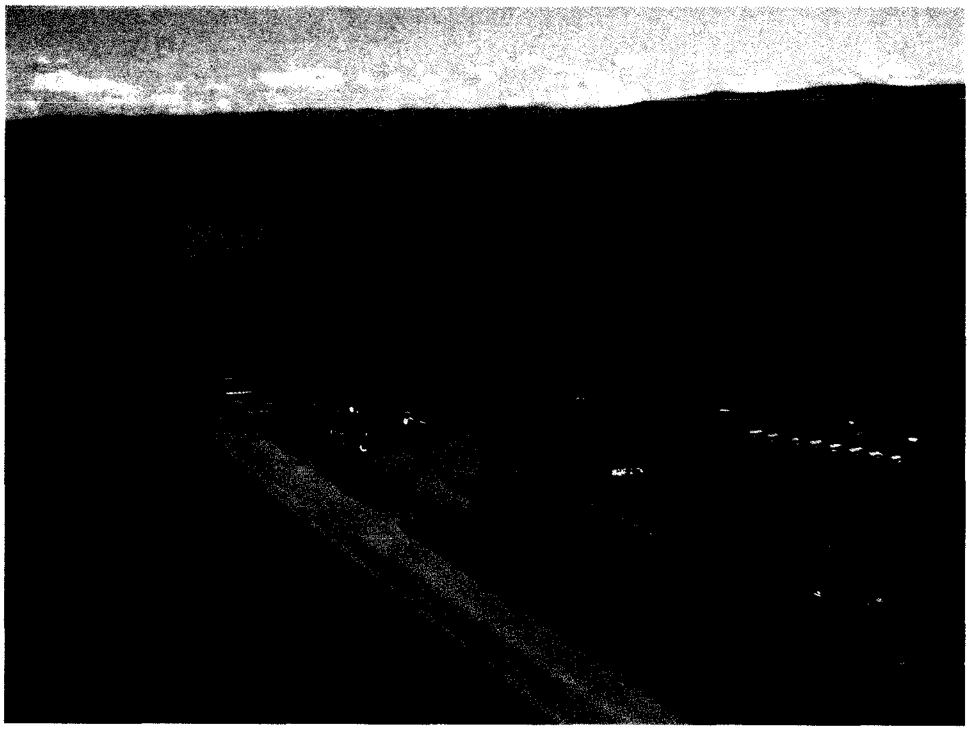

Figure 2 View from the plane above Hughes native village

This is their homeland, it is where they live today, and it is where their ancestors have lived, roamed, and survived for thousands of years. This country is not just their home and their source for sustenance, but is also their teacher. It has taught them the lessons of stewardship for the Earth – patience, humility, respect, reciprocity, and luck (Nelson 1983). They have tread lightly upon these lands, and their experiences and stories today reflect a long-standing and healthy cultural, social and ecological relationship to this land and to each other.

I came to work with the Koyukon by way of an invitation in May 2003 to attend a workshop in the village of Huslia on changes in weather. The purpose of this workshop was to bring together scientists and Elders to share their respective observations of changes in weather and climate. The Elders who had been observing the changes in their region wanted to know from the scientists why these changes were happening. The scientists were interested in learning more about changes on the local and regional scale that the Elders observed. One of the objectives of this workshop was to catalyze collaborative research initiatives between the Koyukon and scientists of which my work became one of those projects. I worked with village collaborators to develop a proposal for a community-based, participatory research project to document Elders' observations and understanding of changes in climate, and per the invitation of the tribal councils of Hughes, Huslia, and Koyukuk began in the winter of 2004.

Between 2003 and 2008 I made multiple field visits in all seasons to almost all the villages in the KMY region to conduct interviews, hold focus groups and community meetings, give update presentations and receive village input for the research, attend tribal and regulatory meetings, and to spend time participating in cultural events and subsistence practices. I had formal partnerships with three of the tribal councils in Hughes, Huslia, and Koyukuk, therefore, I spent the most of the time in those three villages. However, I also spent considerable time in Galena and made brief visits to Nulato, Ruby, Bettles/Evansville, and Tanana to participate in wildlife and subsistence regulatory meetings.[1] The duration of field visits were anywhere from a week to two months at a time. In other words, I spent a substantial amount of time over five years getting to know the Koyukon people and the region as a whole.

I focus on climate change throughout the dissertation, but the broader story must be shared to fully show how the rich social and cultural fabric is combining today with the political and economic changes and challenges that structure the vulnerability and adaptation of this group of people and their responses to a changing environment. I will try to share this understanding as fully as I am capable given my own life experiences, training, maturity, and given my time spent with the Koyukon (Morrow 2003).

[1] I also spent two months living and working in the Yukon Flats region in the villages of Fort Yukon, Beaver, and Chalkyitsik in the summer of 2005. I was working for the Council of Athabascan Tribal Governments interviewing Elders about climate change, which was originally intended to be part of this study. However, I made the decision ultimately to focus only on the Koyukuk-Middle Yukon region for the dissertation.

Climate Change Vulnerability, Adaptive Capacity, and Sustainable Adaptation

Vulnerability to Climate Change

Climate change impacts, vulnerability, and sustainable adaptation are best understood in the context of changes to resource flows - especially the key resources - that are critical for sustaining livelihoods (IISD 2003). A perspective on vulnerability that focuses on human well-being is defined as:

> an aggregate measure of human welfare that integrates environmental, social, economic, and political exposure to a range of potential harmful perturbations (Bohle et al 1994).

Resource-dependant societies (RDS) are especially vulnerable to climate shifts where alternatives to subsistence harvesting are extremely difficult or impossible to obtain on appropriate timescales or where the quality of these alternatives is insufficient for well being. One can correctly argue that all humans are "resource-dependant societies." However, here I refer to societies that obtain a significant portion of their diet by direct harvesting of wild foods from their natural environs (Thomas & Twyman 2005). In this case, I am specifically referring to the harvesting of food that is hunted, fished, trapped, or gathered and goes straight to the harvesters' and their family/community freezers and tables without traveling through other channels of the mass food production system. In Alaska the short-hand for this is "subsistence," however, this term is often contested for political reasons where power relations are unequal and resource access and control differentially distributed (Morrow & Hensel 1992). This is especially true in Alaska where the state of Alaska legally considers all Alaska residents eligible for subsistence designation for hunting whether one is native or non-native living in either rural or urban locales.

Herein, I will use the terms resource-dependant societies and subsistence interchangeably to refer to rural, primarily Alaska Native (though not exclusively) remote communities, often referred to colloquially as "The Bush." Remote, rural Alaska is generally the part of Alaska that is off the road and marine highways system (referred to here together as "the road system") and is characteristically and economically distinctive from the rest of the state (Goldsmith 2007). By standard economic measures such as personal income remote, rural Alaska compared to communities on the road system is significantly less wealthy (ibid). For these communities, the lasting ability to retain access to important ecosystem services through the harvesting of wild foods by hunting, fishing, gathering, and trapping is fundamental to sustainable livelihoods as well as adaptation to climate and socioeconomic change (Berger 1985; Nuttall 2005).

Vulnerability to climate change is the susceptibility of a social-ecological system to suffer negative effects from the stresses or hazards resulting from a changing climate. The study of vulnerability specifically to *climate change* has recently become a burgeoning area of scholarship, though its roots trace back at least two to three decades. These roots are found in several different disciplines or bodies of research such as vulnerability of people and places to environmental hazards and risks (Cutter 1996; Kasperson et al 1988), development and food security (Adger & Kelly 1999; Bohle et al 1994; Chambers 1989; Sen 1981), and global environmental change (Schneider et al 2007; Watson et al 1997).

Research on vulnerability can be largely divided between studies that focus on developing nations and those that focus on risk management in developed nations. There are comparatively few studies that focus on the vulnerability to climate change in poor or "developing" groups or communities in wealthy nations. Some of the best examples are found in the Arctic region (Berkes & Jolly 2001; Ford et al 2007; Krupnik 1993; McCarthy & Martello 2005; Newton 1995; Rattenbury et al 2009). Yet these studies are not yet highly visible in the broader national or international science or policy arenas. This lack of focus on vulnerable communities in wealthy nations is problematic for several reasons. One reason is that for researchers working with marginalized communities in rich nations like the United States, it is difficult to find good models or examples of previous studies that fall into this category. The second problem is that in international negotiations on climate change the debate is often framed in the classic

"North-South[2]" divide, with the emphasis for development and/or adaptation resources placed on poor or developing *nations,* not people – and so the very structures that exist in rich countries that create the inequalities in the first place remain largely unaddressed, and the marginalized groups, communities or nations continue to be left out of the research, agenda, excluded from aid, and ignored or overlooked with respect to the development and implementation of policies for adaptation to climate change.

The focus here is on vulnerability of Alaska Native livelihoods to climate change, which would fall into the category of marginalized communities in a wealthy nation. I use a sustainability science approach to look at social-ecological vulnerability and adaptation. Sustainability science explicitly employs an interdisciplinary (social-natural sciences), place-based approach to vulnerability analysis with a goal of understanding human-environment interactions in order to meet the needs of society while sustaining the Earth's natural life support systems (Kates et al 2001; Turner II et al 2003). In other words, the overarching goal of sustainability science is to do science that serves society by approaching it with a more applied, policy-oriented, and integrative fashion to help address the increasingly complex problems of humans sustaining healthy, productive, sustainable ecosystems.

Human systems can be highly resilient to certain events in the short-term while that very "resilience" can create unintended consequences or conditions that make a system highly vulnerable to other events and/or on longer time scales that can threaten sustaining livelihoods (Holling et al 2002). One relevant example from remote, rural Alaska is the widespread dependence on fossil fuels and outside sources of income that have enabled modern-day Alaska Native communities to become more resilient for many decades to most environmental and economic shocks. Now, however, with rising fuel costs, rising temperatures, and a global economic downturn, they are highly vulnerable due to that very dependency. During the winter of 2008-2009 many rural, native villages in western and southwestern Alaska experienced food insecurity and great hardship after

[2] The North-South discourse refers to northern latitude developed or rich countries such as the U.S. and Europe while the "South" represents developing or "third world" poor countries.

the cumulative effects of bad salmon runs, high energy prices, and unexpected climate conditions that cut off supplies of fuel by barge (during the fall of 2008) (Hopkins 2009).

Vulnerability is not a "state" but rather a set of complex interacting social-ecological variables and conditions that are dynamic and continually changing based on both internal and external dynamics in any point in time (Adger & Kelly 1999; Dow 1992; Handmer et al 1999; O'Brien et al 2004a). In other words, vulnerability to climate change is a *convergence* of *relative* social, ecological, and climatological factors that change over time and therefore are very difficult to capture through quantitative measurements (Luers 2005; Luers et al 2003; O'Brien et al 2004a).

Multiple conceptual frameworks exist to analyze or assess vulnerability of social-ecological systems (Eakin & Luers 2006; Polsky et al in press). Decisions about vulnerability and adaptation are essentially place-based/context-specific and require the incorporation of local ways of knowing and understanding. As such decisions must also incorporate multiple, often competing, interests and goals into the decision making context (Vogel et al 2007). The incorporation of understanding and accounting for the multiple socio-economic, environmental, political stressors that underpin, exacerbate or drive the vulnerability of any social-ecological system of interest is required (McCarthy & Martello 2005). These complexities create challenges for scaling up results from local to larger-scale assessments and/or finding broader understanding and utility of the science for appropriate policy recommendations at the regional, national, or international levels of government.

Academic debates about how best to conceptualize vulnerability and adaptation for assessment notwithstanding, it is generally agreed that vulnerability to climate change is *determined* by two things: 1) the *exposure* of the social-ecological system of interest to climate stress combined with 2) the *sensitivity* or ability of the system to cope with and adapt to the disturbance (Adger 2006; Ford et al 2006; Smit et al 2000; Smit & Pilifosova 2003; Smithers & Smit 1997; Turner II et al 2003). Exposure is the nature and degree to which a system is *exposed to* significant climate variations or the specific biophysical phenomenon or climate stimulus (such as drought, hurricanes, seasonality shift, etc.).

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli given the socio-economic attributes of the social system (Adger et al 2004). The exposure/sensitivity matrix of a society includes the societal conditions that affect its own exposure (such as location in a region of rapid climate change), and the ability of the community to absorb the stress through effective responses, mitigation of damage, or adaptation (Ford et al 2006; Smit & Pilifosova 2003). An exposure unit could be a region, population or groups, community, ecosystem, country, economic sectors, household, business, or individual (Adger et al 2004).

In the study of the human dimensions of environmental change sensitivity refers to the susceptibility of a system to climatic stress, and specifically refers to socio-economic and cultural factors. Some view it as a "precondition" to vulnerability (O'Brien et al 2004b), while others include the response capacity as part of sensitivity (Luers 2005), though the latter tends to blur sensitivity with adaptive capacity and/or resilience. Sensitivity is ultimately about how much a given system is affected by any change in the normal range of climate conditions within the coping capacity of that system.

By "coping capacity" I mean the ability to tolerate a certain range of climatic conditions within a social-ecological system without suffering severe hardship or threatening overall well-being. A system can cope with certain deviations from average conditions, but only within limits of a certain magnitude and frequency (Smit et al 2000). The coping range, of course, is not uniform with discrete boundaries as it is usually represented (Figure 3). Any system is dynamic across time and space, and thus coping thresholds are non-linear and changing.

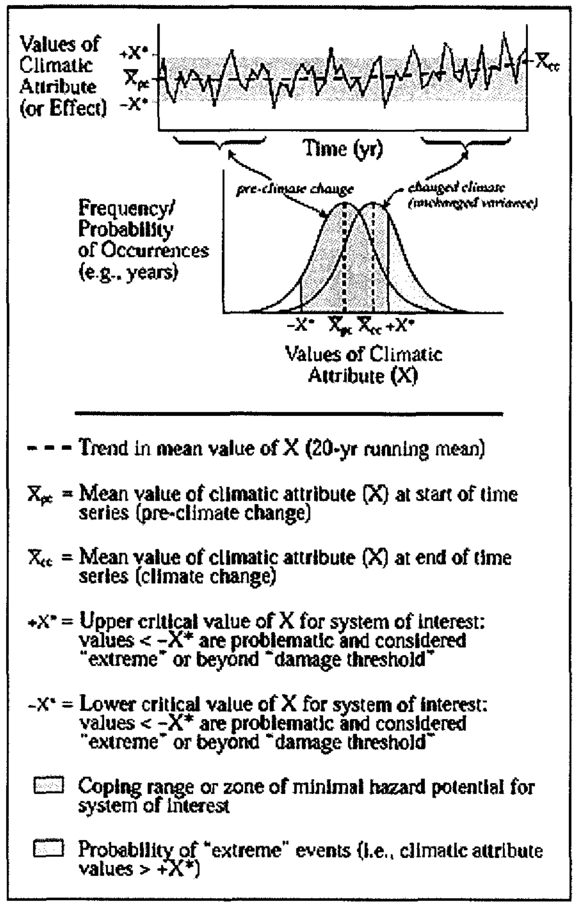

Figure 3 Coping range diagram from (Smit & Pilifosova 2001)

The concept of a coping range, (while difficult to define boundaries that reflect reality) provides a heuristic to conceptualize how a system is vulnerable to conditions that fall outside some range of "normal" or expected climatic conditions. Climatc changes that cause seasonal conditions or extreme events to fall outside of the coping range challenge a systems' adaptability or response capacity. Any system's coping range is spatially and temporally scale-specific, though a goal in vulnerability analysis is to understand where the thresholds might be exceeded to plan for serious consequences of future climate change. Events that breach a threshold are thought of as *extreme events* though they can be more subtle seasonality shifts as I will demonstrate in chapters five and six.

To think of coping range only in terms of extreme events is an over-simplification where more subtle seasonal shifts occur, or where climate stressors' impacts accumulate over time. Instead of focusing only on "hazards" or discrete events we must also account for slow-onset, "hazardous" conditions, sometimes referred to as "creeping environmental problems" (Glantz 1999). In Alaska temperature, rainfall, or snowfall changes cause conditions such as unstable ice, changes in the habits, distribution or abundance of animal populations, or difficulties in the ability to access certain resources; this can be much more important to everyday life and overall food security relative to rarer, situational extremes such as fires or floods. In other words, vulnerability to extremes is important, but often risks are spread out over time and vary in terms of severity. Vulnerability to slower-onset problems that affect safety when out on a landscape and success in hunting, fishing and other subsistence activities are more important in this case study.

In some cases, as in the one I will present here, exposure is not dramatic, and sometimes even so subtle as to be easily overlooked when conventional statistical analysis applied, or worse, when climate considerations are viewed as relatively unimportant in a larger context when competing interests, agendas, concerns or paradigms prevail. Where exposure is small or subtle, but the exposed system is highly sensitive to seasonal shifts, how do we conceptualize the role and importance of sensitivity when assessing vulnerability? To start we look at the range of stressors and involve the local stakeholders themselves in the study combined with the examination of the adaptive capacity of actors in that system to implement collective, strategic action.

Determinants of Adaptive Capacity for Climate Change

Capacity implies *potential*; adaptive capacity is considered to be the potential of a system or group such as a community, city, region, state, etc. to respond to climate change and is determined largely by economic wealth, technology, information and skills, infrastructure, functioning institutions, social and institutional capital, and equity (Smit & Pilifosova 2003). The broader context of a community's range of inputs and outputs, external and internal stresses make up the context within which adaptive capacity is situated. This sets the context and capability to deal with shocks and stresses caused by the climate system, and constrains or enhances the resources on hand to cope as well as the allocation and use of those resources. Multiple and competing stressors influence the degree to which capacity is reduced or enhanced (McCarthy & Martello 2005). For complex problems such as climate change it is critical for decision- and policy-makers to understand, process, and communicate information with a public that has diverse attributions based on differing worldviews (O'Brien et al 2004a) and is a hallmark of institutional capital for adapting to climate change.

Capacity is embodied in the resources that maintain livelihoods ("livelihood assets") and comes from material and social goods or capital in the form of natural capital (i.e., ecosystem services), social-political capital, human capital, physical capital, and financial capital (IISD 2003). Physical (i.e., infrastructural) and financial capital are the easiest to understand and measure in basic economic terms. Human capital refers to the wealth of skills, knowledge, and ability of individuals within a society to work or provide labor. Natural capital represents the capacity of ecosystems to provide services that are beneficial to society (Daily 1997; Millennium Ecosystem Assessment 2005a). The least well-understood or developed is the concept of social capital, yet it is critically important for understanding adaptive capacity to climate change, especially when viewed in relation to regulatory and management issues.

Social capital is a concept that has been around in the social sciences for some time and has only recently been applied to adaptive capacity to climate change (Adger 2003). Generally, social capital refers to the relationships and social networks, agreements, flows of information and features of social organization such as trust, norms, and networks that can facilitate coordinated actions to achieve social benefits and facilitate well-being and security (Adger et al 2004; Fukuyama 2003). It is a societies' ability to act collectively that allows it to utilize its inherent capacity to adapt to climate change (Adger et al 2004). While social capital makes conceptual sense, it is much harder to operationalize and examine in practice as it entails processes that are largely immeasurable (e.g., knowledge, communication, trust, legitimacy).

A closely related concept is that of institutional capacity, which has to do with ability of institutions to build capacity, to buffer risk, and to facilitate planning more effectively for necessary change. The more conventional "institutional view" of social capital used by Ostrom and others (Ostrom & Ahn 2003) holds that the capacity of social groups to act on their collective interest depends on the formal institutions under which they reside. This view holds true, in part, but for marginalized communities such as indigenous communities in the Arctic and Subarctic adaptive capacity often exists internally in the form of the knowledge, customs, and practices with effective transmission across generations, yet a rapidly changing environmental and social milieu, including severed ties to traditional knowledge, erode this capacity. Traditional skills and knowledge for survival and success on the landscape harvesting resources can provide capacity through solutions stored in the reservoir of collective social memory (Davidson-Hunt & Berkes 2003; Ford et al 2006; McIntosh et al 2000). Enduring social networks and practices such as food sharing provide added capacity not often found in modern, affluent societies (Ford et al 2006). In times of need, kinship and close community ties provide a risk buffer against hardships through the distribution of food, goods, and wealth between the haves and have-nots. Community action in times of crisis such as floods, for example, provides a safety net (or added capacity) to help respond and cope with hazards. Ford et al (2006) discuss this concept with the case of the Inuit in Arctic Bay and how they respond to climatic stress through these traditional mechanisms:

> A sense of collective community responsibility and mutual aid; sharing remains an affirmation of Inuit cultural identity. These networks facilitate the sharing of food, equipment, knowledge, and ensure rapid response to crisis...During periods of scarcity or environmental stress, the success of one person benefits others who are part of the extended family sharing network. Moreover, with changing climatic conditions making certain areas inaccessible to people who do not have

the equipment, money, knowledge, or time, shared food underpins country-food security, if not economic security.

Anything that restricts peoples' ability to have a reservoir of options from which to choose when conditions change restricts adaptive capacity (Berkes & Folke 1998; Gunderson & Holling 2002). The need to identify public policies, regulatory measures, and institutional arrangements that impede flexibility of options remove such impediments is a critical but perhaps still unrealized piece of building adaptive capacity (Smithers & Smit 1997). In these societies where natural resource harvesting is still central to livelihoods larger-scale policies and institutions oftentimes either exacerbate vulnerability or undermine adaptive responses to harmful change (Thomas & Twyman 2005). In the case of Arctic indigenous people, harvesting is opportunistic and depends on the ability to make ad hoc changes in strategies, as well as to make substitutions when certain resources are scarce or unavailable (Ford et al 2006; Nuttall 2005). Flexibility in options to respond to environmental variability and change is an important component of adaptive capacity (Ford et al 2006; Thomas & Twyman 2005). Flexibility has to do with options, ability to diversify, innovate, and ability to take advantage of different options moving both in physical space and economic and political space without constraints of the regulatory system (Holling 1978; Lee 1999; Thomas & Twyman 2005).

Determinants of Social-ecological Adaptation to Climate Change

What is adaptation to climate change? Adaptation to climate change in human societies is about responding to climate stimuli not just after the fact, but anticipating and planning for potential changes (Smit et al 2000), especially where early warning signs are present (Glantz 1988). Adaptation is a *fundamental, systemic change* in response to environmental conditions, change through adjustment that maintains, preserves or enhances the *viability* of the system (Smithers & Smit 1997). This definition expands the notion of adaptation of human societies to climate change to incorporate the general concept of a proper functioning of social, ecological and institutional systems and includes a range of human activities that enhance well-being or quality of life. This definition also leaves room to incorporate notions of strategic, purposeful action in order to avoid the negative consequences of a societies' own actions; it requires the examination and questioning of the status quo for necessary change (Bennett 2005).

Barriers to Sustainable Adaptation

Social maladaptation occurs when internal factors of a the social structure (as distinguished from the cultural system) prevents appropriate, adaptive responses in the face of perturbations to the social-ecological system (Rappaport 1978). This is often a result of social complexity that inherently gives rise to institutional complexity with myriad, conflicting interests that lead to gridlock in sustainable collective action (Bennett 1996). For example, problems arise when high-level decision makers with the most power are disconnected from the cultural and environmental context and from changes that underpin the productivity of a social-ecological system (Redman 1999). This is equally true in Alaska where there is a chasm between policy makers in Juneau, Anchorage, Fairbanks, and Washington D.C. and those who live in the small, rural communities off the road system, communities with comparatively little infrastructure and relatively little political influence. This ongoing tension between urban centers of power and rural livelihoods endures in Alaska and is central to issues of sustainability for Alaska Natives who choose to live in their ancestral lands. As societies and their institutions become more complex and fragmented with respect to wealth distribution and social inequities, common problems occur in decision making, problems that include but are not limited to the inability to detect deviations in variables from mean conditions or critical ranges, disconnects or breaks in feedback loops of knowledge, distortion of information between channels of decision makers, and misunderstanding of information received by decision makers (Rappaport 1978; Redman 1999).

John Bennett (1996) defines the "adaptive nexus" to conceptualize the relationship between present goals and past precedents, which becomes problematic when past precedents become outdated because of new or different socio-environmental changes. I will look at one such adaptive nexus in my analysis (chapter six) with regard to wildlife and subsistence management goals that endure, regardless of changing conditions and the difficulty of managers to respond effectively given the lack of flexibility within the system in which they work.

In the Arctic and Subarctic, subsistence hunting remains an opportunistic endeavor that requires flexibility to harvest what is available in time and space, and the ability to make ad hoc adjustments when necessary to take advantage of game availability given local seasonal conditions (Ford et al 2007). When hunting regulations restrict this flexibility, harvest success is affected, and frustration, conflict with government officials, agency managers, and/or "outsiders" who encroach on subsistence resources inevitably arises (Nadasdy 2003). This type of conflict inherently hinders the ability to engender the types of collaborative efforts required to develop sustainable adaptation measures.

Sustainable Adaptation

It is important that we are talking about *sustainable* adaptation, as adaptation on its own does not necessarily imply favorable change. Nor does it imply sustainable change. Sustainable adaptation to climate change requires *strategic, collective action* to respond to and anticipate harmful climate change impacts that have the potential to disrupt key resource flows and to reduce general well being. Present and future vulnerability depend on livelihood assets, including social capital, resources that are equitably allocated, and healthy, functioning institutions legitimized through integration into wider social goals that will drive toward sustainable and adaptive outcomes (Tompkins & Adger 2004).

Sustainable adaptation implies purposive action to sustain ecosystem services and a balanced relationship between humans and their natural milieu given the likelihood of continued climatic warming and potential variability in climate, weather, seasonality, and related extreme events in the future. This will require continual, collective efforts to create institutions and rules of behavior that are able to respond to stressors in a flexible way, given the uncertainty and lack of complete information that chronically conditions response mechanisms available to local communities.

Sustainable adaptation opposes rigid adherence to any policy, strategy, technology, or paradigm that become irrelevant when conditions change. This requires incorporating flexibility into the system of response to uncertain and changing conditions – this in itself is an adaptation in human society. Flexibility is historically a key attribute or determinant to highly adaptable societies, and remains an important determinant for sustainable adaptation strategies today. This includes flexibility not only in physical space, but also in policy and economic space that leave "room for maneuver" for the creative innovation and resourcefulness that are so important to subsistence livelihoods, while upholding principles of equity and social justice (Thomas & Twyman 2006).

Policies and regulations for reducing risks to climate threats are most sustainable when "mainstreamed" into existing decision making and policy goals such as resource and subsistence management (Ford et al 2007; Smit & Wandel 2006). Adaptation measures based solely on technical or engineering solutions are rarely identified in the climate change adaptation literature as priorities over management improvements such as greater institutional commitment and capacity to support existing policies or regulations (O'Brien et al 2004a). This has proved to be especially true for adaptive responses that have been and continue to be successful for Arctic indigenous peoples such as flexibility in relation to seasonal cycles of harvest and resource use, oral traditions that provide social-ecological memory, detailed environmental knowledge and skills sets and sharing mechanisms, social networks, and intercommunity trade that minimize risk (McCarthy & Martello 2005). Yet all of these important characteristics are threatened today by the rapid pace of social complexity on a warming planet.

Analytical Framework and Approach

The conditions that determine vulnerability, adaptive capacity, and sustainable adaptation are *relative* in nature and *dynamic* over time, making the assessment of vulnerability challenging since it requires a knowledge of the past, time-depth, and historical proxies that are not always available and not all equally informative (Redman

1999). This justifies the need to look at vulnerability assessment as a long-term endeavor and highlights the need to view any assessment as providing a baseline "snapshot in time" of current vulnerabilities against which to compare other systems, regions, or future scenarios of potential conditions based on projections of a warming climate. Environments and ecosystems change over time, but so do the technological, political, institutional, economic and cultural factors that shape vulnerability, meaning in turn that the *analysis* of vulnerability and adaptation must be dynamic and evolve over time in response to changing circumstances (Adger & Kelly 1999).

For this research I implemented an interdisciplinary, participatory approach through the synthesis of multiple ways of understanding and analyzing the world. Through collaborations and partnerships with various indigenous experts, scientists, and wildlife agency staff, my role as the Principle Investigator of my research was to integrate these analyses to arrive at the final results. This approach necessarily required the involvement of stakeholders and collaborators in the work to be able to have both the breadth and depth needed to answer my research questions that I will outline below (Drew & Henne 2006). Interdisciplinary can mean many different things depending on the project needs, disciplines used, and the personal creativity of the lead researcher and those of the collaborators. At its most basic level, interdisciplinary research (IDR) is defined by the National Academy of Sciences as:

> a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice (National Academy of Sciences 2004).

I employ a hybrid approach to this research, integrating literature (such as ecological anthropology, indigenous knowledge, human geography, moose ecology/biology, and climatology), methodology, methods, and data from across the *social and natural* sciences. This approach, while extremely challenging, leaves greater flexibility to adapt and add to the existing approaches of vulnerability analysis to better suit the unique conditions of this case, while still seeking to contribute more broadly to general issues of vulnerability and adaptation (Eakin & Luers 2006).

Indigenous Observations and Understanding of Climate (IC)

I join local and indigenous insights, knowledge, and observations about climatic changes with instrumental observations of weather station data. For ease of understanding when working with climate scientists and multiple stakeholders, I use the term indigenous observations and understanding of climate (IC) when talking specifically about observations of weather and climate. There are many terms widely used in the literature such as traditional knowledge (TK), traditional ecological knowledge (TEK), traditional ecological knowledge and wisdom (TEKW), indigenous knowledge (IK), indigenous ecological knowledge (IEK), local ecological knowledge (LEK), and traditional phenological knowledge (TPK) to describe native and non-native knowledge about the environment. To avoid the disciplinary and even interdisciplinary traps embedded in debates about which one is the most appropriate term, I have decided to use my own because it more accurately captures the types of observations I was recording and can encompass traditional and non-traditional, local and regional, native and non-native. IC describes observations of changing weather and climate of a "place-based" people (that have lived in an area for many decades), and who have the knowledge and wisdom to be able to detect conditions that are outside the expected or normal range of climatic variables.

For a more detailed description of all the terms I listed above, I refer readers to Fikret Berkes' *Sacred Ecology* (1999, p. 8-9). When I need to specifically use the term traditional ecological knowledge (TEK) to distinguish from IC, I use Berkes' definition:

> A cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationships of living beings (including humans) with one another and with their environment (Berkes 1999).

My initial goal was to work with communities and other local stakeholders and collaborators to identify: a) regional impacts and stressors of the recent warming climate and b) key factors that structure, drive, or hinder vulnerability and adaptation. This was implemented through an *iterative process* of getting stakeholder input, analyzing it along with instrumental observations, and giving reports and getting feedback from stakeholders at various stages along the way. It was through this approach that I was able to identify, in partnership with the communities and stakeholders, that the fall moos hunt was the most critical time of the year for vulnerability to climate change given seasonality shifts that became increasingly evident throughout the course of the research.

In addition, I collaborated with colleagues in the other fields in which I am less well-versed (biology/ecology and climatology as well as indigenous experts in traditional knowledge and indigenous observations of climate change) to raise the level of analysis and expertise beyond what I could do on my own. Through these collaborations, I assembled a range of expertise that is required for a multi-layered project such as this one. Despite the collective nature of this work, I take full responsibility for what is said in this dissertation and for how it is represented.

Partnerships between climate change researchers and indigenous experts are reciprocal where indigenous observations contribute to the science, and where increased understanding of processes by the scientists can help improve local/regional forecasts at a scale that matters and that are useful to stakeholders such as resource-dependant societies as well as government agencies (National Research Council 1999). Several studies in the Arctic region have demonstrated how indigenous observations can benefit climate change research as local-scale expertise to leverage scientific studies from afar; as a rich source of climate history and baseline data; as a framework for formulating research questions, and as a source of insights into impacts and adaptations (Riedlinger & Berkes 2001). Few have attempted to analyze indigenous observations directly alongside climatic instrumental data because of difficulties in the field work required along with temporal and spatial mismatches; or they have attempted to match them after the fact, instead of in tandem and through ongoing iteration as I have (Huntington et al 2004). While there have been multiple studies that have attempted to incorporate indigenous knowledge and observations into climate research (Ford & Smit 2004; Huntington et al 2004), most ultimately are marginally successful at fully linking or integrating IK and western science. Indigenous observations are most often discussed in terms of impacts and adaptation strategies (Berkes & Jolly 2001; Fox 2002). My approach takes a different tack where local observations and knowledge guided me in the analysis throughout the duration of the project.

The analytical framework and approach of this study was an in-community, place-based, participatory Vulnerability and Adaptive Capacity Assessment (VA). This approach employs historical data to establish baseline vulnerability and adaptive capacity and contributes to practical adaptation initiatives. VA assessment entails understanding the phenomenon and main processes involved in the social-ecological system and identifying relationships and key resources susceptible to harm (e.g., food, financial, or energy resources)(Adger et al 2004). One of the reasons to incorporate indigenous knowledge into scientific studies is to avoid the ethnocentric predetermination of problems (Sillitoe 1998), which can lead to erroneous interpretations (Cruikshank 1998). My approach followed the model set forth by Smit and Wandel (2006) where problems of and determinants of vulnerability are not determined *a priori*, but rather determined with the stakeholders themselves.

During the six years of this research project it evolved in various phases, with each phase occurring over the span of approximately one to two years each. The term "phase" notwithstanding, note that they are by no means discrete and linear and transitioned over time from one to the other, with some research phases overlapping. I began the work in 2003/2004 with very broad questions about the social-ecological system and the environmental changes being experienced within the context of recent climatic warming. These questions were:

- How do climate changes in averages as commonly reported manifest "on the ground" in terms of the characteristics of the environment, seasonal rhythms, patterns, and disturbances?

- How do these characteristic changes interact with the characteristics of the social-ecological system?

Through the evolution of refining the project with my collaborators and community members, I refined and redefined the questions over time until I arrived at a very specific focus on the fall time moose hunt in the Koyukuk-Middle Yukon region, which was determined by the real-world changes to the system during that time span. Then the research questions became:

- What climate trends can be detected during the fall moose hunt?
- How is climate interacting with social and ecological variables to affect vulnerability to climate during the fall moose hunt?
- How is the wildlife and subsistence regulatory system responding to early fall seasonality changes?

This specific focus literally developed right before me as I went along, and *only* could have been addressed at all because of the ongoing, on-the-ground, iterative approach utilized. I needed to be very fluid and flexible to adapt the changing conditions of the research, I will briefly describe each of the phases as they evolved:

Phase 1 began with attending in-community workshops in the native village of Huslia on changes in weather in 2003-2004. I began interviews and focus groups in 2004 with village Elders in Hughes, Huslia, and Koyukuk. These local observations required that I look at the data in appropriate ways to answer more specific questions emerging from the workshops and interviewing process, which developed into phase 2.

Phase 2 was conducted through a collaboration between me and individuals from the U.S. Fish and Wildlife Service and the Alaska Climate Research Center (ACRC). Climatological, local indigenous observations and biological datasets were integrated by asking questions specifically relevant to Interior Athabascan communities, to management issues of USFWS refuge managers and biologists, and to the ACRC in their role as a service organization with a mandate to respond to inquiries from stakeholders on climate. This phase of the research was necessary to document observations and to identify patterns of regional climate change in order to have the appropriate context to discuss the broader issues of vulnerability and adaptation to global environmental change on a regional level (results discussed in chapter five).

Phase 3 entailed observing advisory committee meetings, conference calls, informal discussions with agency managers, biologists, and local advisory committee chairs and members. The purpose of this phase was to understand the regulatory system from a broader perspective that included all the stakeholders in an effort to analyze barriers and opportunities for adaptation strategies (results discussed in chapter six).

The uniqueness of this study is the unusual "buy in" and involvement of a full spectrum of stakeholders, although with commitments from each varying in scope and degree as is to be expected. This included not only Alaska Native communities, tribal councils, Elders, and youth, but also the state agency the Alaska Department of Game and Fish biologists, managers, subsistence specialists; federal agency United States Fish and Wildlife Agency (biologist, managers, etc.); and climatologists. Most of these stakeholders operate within the institution of subsistence and wildlife management and understand that biophysical changes in Interior Alaska are in part a consequence of a warming climate and changing environment. These stakeholders differ in goals, mandates, jurisdiction, populations of interest, etc., but share a common goal of sustainable adaptation to climate change.

Methods

The "system of interest" in this study is the Koyukuk-Middle Yukon (KMY) region. Because this is a regional study the unit of analysis is the regional livelihood zone (LZ) referred to as the Koyukuk-Middle Yukon (KMY) region. A livelihood zone is a "relatively homogeneous area defined specifically in terms of four variables: (1) primary food sources; (2) primary income sources; (3) hazards; and (4) socio-cultural dynamics (Downing & Patwardhan 2004)." Using an LZ as the unit of analysis allows the research to sample only a few villages within a large area and make a statement about the whole area. The KMY livelihood zone is comprised of 11 villages (see Figure 1) and an area of approximately 50,000 square miles. It encompasses four national wildlife refuges and two game management units (discussed in chapter six, see Figure 24).

Methods for Data Collection

Method 1: Key Informant Interviews

I conducted key informant semi-directed interviews and held focus groups with local Elders (Huntington 1998; 2000). I began with an assessment of current exposures, sensitivities and current adaptive capacity employing ethnographic methods such as semi-structured interviews, participant observation and focus groups in the communities, collecting insights and IC from local and regional decision-makers, resource managers, and scientists through formal and informal interviews, meetings and conversations, from the published and unpublished literature, and from all other discoverable, available, and accessible sources of information.

Field visits were made to villages in the region during all seasons for varying lengths of time starting in May 2003 through February 2008. In 2005 I was invited by the Council of Athabascan Tribal Governments (CATG) to expand the geographic scope of my research to include villages in the Yukon Flats (Beaver, Chalkyitsik, and Fort Yukon) with the idea that I would do a comparative analysis between the Koyukuk-Middle Yukon and Yukon Flats regions. However, the Yukon Flats region was later dropped from the analysis as this expanded the scope of the project beyond what was manageable or realistic given time and financial constraints. I mention this, though, because this experience in the Yukon Flats enabled me to have a broader understanding of the similar patterns as well as the cultural and biophysical heterogeneity in Interior Alaska. This greatly sharpened my analysis of the Koyukuk-Middle Yukon region.

Formal interviews were conducted in three KMY villages (Koyukuk, Hughes, and Huslia) from 2004 to 2005. The interviews were semi-directed, lasted anywhere from 30 minutes to two hours, and interviewees were chosen based on age (Elders and so-called "younger Elders", i.e., 55+), long-term residency in the region, participating in subsistence activities, availability, and willingness to participate (N=25). The participatory process involved multiple trips back to villages to report on results and get feedback and corrections where necessary. All interviews were recorded and archived with each of the village tribal councils. In addition, I held a two-day focus group with Elders from Huslia and Koyukuk (the invited Elders from Hughes could not attend last minute) at the Huslia Elders center where we discussed weather changes for the two-days. This was part of the participatory development of the project as I asked them to tell me what they thought was most important in terms of the focus and direction of this research. The focus group was held in the spring of 2004, which followed the two workshops in Huslia on weather changes in which I participated. Discussions and observations from the two Huslia workshops guided me in the proposal writing phase as well as my design of the focus group with the Elders.

I hired Koyukon high school students in each of the villages to work as my research assistants. The students helped in myriad ways such as helping to schedule interviews, providing transportation around the villages, operating the recording equipment, educating me about youth perspectives, running errands for me, helping with some transcribing, and archiving interview recordings and materials with the tribal offices. They also helped tremendously in the Elders' willingness to participate in my project since traditional opportunities for Elders to share stories with the youth are dwindling as modern life is much more isolating of Elders than in the past. Having a student by my side to both learn research skills from me as well as to hear stories and learn from their Elders was an invaluable addition to the research approach that I believe strengthened my individual capabilities as a researcher. Trust and rapport-building are vitally important to ethnographic field work, and the students helped to smooth the progress of developing relationships with the Elders and the community as a whole.

Interviews provided valuable indigenous observations and understanding of climate (IC) as well as supplying the broader context to understand the science by guiding the analysis to develop the appropriate questions of the data, helping to interpret the data, and identifying patterns of social-ecological change on local and regional scales of the whole system. Examining weather station data, interviews, and biological data in parallel is one step in the direction of integrating IC and western science.

Method 2: Participant Observation

I participated in and observed subsistence practices and relevant community events, tribal council meetings, and other tribal institutional meetings . Participant observation method is a hallmark of ethnographic work as it provides the experiential knowledge and understanding necessary to understand culture, communities, and social systems (Bernard 2002; Grenier 1998). During my village stays I joined in community activities such as holiday celebrations, coverdishes (potlucks), memorial potlatch ceremonies, bingo, school events, Elder dinners, etc. as well as mundane day-to-day activities around the villages especially spending time with the Elders and assisting them in whatever ways that I could. I both observed and spoke at several tribal council meetings in the villages. I also participated in subsistence activities such as going on the river to check the fish net, spending time in fish camp, gathering berries, "looking around" for animals, butchering meat, chopping wood, hauling water, and so on.

Participatory observation during such activities often provides as much if not more learning than formal interviews about not only the social and cultural aspects of a community but also about the natural world and climate issues. It also helped me to fine-tune my interview questions according to local speech patterns and colloquialisms as well as learn family histories so that I could talk to Elders about their families, which helped break the ice and was always appreciated. Participant observations reduce problems of reactivity – i.e., when people change their behavior or watch their words when they know they are being recorded (Bernard 2002).

Weather and climate are so much a part of subsistence activities that day-to-day, normal conversation often centers around or touches on topics of interest to this research. Environmental conditions are part of the constant chatter in villages as hunters, fishers, trappers, gatherers are continually going back and forth between the villages and camp or the open country in pursuit of wild foods and materials, and conditions in the sky, in the rivers and sloughs, and on land are shared to prepare others as they are about to embark afield. My field notes, photographs, and videos from participatory observation were both complementary to and synergistic with the interview transcripts.

Participant observation also involved spending time with professionals in the regulatory offices of the Alaska Department of Fish and Game as well as the US Fish and Wildlife Service. I spent a lot of time with biologists and managers of both agencies in Fairbanks and in Galena discussing management issues as well as their own observations and understanding of climate changes. This helped me to understand the extremely complicated regulatory and dual management system as well as the respective agency cultures and how agency and village culture both clash and inform each other.

Method 3: Observation of Regulatory Meetings

Throughout the third phase of the research as mentioned above I focused on understanding the regional state and federal wildlife and subsistence regulatory system. In this effort I attended multiple meetings of village advisory committees to the Board of Game and the Federal Subsistence Board. I attended meetings in person and by teleconference of the Koyukuk River Advisory Committee and the Middle Yukon Advisory Committee. I virtually attended the February/March 2008 Board of Game meeting via the live stream on the internet. I collected meeting recordings either recording them myself or from agencies. I collected the transcripts of all the Western Interior Regional Advisory Committee (to the Federal Subsistence Board) meetings that are available on the internet from 1994 to present.

I also attended US Fish and Wildlife Service meetings in several villages when they were getting village stakeholder input for the update of the refuge comprehensive conservation plan (CCP) (USFWS 2008). USFWS staff went to each of the KMY villages and held community meetings to get input on the various wildlife and subsistence management issues guided by the CCP, so I was able to go with the staff and attend meetings in Tanana, Ruby, and Koyukuk in the fall of 2007.

By participating in all of these meetings within the institutional context of subsistence and wildlife management, I gained insights on the social production of the outcomes of these meetings (decisions, proposals, policies, and laws) as well as the related historical documents I analyzed from similar meetings in past years.

Methods for Data Analysis

Method 1: Coding, Memoing, Concept Building, and Network Analysis of Interview Data

To identify patterns in the social system analytic induction is fundamental whereby concepts are developed, higher levels of abstractions made from those concepts, and the relationships between them are determined (Ragin 1994). I performed the qualitative data analysis (QDA) of interview and meeting transcripts using the software Atlas.ti to identify themes, concepts, relationships, and patterns in the data through a grounded theory approach (Glaser 1994; Glaser & Strauss 1967). This is a process of memoing and inductive coding, which converts complex volumes of narrative text into nominal variables. The variables are systematically queried for pattern identification and theoretical development. Coding is the process of categorizing pieces of the narrative into themes or analytic categories with an objective to conceptualize the data. Memoing is the process of recording ideas with the pieces of text that range from descriptive commentary to methodological ideas to theory building and conclusions about the data. Theories are derived through higher level theoretical coding combined with theoretical memoing (Strauss & Corbin 1990).

I performed network analysis in Atlas.ti where links and relationships between variables are visualized to understand causality and social-ecological system relationships and dynamics (Miles & Huberman 1994). I created multiple conceptual models for each season and for biological or ecological themes within each season; ultimately I focused most on the network analysis of the fall season and moose hunt when it became the specific focus of the case study.

Method 2: Statistical Analysis of Instrumental Weather Data

This was performed in partnership with Martha Shulski of the Alaska Climate Research Center at the University of Alaska Fairbanks and Karin Lehmkuhl-Bodony from the U.S. Fish and Wildlife Service Koyukuk-Nowitna Refuge office in Galena. We performed linear trend, significance tests, total change calculations, and threshold/frequency distributions for temperature, precipitation and snowfall data. I created an "integrated knowledge matrix" using Excel spreadsheets to make columns of IC with instrumental data in an effort to combine local observations with instrumental data, which helped to identify patterns and differences between them including data gaps. This also helped us to identify mismatches in data availability and scales. A more detailed description of these methods is provided in chapter five.

Method 3: Document Content Analysis

Archived documents from Western Interior Regional Advisory Council (WIRAC) meetings, Board of Game (BOG) meetings, agency position papers, state advisory committees to the BOG and WIRAC petitions and proposals to the Board of Game and Federal Subsistence Boards, records of decision, moose management reports and plans were all analyzed in order to understand the context of the regulatory system and institutional setting as well as when and why specific decisions and policies were made. I performed queries on the WIRAC transcripts to determine when and how the issue of climate change arose in this context over time with a special focus on when warmer falls and impacts on moose hunting became part of the agenda for the WIRAC. I also used all of these documents to develop a timeline of when and where the issue of extending the fall moose hunt in response to warmer falls developed. The documents were central to my analysis of barriers and opportunities for sustainable adaptation in that the history of the issue evolved and how the regulatory system has or has not responded to the issue is found in these documents.

Prior to this study, there were no systematic or comprehensive studies looking at recent climate trends, impacts, vulnerability, and adaptation in the Koyukuk-Middle Yukon region of Alaska. In part for this reason, questions went unanswered about what recent trends or patterns were actually occurring in the region and whether any such trends were part of a longer-term climate change pattern. Because of a lack of any pointed study in the region on the connections between climate, seasonality shift, and subsistence practices, regulatory decisions as of this writing have largely omitted any consideration of climate patterns or local observations of seasonality shifts. My research provides a baseline understanding of the patterns and trends of recent climate changes, impacts, vulnerability, and adaptive capacity to build ongoing analyses, decision making, and adaptation strategies for adaption to climate change from here forward.

Outline of the Study

There are several unifying themes that emerge from this study that structure the outline of this dissertation. Those themes are: 1) climate change observations and understanding about causes and consequences from both a western and a Koyukon perspective; 2) The Koyukon perspective on the role of humans in nature and how ideas about interdependence, respect for animals, their environment, and other forces in nature define their own risk, well-being, and vulnerability to climate change; 3) western concepts of vulnerability and adaptation to climate change; and 4) how the differences in western and Koyukon perspectives on causality and vulnerability to climate change interact in the regulatory setting on wildlife and subsistence, and how these differences have constrained the flexibility of adaptation to climate changes in the KMY region.

Chapter two covers the socio-economic, political, and institutional context in the KMY region as well as the changes to Koyukon livelihoods over the last century. This will provide an understanding for the regulatory setting that determines hunting access and rights. Chapter three is about the Koyukon seasonal subsistence activities and traditional worldview, particularly as it regards human relationships with the natural world.

In chapter four I will give a summary of the state of knowledge, observations and uncertainty about climate change in the Arctic in general and in Alaska specifically. This combines conventional western scientific observations of climate change with indigenous observations and understanding of climate.

Chapter five focuses on the integrated analysis of the interviews with Koyukon Elders on their Indigenous Observations and Understanding with the analysis of the instrumental weather observation data to understand seasonality shifts and social-ecological vulnerability within recent decades of warming.

Chapter six then ventures into the regulatory system that is bound by land tenure and policy structures that confine the ability to move freely in both physical and political space, which therefore limits realizing adaptive capacity and sustainable adaptation strategies.

Chapter seven will conclude with exploring ideas for addressing these constraints and working towards more flexibility and capacity to respond to inevitable future climatic changes. Are these rural villages sustainable given threats to native livelihoods given food and energy security as costs rise and the planet continues to warm? This is on the minds of many in Alaska as I write this in 2009.

The answers to these very complex questions are inherently uncertain and depend entirely on the paths that a society chooses. Though I hope this work can be a reflection on some of the critical needs for understanding vulnerability and sustainable adaptation to climate change, as well as contribute to advancing our knowledge about how these issues are manifested in this part of the world. Above all, I hope this piece of work does some small bit of justice in respecting the rich and amazing culture and livelihood of my Koyukon teachers.

Chapter 2: Socio-economic Context and Social-ecological Changes in the Subsistence Livelihoods in the Koyukuk-Middle Yukon Region

The Koyukuk-Middle Yukon Region

Since the turn of the 20th century the indigenous people of Interior Alaska went from highly mobile bands and clans that moved seasonally to different resource harvesting areas and lived in camps to modern, fixed village-based tribes. During this same time a huge change in social and political organization occurred that resulted in a transformation from socio-cultural groupings (bands and clans) to political ones (tribes) (Clark 1974; 1975; Nelson et al 1982; Sullivan 1942b; VanStone 1974). Despite the dramatic changes over the last century, the Koyukon people remain characteristically Koyukon through the endurance of knowledge, beliefs, and practices that center around the harvest of wild foods for sustaining their livelihoods. However, they live in an era of ongoing changing practices and traditions shaped and reshaped by mainstream Euroamerican and western culture, modern technology, and a mixed cash-subsistence economy. This includes changes in transportation and mobility, settlement patterns, technology, subsistence practices, and the traditional belief system carried on by the Elders. All of these aspects of life intermingled and evolved together over time to create the modern-day Koyukon culture.

The Koyukon in this study live in their native homelands referred to here as the Koyukuk-Middle Yukon (KMY) region, which historically was inhabited primarily by the Koyukon Indians and small numbers of inland Eskimos. Today the section of the KMY region of interest to this study is comprised of about 2,060 people, still mostly Koyukon, who live in 11 settlements along the Koyukuk River (from Allakaket to Koyukuk) and the middle portion of the Yukon River (from Tanana to Kaltag) (Windisch-Cole & Fried 2001)[3] (see Figure 1).

[3] Here I am including the villages of Allakaket, Alatna, Bettles/Evansville, Galena, Hughes, Huslia, Kaltag, Koyukuk, Nulato, Ruby, and Tanana. The larger KMY census area includes about 10 more villages and

Historically four regional bands roamed the area: Yukon-Kateel; Huslia-Dulbi-Hogatza; Todatonten-Kanuti and South Fork bands who shared a collective identity, but had no centralized leadership (Marcotte 1983). Prior to the late 1800s there were no real "chiefs" (though "bosses" led band activities in communal hunts and ceremonies) and authority was within family units (Clark 1975). Shamans also held a lot of power and would sometimes fight amongst each other for dominance (Jetté 1911).

The uncertainty of the environment and harvest success required great flexibility across the landscape and across time to move to where animals could be found (Bane 1982). The essential need for unencumbered movement meant that land was thought to be communally owned and shared, although beaver houses, fishing sites and bear dens were family held (Clark 1974; Marcotte 1983). The core belief that land should not be owned is still valued by the traditionalists in Koyukon villages, which clashes with the Western capitalist mentality of entitlement and ownership. This can sometimes create tensions between older and younger generations.

Subsistence cultural practices that have been increasingly interfered with through state and federal wildlife regulations undermine adaptive traits and restrict the flexibility of Alaska Native livelihoods (Chance 1990). The ability to successfully harvest wild foods in the Interior requires "territorial freedom" – that is, flexibility across space and time according to the seasonal and yearly fluctuations of the environment (Nelson 1983). The loss of such flexibility in any aspect of subsistence jeopardizes the overall viability of the people (Bane 1982).

This chapter examines the social, economic, political, and to a lesser extent, the ecological transitions leading up to the combination of traditional and modern elements that characterize Koyukon livelihoods today. I use the term "Koyukon livelihoods" to generalize, but also acknowledge that there is a spectrum of exactly who, how, and to what extent people living in the KMY region engage in this livelihood. Many are non-native or mixed race, and are certainly ethnically mixed. Even amongst those who consider themselves to be Koyukon, the majority are mixed race to varying degrees.

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approximately 1200 more people. Here I am looking at the KMY portion that is off the road system and socially and culturally more interconnected via family and geographic ties.

What I will describe here is a way of life, a livelihood that includes certain beliefs, practices, technology, and language. I also look at the important role subsistence plays in the cultural vitality and sustainability of rural Alaska Native villages. How important is subsistence to sustainable livelihoods of the Koyukon? What are the threats to sustainability? I make the argument that threats to subsistence translate to threats to cultural survival and sustainable livelihoods.

Profile of Koyukuk-Middle Yukon Villages

The nature of the cash-subsistence economies of rural Alaska is such that financial resources and locally harvested resources are completely interdependent and mutually supportive (Langdon 1986; Wheeler 1992). A chronic problem in Alaskan rural areas is that the cost of living is considerably higher and opportunities for jobs are lower than in urban areas (Goldsmith et al 2004). The Koyukuk-Middle Yukon region is one of three sub-regions in the Yukon-Koyukuk census area (YKCA) where wage and salary income in 1999 was 20% below state average, unemployment was at 13.5% (compared to 6% statewide), per capita income for 1998 was 35% below state average, and household income ranked 25th out of 27 census areas in Alaska (Windisch-Cole & Fried 2001). The most recent census shows that the YKCA region is 70.7% Alaska Native (Alaska Department of Commerce & Community and Economic Development 2002) and subsistence is essential to the viability of communities and residents who on average harvest 613 pounds of wild foods per person per year (57% of total required calories) with a replacement value estimated at between $19 to almost $32 million for the region (Wolfe 2000). This points to the critical role subsistence still plays in economic terms in the rural Interior.

The villages in the KMY are entirely off the road system, accessible only by airplane or by boat along the major rivers with mail, fuel, food, and other supplies either flown by daily bush airlines or brought in by barge when the rivers are free of ice. Inter-village regional travel in the winter is by snow machine on winter trails and rivers that become ice roads. Transportation for hunting, fishing, trapping, or gathering is by boat or snow machine, though cars and ATVs are used locally for short trips. The village populations are small ranging from 28 people in Alatna to 580 people in the "hub" village of Galena (Table 1).[4]

Table 1 Population of villages in the Koyukuk-Middle Yukon Region in 2007/2008. Source: (Alaska Division of Community and Regional Affairs 2009)

Community	**2007/2008 Population**
Alatna	28
Allakaket	96
Bettles/Evansville	36
Galena	580
Hughes	81
Huslia	277
Kaltag	188
Koyukuk	88
Nulato	274
Ruby	160
Tanana	252
Total	**2060**

The population in the region has been declining in recent decades, and from 2000 to 2007 the region lost approximately 14% of the population primarily as a result of lower birth rates combined with a lack of work and higher educational opportunities and exorbitant and rising costs of living in the bush (Alaska Division of Community and Regional Affairs 2009; Martin et al 2008). Per capita income is quite low; for example, the three villages I spent the most time in it is $10,194 in Hughes, $10,983 in Huslia, and $11,342 in Koyukuk (Alaska Division of Community and Regional Affairs 2009). Only the cities, tribes, schools, and stores provide year-round employment and seasonal

[4] Galena is where many of the regional government offices and services, airport, and formerly the military base are/were located.

employment primarily includes fire fighting and construction. Homes are mostly either log cabin construction mixed with some newer, less efficient HUD homes.[5]

All villages and most homes have electricity and some degree of plumbing, but the majority of houses does not have full indoor plumbing and still haul water and use either honeybuckets or outhouses, while community facilities such as schools, tribal and city offices, laundry mats, and health clinics have plumbing and sewage. Small community stores provide a limited amount of expensive food and supplies flown in from urban areas.

Figure 4 Photo of village stores in Huslia (left) and Hughes (right)

Subsistence on wild fish and game is the central element of the local cash-subsistence economy. Dependence on wild foods is high providing about 57% of the total calories and 396% of required protein needs compared to around 2% of caloric needs in urban areas such as Fairbanks and Anchorage (Wolfe 2000). Of the wild foods harvested, moose is the most important big game animal in the Koyukuk-Middle Yukon region and will be the focus of chapters five and six (Brown et al 2004; Nelson 1983). Overall 92% of the households in the KMY use moose (Brown et al 2004). Even in communities where no moose harvest is reported as harvested, almost all households still report using moose, again confirming not only the critical importance of moose, but also that sharing

[5] HUD is the federal Housing and Urban Development program that provides funding and resources for building low income houses. The lack of proper insulation and high ceilings in these homes prove to be much less insulating and energy efficient than the log cabin construction.

and food distribution continues to be important in these communities (ibid). Despite the relatively recent arrival of moose to Koyukuk River valley within the last 70 years, moose have become something the people are economically and psychologically attached to and have become central to the culture (Nelson et al 1982). Maintaining a healthy moose population and hunting access and opportunity is a top priority in the region. Moose are the most efficient wild food to harvest in terms of pounds of meat harvested per unit of time, energy, and money put into the harvest effort (Feit 1987).

In addition to this dependence on locally available moose along with salmon and other wild foods and resources, the cash-subsistence economy is largely dependant on outside sources of funding through government subsidies, grants, and transfer payments. Only 48.7% of personal income is through wage employment, and 38.7% comes from transfer payments from the government in the form of income maintenance, health payments, retirement and disability, veterans benefits, and others (Windisch-Cole & Fried 2001). The growing economic dependence of rural villages on government funding has eroded much of the self-sufficiency that characterized pre-contact native societies (Dryzek & Young 1985). Self-sufficiency is a highly valued cultural trait in Athabascan societies who for thousands of years had to rely on their own adaptability and resourcefulness prior to European contact (Nelson et al 1982). Now villages are heavily dependant on outside sources of money, supplies, health care, and energy.

The economy is primarily dependant on fossil fuels for electricity, heating homes and public buildings, and for gasoline to fuel the snow machines and boats necessary for subsistence hunting. Rising costs of exogenous energy resources are threatening the economies of rural villages where gas often averages twice the state or national average (Alaska Department of Commerce & Community and Economic Development 2007). In a 2007 report by the Alaska Department of Commerce it was stated that "[s]ignificantly increased fuel and energy costs combined with high unemployment rates, limited local economies, and local governments struggling to provide basic local services continue to present rural Alaska communities and households with challenging circumstances with no long-term solution in sight" (Alaska Department of Commerce & Community and

Economic Development 2007). A standard of living based on growing needs for fossil-fuel energy is simply unsustainable over the long-term under the current economic conditions.

Increased exposure to western standards of living and affluence are transferred through television and the internet, raising Indian consumer aspirations over recent decades in ways that cannot be sustained by the economic base (VanStone 1974). Patterns of consumption typical for the rest of the US are now repeated in rural Native villages. The reality is that much of the money from transfer payments goes to increased consumerism/materialism, increased energy use, and ultimately the increased creation of pollution and waste, which is unsustainable without continuing to be subsidized by the government. Sustainability through conservation and efficiency of energy is vital for rural Alaska villages. The effects of modernization have provided new opportunities in many ways through faster modes of transportation, more efficient hunting technology, and supplementation of stored or store-bought food when necessary all make the threat of starvation a thing of the "long time ago" past for most. Yet a subsistence livelihood and well-being is about much more than just starvation or survival alone (Active 1998; Johns 1998). In remote, rural Alaska Native villages a diet with increased reliance on store-bought, industrialized food shipped in from cities is nutritionally inferior to wild foods and has resulted in growing health care costs (Kuhnlein et al 2004). Additionally, subsistence practices that are based in the cultural institutions that maintain physical and spiritual connections to the land and social connections to each other is what sustains Natives communities in bush Alaska (Bersamin et al 2007).

A Century of Social, Political, and Cultural Changes

Multiple forces of change have shaped and re-cast Koyukon cultural traditions into a modern form, yet many of the so-called "traditional" characteristics of the past are still present to varying degrees. Practices and beliefs of the Koyukon were considered "aboriginal" or "traditional" by westerners around the turn of the 20th century yet there were already transformative forces at play that began with Euroamerican contact during the mid-1800s that were affecting Koyukon settlements, economy, and culture.

The late Koyukon Elder, Edwin Simon, from Huslia was born just before the turn of the 20th Century in 1898. He said in an interview just before he died in 1979 that he felt he had lived three lives (Madison & Yarber 1981). The "three lives" of Edwin Simon tell the tale of almost a century of change. According to Simon his "first life" from when he was born in 1898 until 1930 was mostly primitive by today's standards when people possessed little material items; they used little to no outside energy sources; and they still lived mostly nomadic lives following the seasonal movements of animals. Simon's "second life" was roughly from 1930 to 1960 when Native people began to live in villages year round; boats were powered with gas and inboard motors; airplanes were bringing mail and supplies; more material possessions began to accumulate; and some food was purchased at trading posts. During his "third life" from 1960 until he died in 1979 communities were settled year round, and many homes had electricity and running water; people hunted mostly within easy travel distance from home; transportation means included snow machines and 3-wheel ATVs; people owned refrigerators to store food and radios to get news from the outside world. These three lives of Edwin Simon demonstrate how the participation in an increasingly modern society and way of life worked to transform an aboriginal culture in the modern Alaska Native Interior "bush" livelihood.

What was this life in the "old ways" at the turn of the 20th century like? A closer look at the Koyukon around that time tells us something about the modern-day Koyukon and how their relationship to the Earth was shaped and continues to inform to a significant degree how they live to this day. An important question for this dissertation is what role these changes played in the sustainability of Koyukon culture and livelihoods in the past and still play today.

Because the so-called "historic period" for the Koyukon starts with the first explorations by Europeans in the 1800s, it is not possible to separate with absolute certainty some of the patterns that emerged with the fur trade from those that existed previously (Clark 1975). However, the fur trade was undoubtedly the first major post-contact driver of changing economy and settlement patterns for the Interior Athabascans in the first stage of the cultural metamorphosis on the path toward modernity (VanStone 1974). European traders who started coming to the Interior in the mid-1800s reorganized the aboriginal barter system of trading that had preceded them, and introduced cash and commodities into the region as a new form of currency (Dryzek & Young 1985).

By around 1900 trading posts were established in most of the larger villages along the Koyukuk and Yukon Rivers (Huntington & Reardon 1993). The increasing dependency of Natives on traders for some food items and material goods such as clothing and money resulted in reducing mobility to be closer to the trading posts (VanStone 1974). Dryzek and Young (1985) call this growing dependence on traders and their cash and material goods a crucial element in the "historical spiral" away from self-sufficiency and toward the dependence on outside resources to sustain Athabascan livelihoods.

Growing Dependence

At first trade-post items were luxuries, but increasingly became necessities (such as ammunition, sugar, tea and coffee) fueling a cycle of debt-credit with traders that necessitated more trapping and, hence, more pressure on certain animals populations such as beaver, for example (VanStone 1974). By 1910 Alaska's beaver were severely depleted from trapping, which was then prohibited from 1910 to 1923 to save the population (Huntington & Reardon 1993). In addition to trapping, steamboats that brought goods to the trading posts became a big part of regional commerce and employed many Alaska Native men as woodcutters, deck hands, and even pilots because of their knowledge of the river channels (Schneider 1986).

Those same steamboats also carried germs the Native people had no immunity to and several disease outbreaks of the measles and flu and eventually tuberculosis occurred in the early 1900s (Madison & Yarber 1981). European diseases that came first with their goods traded with the Eskimos, and then with the people themselves caused a decrease in the population of Interior Natives (Langdon 2002). Help from outsiders became increasingly important as Natives were exposed to diseases for which they had no natural immunities or traditional cures. It was the Christian missionaries that played a major role in providing for the Native people.

The Christian missionaries came with or in the footsteps of the traders in order to save the souls of the so-called "primitives" who populated the Interior. After the U.S. purchased Alaska from Russia in 1867, most of the Koyukon were converted by either Catholic or Protestant denominations, and by 1900 virtually all Alaskan Athabascans were Christians at least by name if not entirely by practice (VanStone 1974). In the Koyukon-Middle Yukon region, the first Catholic mission was established in Nulato in 1888. Around the turn of the century two missionaries in particular left their mark in the Koyukuk-Middle Yukon area. Jules Jetté, a Jesuit priest who documented the language and culture of the Koyukon Indians he came to convert, resided in Nulato (Jette & Jones 2000). The second European "holy man" to establish a Christian mission in the region (and the first on the Koyukuk River) was the Episcopalian Archdeacon, Hudson Stuck, who founded the Allakaket/Alatna mission in 1906 (Stuck 1988). The missions drew many of the regional Natives into settlements looking for help largely in the form of food, education, and medical care. This continued the trend, which began with the fur trade, of settling the Natives in fixed locations.

The socio-cultural impacts of the missions on the Koyukon – some positive and some negative – cannot be overstated. Missions were the location of the only hospitals and schools, so during this time of transition for the Native people, they provided much in the way of health care and assistance (Huntington & Reardon 1993; Schneider 1986). However, the missionaries were often prejudiced against native spirituality and cultural practices and preached against them (Schneider 1986).

A paternal attitude toward indigenous people was prevalent throughout the world at that time, based on 19th century notions of "un-civilized" peoples. Patronizing attitudes such as this greatly affected the Native self-image and identity (VanStone 1974). In most cases the native people were indoctrinated in the Christian ways and taught to be shameful of their own "primitive" culture. The Koyukon held religious practitioners such as Jetté in such high regard, and so willingly accepted the Christian ideology that the religious men's opinions or ideas at the time where hardly questioned. It was the attitude toward the Native culture as primitive and backwards that worked to erode many of the traditions of the past (Berger 1985). The mission schools often taught religion only, and forced the students to speak English (Huntington & Reardon 1993). But whereas the missions were there to help the Native people, the miners came just to exploit the land with little or no regard for the local inhabitants (Haycox 2002).

The turn of the 20th century was ushered in with the Gold Rush. When gold was found in the late 1890s in Klondike, Canada the prospectors soon began to flood into Alaska. 1898 was the year they came to the Koyukuk drainage, and around 1,000 miners descended on the region dotting the rivers with makeshift mining camps, only for 90% of them to leave by the following year after unsuccessful ventures (Henning 1983). They left behind many mining settlements, which also shaped settlement patterns and economy as the local Native populations co-located to work for the miners (Mills 1998). Alaska was still a territory, so Natives had no citizenship and were treated as second-class people or less in their own homeland (Schneider 1986). Indians were paid half the wages that the White prospectors earned, and they were not afforded the same respect or rights (Madison & Yarber 1981). While the number of miners declined by the time of WWII, mines continued to play a role in the Interior, and many of the Elders in villages today worked in mining at some point during the mid-century as fluctuating fur prices along with increasing dependency of cash meant the need for other forms of employment.

By mid-20th century life for the Koyukon Indians was in many ways beginning to look very different and increasingly like that of the Euroamerican, western cultures. By the 1920s airplanes began delivering mail and supplies to villages, which led to the end of the mail dog teams, and the extensive trail system and network of roadhouses scattered roughly 25 miles or a day's travel apart, were largely abandoned by the 1930s (although some of them continued to be used until after WW II) (Schneider 1986). The Great Depression of the 1930s caused a drop in fur prices, which impacted the trading-trapping economy now so embedded in the regional economy. However, most of the Koyukon still depended largely on wild foods at that time, so according to Koyukon Sidney Huntington, they did not suffer as much from the shock to the cash economy as did many others in the U.S. (Huntington & Reardon 1993). However, alcohol and tuberculosis, both brought by the Whites, were taking their toll on Native families. According to locals there was not a family in the region that was not affected by these two diseases during the middle of the century (Madison & Yarber 1981).

VanStone (1974) refers to the 1940s as the beginning of the "government-industrial" period with the decline of the fur trade combined with the increase of government services and the emergence of extractive industries such as oil and gas development, and new forms of hard rock rather than placer mining. The decline of the world fur market meant decreasing commercial importance of trapping, yet it remained an important part of the Athabascan culture (VanStone 1974). Trading posts still bought some furs but were increasingly becoming more general commercial stores with material goods and food items (Huntington & Reardon 1993). A few fur buyers still visit some Yukon River villages on a yearly basis to purchase fur, but there seem to be fewer and fewer of these every year, as there are fewer and fewer active trappers in the villages from which to purchase fur.

World War II brought an influx of people into the Interior with the build up of military bases. Galena went from a small native settlement of around 35 people in 1941 to as high as 3,000 people during war time (Huntington & Reardon 1993). As a result, Galena became a regional "hub" village or distribution center for the people of the Koyukuk-Middle Yukon region, providing many of the health and government services not found in the smaller villages. Unfortunately for Native people, this also came with a regulatory structure that was determined in far away places such as Juneau or Washington D.C. (Schneider 1986). This was also a time in the United States when the goal was to "assimilate" all Natives throughout the country, including Alaska Natives, into Western culture (Wilkinson 2006), with formal, secular education and religion the primary means through which to accomplish this. During the 1950s and 1960s (especially after statehood in 1959) federal agencies became more involved in Alaska Native affairs.

The Bureau of Indian Affairs, Indian Health Service and the Territorial School System were increasingly involved in rural Alaska and were taking over a lot of the health and education responsibilities previously left to the missions (Schneider 1986; VanStone 1974).

The final anchor tying Natives to fixed settlements were the schools built in villages in the 1950s-60s as primary education became mandatory.[6] This was a mixed blessing as previously in order for Native children to be formally educated they had to be sent to either mission schools or BIA schools in far away locations such as Southeast Alaska, Chumawa in Oregon, and even to schools in Oklahoma and New Mexico (Hirshberg & Sharp 2005). The trade off for Native communities was the loss of a "bush" education for the youth, which included cultural beliefs/traditions, and traditional ecological knowledge and survival skills. It also meant the gradual loss of language that encoded so much of their cultural knowledge (Barnhardt 1977; Basso 1996; Hirshberg & Sharp 2005).

In the early 1900s the Episcopalian Archdeacon, Hudson Stuck, prophetically stated "if such boys grow up incompetent to make a living out of the surrounding wilderness, whence shall their living come?" (Schneider 1986). So, village schools meant the children could be educated while still living with their family, thereby enabling closer ties to their culture. But it also meant that families, who were previously accustomed to a nomadic way of life seasonally moving seasonally to find the animals they depended on, now had to stay in the village throughout most of the year. The tension between staying to live the bush life in the villages is not unique to the Koyukon, yet it is ongoing conundrum for young people.

Very few opportunities for education and jobs exist in rural KMY villages today, thus pressure to leave for better opportunities conflicts with pressure to stay with family and culture. In these remote Alaska villages with small populations, the loss of potential hunters and/or wage earners can have a disproportionally significant impact on the households, families, and community as a whole, and for those who stay.

[6] Some schools in the region were built in earlier decades, however, the schools in the three villages where I spent the most time were built in Hughes in 1956, Huslia in 1950, and Koyukuk in 1939.

The 1930s through the 1950s was the time of Edwin Simon's "second life" with the increasing dependency on outside sources of technology and energy such as the inboard motor and gas boats in the 1930s and the outboard motor (or "kicker" as it's locally called) in the 1950s (Madison & Yarber 1981). This meant the newfound ability to get places more quickly for hunting and fishing excursions from a central location. The effects of this transition from nomadic to sedentary lifestyle are numerous. The fixed settlements paved the way to further reorganizing traditional society as modern amenities such as electricity, plumbing, and sewage would follow for some villages requiring great amounts of investment, energy, and maintenance. Native people started accumulating more materials items now that they had permanent homes to keep them in. And a more sedentary life combined with the ability to buy processed foods from the village stores had and still have effects on health and time spent on the land.

Edwin Simon's "third life" starting around in the 1960s included even more modernized, fossil fuel powered technology such as propane tanks and stoves, electricity, refrigerators and snow machines (Madison & Yarber 1981). The refrigerator and snow machine were two technological changes that had major effects on Native subsistence. Now winter travel could be accomplished more quickly and with greater ease (unless the machine broke, which in the early days was all too common), and meat could be stored and preserved for much longer periods of time (Huntington & Reardon 1993; Madison & Yarber 1981). The threat of starvation was now almost entirely gone, with the ability to freeze food combined with increasing percentages of store bought food. Snow machines also replaced dog teams as the main form of winter transportation, and so began a short decline in the importance of subsistence fishing (VanStone 1974). Though, in the 1970s dog teams for racing made a comeback and fish camps regained importance in Athabascan society (Bane 1982).

Modernity brought many benefits and quality of life improvements to the region (Goldsmith et al 2004); but while the quality of life was improving in some ways, modernization also came with many new complexities and drawbacks. With new opportunities for wage employment such as resource extraction, schools and government services, the cash segment of their mixed subsistence economy was growing. This was, and continues to be, yet another mixed blessing. On the one hand cash provided the means to buy the technology now essential for engaging in harvest activities, but on the other hand wage employment took them away from harvest activities and time spent on the land (Callaway 1995). It is the ongoing connection to the land has always defined Alaska Native culture and identity (Berger 1985). It is the land that provides the natural resources they depend on for survival. But the struggle to keep their land in the face of encroaching state and federal government interests proved to be the newest and biggest challenge to Native culture and identity in the later part of the 20th century.

Following statehood, beginning as early as the 1960s, Native people throughout the Interior and Alaska as a whole started organizing because of increasing threats to their Native lands, natural resources, and culture (Chance 1990). The threat of the proposed construction of a Rampart Dam on the Yukon River was one unifying force for Interior Athabascans, who organized in 1963 to formally oppose the project (Schneider 1986). The dam would have flooded almost the entire Yukon Flats basin inundating seven Upper Yukon River Native villages as well as a tremendously productive fish and waterfowl area. The Natives along with environmental groups fought the Dam construction in the area that eventually became the Yukon Flats National Wildlife Refuge. Several other regional and statewide tribal organizations were formed during this time such as the Rural Community Action Program (RuralCAP), the Fairbanks Native Association, and the Alaska Federation of Natives, among others. The Alaska Federation of Natives (AFN), established in 1966, was the first major statewide political Alaska Native organization, and immediately following its inception, the AFN called for a moratorium on land deals until the Native claims could be settled.

The Alaska Native Claims Settlement Act (ANCSA)

Native land claims in Alaska were gaining momentum in the 1960s and along with it the contention between the federal, state, and Native entities. Pressure from the Alaska Federation of Natives resulted in the U.S. Interior Secretary Udall in 1966 declaring a "land freeze" until the claims could be settled (Case & Voluck 2002). With the discovery of oil at Prudhoe Bay in 1968 there was an increased urgency on the part of the state and federal governments (and the oil industry with their powerful lobby) to settle the Native land claims in order to clear the way for oil field development and the construction of a trans-Alaska pipeline (Schneider 1986). Hence, came the 1971 Alaska Native Claims Settlement Act (ANCSA), for which the Alaska Native population as a whole received $962.5 million, with 45 million acres of land in exchange for the 365 million acres they had previously held through aboriginal title. Not only did ANCSA abolish aboriginal title to the land, but it abolished aboriginal hunting and fishing rights along with it, with clear and dramatic implications for Native subsistence (Berger 1985). Alaska Natives were also required to set up regional and village corporations to receive title to the lands and allocate the money to their "shareholders" through the corporate profit-making structure. Thirteen regional corporations were created (12 in Alaska and one later created for Alaska Natives living outside the state) that range in size from around 1,000 to 16,000 native shareholders and approximately 220 village corporations were created. These for-profit corporations were authorized to pay dividends to shareholders through the profits ideally derived from the allocated money and lands.

Critics of ANCSA say that the goal of the U.S. government at the time was to turn Alaska Natives into shareholders and businessmen in the ongoing attempt to assimilate or acculturate Native people – to become "part of corporate mainstream America" (Berger 1985; Chance 1990). The assumption that commercial interests should prevail over cultural values was an ideological contradiction to the traditional Native worldview (Johns 1998). There was also an inherent contradiction between this capitalist ideology and the expressed desire of Congress for the state of Alaska and the Secretary of the Interior to "take any action necessary to protect the subsistence needs of the Natives" (Case & Voluck 2002). The contradiction was in the fact that Alaska Native cultural preservation is inextricably connected to subsistence, which requires unencumbered access to and use of the landscape (Berger 1985; Case & Voluck 2002). Since ANCSA resulted in a patchwork pattern of state, federal, private, and native corporate ownership across the landscape along with a fragmented regulatory system, it served to limit the freedom of unencumbered movement and subsistence practices across both time and space (see land ownership patterns in Figure 22).

Culturally, ANCSA represented a fundamental shift in orientation to the land from a culture where land ownership was traditionally communal (Clark 1974) to a capitalistic mindset where land is a privately owned asset to be bought or sold and exploited for money making ventures (Schneider 1986). Yet the "gospel of capitalism" was attractive to some native corporate leaders who profited through the high wages they received (Berger 1985; Dryzek & Young 1985). The ANCSA ideal was underpinned by an economic development model with the central thesis that large-scale economic development of the modern sector of the economy will expand to incorporate the traditional sector (which would eventually disappear) (Chance 1990).

These ideals formed policy that worked to disconnect, to disenfranchise even, Alaska Natives from the land. Therefore, ANCSA threatened a fundamental and deeply ingrained cultural value of Alaska Natives – their continuing close connection to the land. The fragmenting policy approach of ANCSA also led to a schism within the Alaska Native communities between those in the villages who had the most to lose from ANCSA, and those in the cities and AFN leadership who were lured by the idea of corporate power and wealth after years of political powerlessness and poverty (Chance 1990). The latter – i.e., the small number of "winners" of ANCSA - were not representative of the majority of Alaska Natives who lived in rural areas and/or were the economic losers (Berger 1985).

ANCSA is viewed by many Native people to be an imposed system and a failure in terms of bringing the economic gains and well-being it was promised to bring, nor does it protect their hunting and fishing rights as was hoped (Berger 1985; Madison & Yarber 1981). Testimonials of Natives heard by the Alaska Native Review Commission in the mid-1980s demonstrated that there was a lot of resentment throughout Alaska toward the settlement and those in Native leadership positions who agreed to the deal and eventually benefited while so many others did not (Berger 1985). Economic analysis by

Colt (2001) showed that the benefits of ANCSA did not reach the majority of Natives as promised, with many "shareholders" receiving only small payments in exchange for the land and subsistence rights they were forced to give up. In economic terms, from 1973-1993, the 12 regional corporations collectively lost 80% of their original cash endowments (about $380 million) as a result of transaction and legal costs combined with bad investments (Colt 2001). However, it was the impacts on subsistence, a dimension that is difficult to measure in strictly economic terms, that had a far greater overall affect on Alaska Natives.

ANCSA, ANILCA, Subsistence, and Institutionalized Conflict

> As long as the people and the land were one, the culture would survive. If the two became separated, it could easily wither and die. (Chance 1990)

> Subsistence is at the core of village life, and land is at the core of subsistence. (Berger 1985)

Because of these schisms discussed above, conflicts over subsistence are arguably among the most politicized and polarized debates in Alaska (Caulfield 1992). The seeds of conflict can be traced to when Alaska became the 49th state in 1959. A section of the new Alaska State Constitution decreed that there would be no differential treatment of Alaskans, Native or non-Native, and Article VIII, Section 3 stated that "Wherever occurring in their natural state, fish, wildlife and waters are reserved to the people for common use." This clause eventually had huge implications for Native subsistence, as it was used by the Alaska Supreme Court to rule against special state protection of rural Native subsistence rights (Case & Voluck 2002). Unlike the federal government that had a special trust relationship with Native Americans through treaties and, therefore, could provide special protections for their hunting and fishing rights, the state of Alaska officially viewed all residents in common when it came to these rights.

Conflict over the land, its fish and wildlife resources, and subsistence rights can only be understood in the context of competing ideologies of the value of land and the human relationship to it (Caulfield 1992; Thornton 1998). One ideology is the traditional view of indigenous people that connection to the land is an inalienable right and is necessary for the continued spiritual, physical, and cultural health of humans and communities (Active 1998; Johns 1998). The competing capitalist ideology views land as a commodity to be bought and sold and valued for exploitative purposes (Caulfield 1992). The state of Alaska's economy has depended on exploiting natural resources since its inception, which has defined its culture and politics since (Haycox 2002). The result is that commercial interests dominate Alaska state policy and thus sportsmen and commercial interests dominate state management of fish and game (Bosworth 1995; Caulfield 1992). The ongoing debate and conflict over subsistence has been a legal battle of control between the federal government, state of Alaska, commercial interests, environmentalists, and the Alaska Natives since the inception of ANCSA.

The 1971 Alaska Native Claims Settlement Act (ANCSA) abolished aboriginal title to land as well as the aboriginal rights to hunting and fishing on those lands (Alaska Native Claims Settlement Act 1971). Though the U.S. Congress expressly stated their hope that subsistence rights of Alaska Natives should be protected in any way possible, specific protections were not included in ANCSA. Privatized ANCSA Native corporations became the title holders of the allocated lands coming under the regulatory jurisdiction of the state. The allocation of federal lands for conservation purposes (national refuges, parks, wilderness areas, etc.) as well as the issue of subsistence was left for a future date. The federal government addressed the issue of subsistence in the 1980 Alaska National Interest Lands Conservation Act (ANILCA), which established 104 million acres of parks, refuges, preserves, and wildlife monuments for conservations purposes making up about 60% of Alaska's entire land base (Alaska National Interest Lands Conservation Act 1980). ANILCA defined subsistence uses as:

> The customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel,

clothing, tools, transportation; for the making and selling of handicraft articles out of non-edible byproducts of fish and wildlife resources taken for personal or family consumption; for barter, or sharing for personal family consumption; and for customary trade.

The rural distinction for subsistence uses in ANILCA drove a wedge between federal and state subsistence policies. The federal government implicitly associated "rural" with Alaska Native based on the traditional rural character of Native subsistence. The state dominated by commercial interests has fundamentally opposed preference for either rural residents or Alaska Natives. ANILCA set the legal stage for the battle between these perspectives that endures to today. During the 1980s several Alaska state rulings resulted in a state definition of subsistence users that made all Alaska residents eligible for subsistence use designation, which made the state out of compliance with ANILCA's Title VIII rural priority (Madison v. Alaska Dept. of Fish and Game 1985; McDowell v. State of Alaska 1989). The federal government responded in 1990 by taking over the management of subsistence uses on federal lands. Hence, began the dual management system for subsistence management in Alaska.

From 1990-1992 the Federal Subsistence Program in Alaska established the Federal Subsistence Board (FSB) and the regional advisory councils (RACs) to the FSB along with a process for identifying rural areas and customary and traditional uses. Both the composition of the RACs and the criteria for defining customary and traditional uses continue to be debated and controversial to this day. The federal multi-agency Office of Subsistence Management (OSM) was placed in the Alaska Region Fish and Wildlife Service where it still resides. In 1992 the Alaska state legislature revised the Alaska state subsistence statute, officially providing subsistence eligibility to all Alaskan residents (Alaska Statute 1992).

Since 1993 until today continues to be an intricate back-and-forth battle in the court system between the federal and state governments, primarily focusing on issues of rural priority and management of fisheries in navigable waters among other subsistence-related issues. The major implication for game hunting depends on the final outcome of the rural/urban battle as this determines who has priority access to hunt – i.e., Natives or non-Natives who are either rural or urban residents. As it stands the federal government still maintains rural priority on federal lands in times of shortage, and the state identifies all Alaska residents as eligible for subsistence uses, which take priority over all other uses in times of shortage and uses a "Tier II" system based on customary and traditional use determinations to make distinctions between state residents in times of shortage. It is important to clarify that the state of Alaska maintains primary authority for wildlife management on all lands (including federal) statewide. It is only in times of shortage that the federal government can step in to provide rural priority for subsistence - and on federal lands only to be decided on a case-by-case basis by the Federal Subsistence Board.

The state government continually works to amend or overturn the federal rural priority clause through reference to its unconstitutionality. The federal government, on the other hand, continues to defend the rural priority and has been consistently backed by the federal court system all the way through to the January of 2007 U.S. Supreme Court ruling that upheld ANILCA's rural priority clause. Measures by the federal government have also included attempts to enact an amendment to the State constitution to align with ANILCA.

Political winds have blown subsistence policy in different directions depending on the makeup of the state legislature, who sits in the Alaska Governor's office, and the relationship between them. One Democratic Governor, Tony Knowles, spent his term from the mid-1990s until 2002 calling several special sessions on subsistence legislation, which included multiple attempts for a constitutional amendment to comply with the ANILCA rural preference. Knowles' proposed subsistence legislation was repeatedly either ignored or voted down by the Republican-dominated state legislature. The Republican Governor Frank Murkowski's years were characterized by frequent attacks on the rural preference, and by gubernatorial attempts to overturn ANILCA Title VIII in an attempt to wrestle back state control of subsistence on all lands, an effort that was repeatedly thwarted by the federal courts.

The Republican Governor, Sarah Palin, said she would not support revisions to the state constitution, but called for more predator control with the intention of providing more wildlife for subsistence purposes, but with subsistence access rights available to all residents regardless of whether they are rural or urban. Predator control is politically difficult because of the environmentalist lobby against it, but an increasingly popular sentiment in Alaska Native communities; though it depends on the method of predator control to the Koyukon traditionalists. Koyukon traditional beliefs do not support aerial predator control, as this would be *hutlaanee,* meaning taboo, (explained in chapter three) and would violate the proper treatment of animals. Natural wild predators (wolves and bears) are the biggest competitors for their subsistence foods, so some level of predator control is desired where low moose and caribou populations are of concern. Whichever way the political winds blow, the Alaska Natives continue to be caught in the middle and fight for their own self-determination on issues of subsistence hunting, fishing, trapping, and maintaining access and rights to their traditional hunting grounds and natural resources.

Effects on Extant Subsistence Practices

The ongoing power struggle between the various stakeholders over subsistence management has left Alaska's Natives feeling bewildered and trapped in the maze of regulatory wrangling and bitter at the tightening of regulations and restrictions of their traditional subsistence patterns and livelihoods. This has led to much confusion and frustration with the regulatory process and laws (Bosworth 1995). Caulfield states that "no public policy issue divides Alaskans more deeply than that of prioritizing subsistence hunting and fishing for Alaska's rural residents" (Caulfield 1992). This, he says, is mainly a result of differing ideas on a "vision for Alaska" that is based on the one hand on the dominant Euroamerican values of "individual rights" and "equality under the law," and on the other hand the minority Alaska Native view of "tribal rights" that are more communal in nature, and that are situated within the special relationship of Native Americans to the federal government, which recognizes traditional Native governments for purposes of federal Native programs, services, privileges, and immunities (Case & Voluck 2002).

When the state of Alaska began providing open access of hunting and fishing to all state residents, combined with the population boom in the mid-1970s that came with the construction of the Trans-Alaskan Pipeline, this necessarily led to increased pressure on a wider area of lands and natural resources (Nelson et al 1982). To Alaska Natives this was perceived as increased threat to their traditional hunting, fishing, trapping, and gathering lands. In rural areas hunters and fishers were increasingly coming from the cities and "outside" (i.e., non-Alaska residents) to hunt on what had traditionally been Native land and community hunting areas. Increased hunting pressure often resulted in population declines of the most key subsistence foods such as moose, caribou, and salmon throughout the 1970s, 80s, and 90s (Berger 1985). Conflicts between Alaska Natives and the urban and "outside" hunters grew increasingly contentious (Bosworth 1995; Thornton 1998). The institutionalized conflict that ANCSA and ANILCA created pitted Alaska Natives against other hunters, but also against both the state and federal government where tightening regulations threatened traditional subsistence practices.

The identity of Alaska Natives is still tied to the ability to harvest wild foods, and the sharing of food, resources, and ecological knowledge based on kinship and community ties provides the social glue that allows for continuance of rural native villages throughout Alaska today (Bosworth 1995; Magdanz et al 2002). Most households in rural areas continue to participate in the harvest of wild foods with at least 60% to 83% participating directly in harvest activities of wild game and fish, respectively, and 86% to 95% using wild game and fish either harvested themselves or received from other family and/or community members (Bosworth 1995; Wolfe 2000). For the Koyukon region, in 1983 the village of Huslia's community per capita subsistence of 1,082 lbs per person per year, was among the highest recorded in the state at that time (Marcotte 1983). The average for the Interior region is still very high at 613 pounds per person per year, with a wide range of inter-village and intra-village variability acknowledged (Wolfe 2000). And recent studies by the Alaska Department of Fish and

Game demonstrate the enduring importance as very high rates of resource sharing and food distribution continue in KMY villages (Brown et al 2004).

The tradition of community-based sharing networks of food and subsistence resources is a characteristic of Alaska Natives that accounts for uncertainty of environmental conditions, resource availability, and the variable nature of harvest participation, ability, and success across generations, between and among individual households in any group (Langdon & Worl 1981). Therefore, subsistence regulations that are typically aimed at the individual instead of the community, which many game laws are, undermine this ability (Callaway 1995). For example, hunters often hunt for members of their family or community who are unable due to various reasons such as health, age, employment, etc. (ibid). The village wage earners exchange cash in the form of gas for boats or snow machines or equipment in exchange for the wild foods harvested by those whom they supply (Bosworth 1995; Langdon & Worl 1981; Wheeler 1992; Wheeler 1998). Some regulations are at least partially supportive of this cultural mechanism, such as those for "proxy" hunters who can legally hunt for the Elderly. Yet, subsistence regulations that limit individual harvest amounts of these community hunters thereby constrain this adaptive trait (Callaway 1995).

Conclusion: Threats to the Sustainability of the Koyukon Livelihood

> The right to an acceptable standard of living is meaningful only if it can be achieved in the area where people have chosen to live (VanStone 1974).

> A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (Carney 1998).

All of these economic, political, social, and cultural issues have combined to make the long-term viability and sustainability of rural villages questionable. Maintaining connections to the land and opportunities for subsistence are clearly of major importance. In recent years, an additional threat has begun to surface. The threat of rapid global warming with local effects on ecosystem services, mobility, and harvest success is a growing concern to the sustainability of rural Alaska Native communities.

Laws and regulations that do not account for the cultural and economic realities of village livelihoods are often met with resistance and lack of compliance (Caulfield 1992). If wildlife managers and biologists are seeking a high level of compliance in order to protect sustainability of subsistence resources, this must be taken into account. Violating regulations is not viewed as criminal by Natives when adherence to custom and tradition that existed for much longer is being fulfilled (Berger 1985). Threats to Native subsistence practices are direct threats to the sustainability of livelihoods and Alaska Native rural villages in general (Bane 1982; Thornton 1998). It is the enduring ties to and reliance on the land and its resources to provide economic, physical, spiritual, and ultimately cultural sustainability (Berger 1985). However, threats to subsistence must be considered in the context of a range of other economic and ecological factors that threaten Native livelihoods.

The Koyukon have experienced an enormous amount of change to their livelihoods over the last Century that has resulted in a transition across a spectrum from the traditional way to a more modern way of life. Yet the Koyukon livelihood in rural villages is still largely dependant on the ability to live off the land and continue a subsistence way of life. Multiple stressors such as lack of access to locally derived wages, rising costs of energy, and climate change combine to threaten their way of life. The current complicated regulatory system that resulted from ANCSA and ANILCA further restrains options and threatens to restrict adaptability through limiting cultural adaptive behaviors. Decisions made today about how to respond to these threats to livelihoods will have major implications for the long-term sustainability of the Koyukon Athabascans in their traditional homeland. In order to make informed decisions it is important to understand how all of these factors discussed here underpin and continue to shape the vulnerability and adaptability of the Koyukon and the regulatory system in which they function to the continuing rapid social-ecological changes that global warming will bring to the region.

Chapter 3: The Koyukon Worldview and Seasonal Cycles

The Koyukon Seasonal Cycles

Despite the tremendous changes to the Koyukon livelihood over the last century as discussed in chapter two, some cultural vestiges remain strong, especially those regarding the position of humans in the natural world. Their livelihood is still closely tied to the natural seasonal cycles of their environment throughout the year. As such, seasonality patterns the annual social-ecological cycles and relationships and continues to inform the Koyukon worldview. This worldview continues to focus on the need for humans to respect the land and life-giving animals on which they depend. As recently as the 1800s until around the turn of the 20th Century, Koyukon lived a seasonally mobile hunter-gatherer way of life moving to find the fish and wildlife across the landscape. Though not as mobile as in times past, the timing and rhythm of the seasons still drives and patterns the livelihoods of the Koyukon:

> *We used to go to fish camp around the first of June about or middle of June till late fall. Then late fall we'd stay in village for about a month. Then we'd go out trapping area, fur trapping area. Then we'd never come back till Christmas time. Stay in village for month. Go back out for beaver trapping when ducks come in. Springtime come, late in March come back stay about a month. Go back out to trapping area for muskrat. And it just keep going round and round like that all the time. There was no school, that was our education there, because no school to go to. No school building, no church.* Bill Williams, Hughes (Williams & Williams 2004)

This seasonal cycle is now commonly referred to in wildlife/subsistence management circles as the "seasonal round." Survival was almost entirely a matter of opportunism, i.e., being able to find, catch, and eat anything available in the environment (Nelson 1986). This required a close connection with and understanding of the cycles of nature, including when and where to look for food and the ability to anticipate good or bad weather conditions that affected both animal behavior and safety (ibid).

What did the "traditional" seasonal annual round of the Koyukon Indians look like during the first part of the 20th century? A purely "traditional" seasonal round is impossible to reconstruct accurately because it required seasonal, annual and decadal flexibility and was thus not a static entity and has thus undoubtedly changed in myriad ways throughout time even before European contact. However, the limited records that do exist around the turn of the century give us a good idea since – according to the late Koyukon Elder, Edwin Simon, for example – Interior Natives were *still* living mostly the "old ways" based on stories told to him by his Elders who lived before contact with European traders, and who still remembered and passed on the oral traditions of a time before they were born (Madison & Yarber 1981). These oral traditions of the Koyukon provided the glue that connected family members to each other and families to their ancestors, the land, and the seasons. Their livelihoods were so tied to the seasonal cycles that instead of the four seasons we normally think of, the Koyukon have at least 11 distinct names for seasons based on seasonal activities determined by climatic conditions and the timing of light and dark, snow and rain, hot and cold as well as plant growth and death, animal behavior, and access to subsistence resources depending on the condition of the landscape. I briefly describe below the traditional seasonal round, and in chapter five I discuss changes to these seasonal cycles resulting from recent warming trends.

Below is an original drawing of the Koyukon seasonal round (Figure 5) that combines the so-called "traditional" aspects along with the modern ones, as will the discussion to follow. This drawing was a collaboration between me and Travis Cole, a 20-something Koyukon from the village of Hughes on the Koyukuk River. I mention this here to highlight that these practices and traditions that I will discuss in this chapter are still alive and transferred between generations, albeit less-so than in the past, in the Koyukuk-Middle Yukon region. This is, in part, to dispel the myth that modernization has totally taken hold and that as a result this worldview only exists primarily among the Elders. In the spring of 2007 my collaborators and I (chapter five co-author and collaborator, Shulski and Lehmkuhl-Bodony, respectively) were in Hughes to give a presentation to the community about the research results to date and to get their feedback for the next phase of work. After the workshop I was describing to Travis an idea that I had for a drawing of the Koyukon seasonal round. Travis went home and by the next day had hand drawn what is seen here in the wheel portion of this drawing. Together with graphic designer, Mike Shibao, I had this version created, which will ultimately be the center-piece of a poster that I will gift to each of the villages in which I worked.

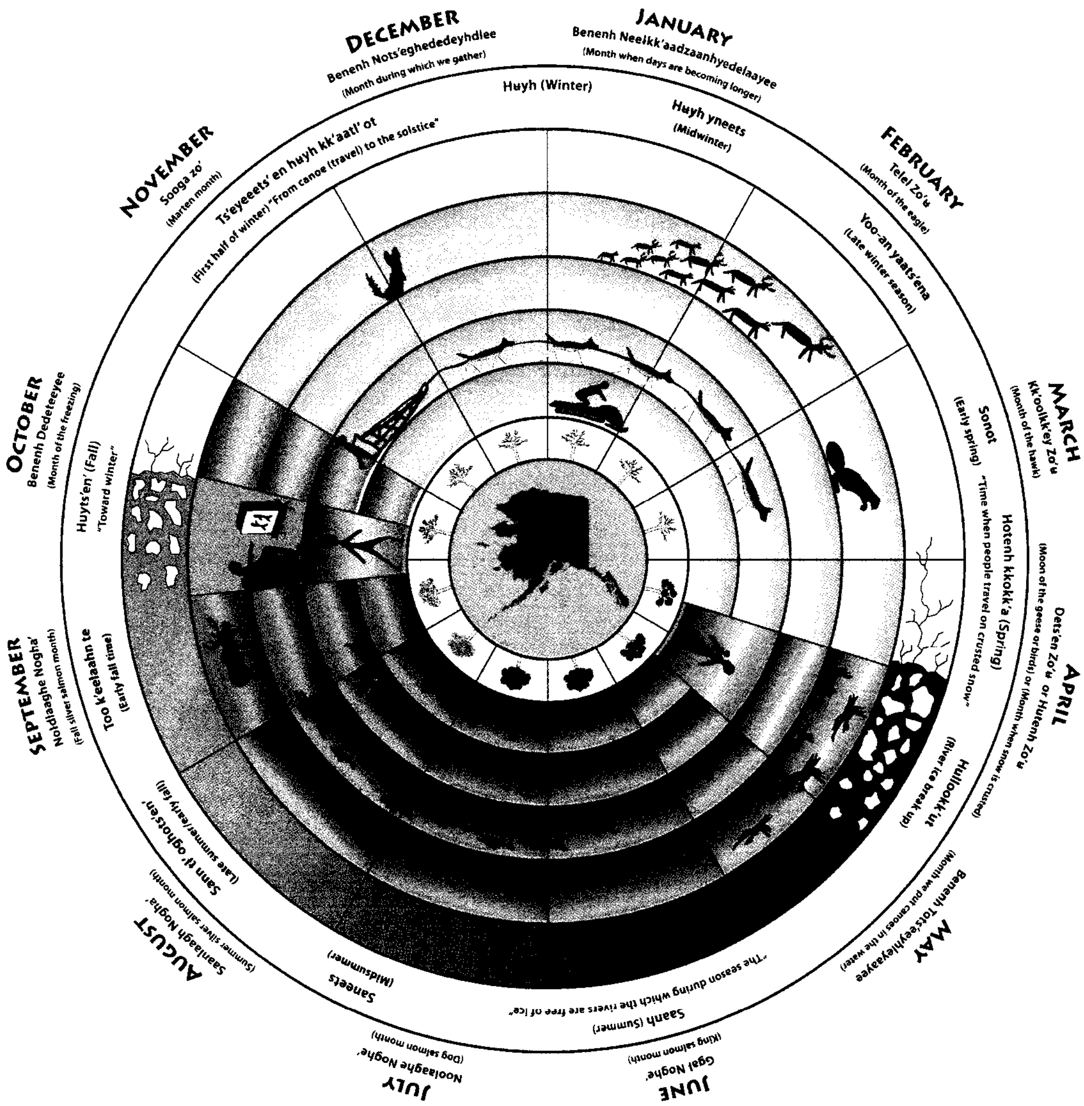

Figure 5 The Koyukon Seasonal Round. Original artwork by Shannon McNeeley, Travis Cole, and Mike Shibao. In the traditional Koyukon lunar year there were 16 months starting with our December month during which time they would gather and which includes winter solstice (Jette & Jones 2000). Here I chose to include the more modern version with the twelve months of the Gregorian calendar with the appropriate Koyukon name.

***Saanh* (Summer)**

"The season during which the rivers are free of ice" (Jette & Jones 2000)

Throughout most of the year, it was the family unit that spent its time together in the food quest, and larger bands of about 50 or more people coming together and then breaking apart, depending on the seasonal shared labor needs and ceremonies (Clark 1975; Sullivan 1942b). In early June families moved from spring camps to their summer fish camps along the rivers in preparation for the first run of salmon (ibid). Having spent winter mostly apart in small families, this was an important time to re-group and socialize with other members of the band through traditional feasts or potlatches while preparing for a summer of fishing. They would stay in fish camps (usually made up of one or two extended families) all summer long to catch and dry king, chum, and silver salmon for themselves and for their work dogs –the main form of winter transportation (Clark 1975; Huntington & Reardon 1993). Traditional fish traps made of birch were used, and the work of catching, cutting, drying and storing fish for the winter was highly labor intensive and required full participation by everyone in camp (Anderson et al 2004). By ***Saneets* (midsummer)** fish racks would be full of drying fish.

By late summer (August), called ***sann tł' oghots'en'*** ('late summer/early fall'), ducks and other migratory waterfowl started moving south, and the men would go for short trips to hunt them. By the mid-1900s this was also the time when moose started moving to signal the beginning of the fall rut and Koyukon hunters would start "looking around" for them in mid-August (Nelson 1983).

***Huyts'en'*(Fall)**

"Toward winter" (Jette & Jones 2000)

***Too k'eelaanh te* (early fall time)** (when the water hasn't completely frozen yet) was spent preparing for winter by gathering wood and repairing hunting and trapping equipment. During this early fall season (late-August to mid-September) they would leave the summer fish camps to move to different camps located by lake or stream outlets and the men would take trips to first hunt moose, then caribou and bear while women stayed near camp and snared smaller game (Clark 1975). Moose were locally very sparse or nonexistent, and hunting for them required long trips or days of stalking one moose as they were highly valued for their meat and skins (Huntington & Reardon 1993). There were no moose or caribou at all in the Upper Koyukuk River drainage, so travel over great distances was required to find them (ibid). Before moose came to Koyukuk River drainage people traveled to the Melozitna River drainage where moose were relatively abundant (Huntington & Reardon 1993; Madison & Yarber 1981).

Fall-time fishing meant setting traps for whitefish and grayling that would be fat from eating all summer (Clark 1975). During early- to mid-October the rivers would begin to freeze, and by late October the first snow would start to fall. Men would go out after freeze up to hunt bear in their dens – a feat of great skill and bravery.

***Hʉyh* (Winter)**

The whole Koyukon winter season was considered to be generally the seven months between river freeze up in the fall through spring break up. ***Ts'eyeets'en hʉyh kk'aatl'ot* is the first half of winter**, which literally translates to "from the canoe (travel) to the solstice," which – according to the notes of Jette – generally lasted two to two and a half months indicating the mid- to late-October freeze up time period (Jette & Jones 2000). In November, with deeper snow and colder temperatures, trapping for furbearing animals became the primary activity; by the early 1900s trapping was the main element of the economy and culture (Bane 1982). Caribou were also hunted during the winter, and in the early 20th century, and before moose became abundant they were the primary ungulate found in the region, though availability was variable and highly dependant on the herd dynamics (Skoog 1968). Also, before moose snowshoe hare, ptarmigan, and spruce hen were abundant and oftentimes the main source of protein throughout the winter.

During the winter holiday season people would gather in the villages. What had before the influence of Christianity been a winter feast/potlatch around the winter solstice in December, later turned into the Christmas and New Year celebration as per the Christian calendar (Sullivan 1942a). ***Hʉyh yneets* (midwinter)** was marked by the winter solstice *(hʉyh kk'aatl'ot),* and was determined by when the sun reached a landmark known to be the southern most part on the horizon (Jette & Jones 2000). This marked the beginning of the new year and was celebrated with a week or two of traditional festivities before introduction of the Christmas holiday and the Western calendar (ibid).

January through February temperatures stayed for lengthy periods in the -50s Fahrenheit or below and trapping for wolf, wolverine, lynx, mink, fox, marten would pick up again and continue through the winter until early spring with the trapping of otter and beaver. This **late winter season *(yoo-an yaats'ena)*** could be difficult in terms of hunger, yet the returning light and warming temperatures signaled that spring was imminent and peoples' moods would start to lighten. When moose became abundant, a cow was often harvested in late winter/early spring to supply food when the winter cache started to dwindle. Fishing under the ice for blackfish was also survival food when food was getting short in late winter/early spring (Anderson et al 2004).

Hotenh kkokk'a (Spring)

"Time when people travel on crusted snow" (Jette & Jones 2000)

S*onot* (early spring) began around early April when the snow began to melt. Spring was reportedly a time of joy when the river ice finally broke and waterfowl started to return in early May (Madison & Yarber 1981). **River ice break up (*hullookk'ut*)** was a dramatic event when ice thickness would often grow to be four or five feet thick (Huntington & Reardon 1993). It was an event to watch with thundering sounds of crashing walls of ice that would often cause ice jams and flooding. Moving to high ground when flood waters rose was common then and relatively easy (compared to today) given the need for few material possessions and ease of mobility (ibid). Once the rivers and lakes were ice free in May this meant ability to travel again and moving to spring camp to hunt muskrats, beavers, ducks, and geese. In June the seasonal round would begin again with a return to fish camps. This was the annual seasonal cycle of the Koyukon people that shaped their worldview and social-ecological relationships.

The Koyukon Worldview on Social-Natural Relations

Family relationships are central to resource harvest activities and the distribution and consumption of those resources. Socially adaptive characteristics of the Koyukon were historically, and continue to be, important to survive the harsh conditions of the region with the cyclical, often unpredictable, and ever-changing conditions of the natural world. Communal and reciprocal sharing and distribution of foods and resources of all kinds are significant elements of Koyukon social organization (Brown et al 2004; Clark 1974). The sharing of food is a critically important adaptive strategy throughout rural Alaska to ensure that risks of a poor individual or family harvest are distributed throughout the community (Wolfe et al 2000). This social connectedness has long operated to ensure that all in the group had what they needed to survive regardless of an individual hunter's success, which was always uncertain in this difficult environment where resources were sometimes sparse and spread unevenly across the landscape (Langdon & Worl 1981).

Potlatch ceremonies have long played a strong communal function in the social fabric of the Koyukon (Simeone 2002). During potlatch ceremonies today, the Koyukon people continue to acknowledge and pay respects to their social connections to each other and to their ancestors, their physical dependence on the harvest of wild foods, and their spiritual ties to the natural community of which they are a part (KUAC-TV 1997). A myriad of traditional seasonal and religious potlatches were important ceremonies that included feasts to honor life-giving animals or ancestors and provided an important social glue for the larger group (Loyens 1964).

In the past, funeral or memorial potlatches provided a means for distribution of resources throughout the group as the possessions of the dead and other gifts would be given out to everyone by the deceased's family (ibid). Missionaries preached against the potlatches, which were seen as sacrilege and wasteful (Schneider 1986), and many of the ceremonies were eventually abandoned even as early as 1900 (Clark 1970). The funeral and memorial potlatches are the most enduring traditional ceremonies today and one of the most important cultural vestiges that maintain the ties between the traditional and the contemporary (Jette & Jones 2000; Sackett 2008).

A tremendous amount of labor, time, energy, and money are still put into these memorial potlatches. Preparations usually start months to a year in advance. In modern times, the potlatch is culturally and socially important to maintain community and family ties, yet highly consuming of precious financial, material, and natural resources. In a modern context it is increasingly an accumulation of material items, but is yet an important way of keeping stories, native songs, and traditions alive. With so many of the cultural traditions becoming obsolete in the modern world, the Koyukon Elders see the memorial potlatch as crucially important for passing relevant traditional knowledge, beliefs, and practices to younger generations.

Family, food, and resource sharing networks go beyond intra-village sharing, they extend regionally between villages, and between urban areas and rural villages such as Anchorage and Fairbanks where relatives often live for jobs and/or schools permanently or temporarily (Meadow et al in press). In today's context, where jobs and school opportunities are few in rural villages this is a necessity for the extended network of families. Relatives and community members are mutually supportive between urban and rural areas.

Living off the land in the traditional way meant a close connection to the rhythms of nature as well as the necessity for deep and intricate knowledge of their environment for survival (Nelson 1983). To the Koyukon nature was alive and full of spirits from the animals to the physical landscape and weather (Jetté 1911; Nelson 1983). This belief system was based largely on the need for humans to be humble to the natural world in order to be successful in the ongoing food quest (Sullivan 1942b). It defined the role of humans in the natural environment, where those things greater and more powerful than humans – i.e., the animals, weather, and even the cosmos – were to be treated with utmost respect and trepidation (Jetté 1911; Nelson 1983; 1986). Hudson Stuck who traveled extensively throughout Interior (and coastal) Alaska in the early 1900s wrote about the "awe-inspiring" character of the "strong cold" of winter which he said "brought fear with it," as temperatures of -50 to -70 below were not uncommon (Stuck 1988). As such, the consciousness of the Koyukon was geared to hold weather and nature in high reverence as they were astutely aware of its awesome power. This required humility, respect, and strict adherence to taboos, as arrogance or carelessness could often mean death (Stuck 1988).

Jules Jetté documented the Koyukon belief system during the early 1900s and wrote about their many taboo-oriented beliefs toward the natural world. Jetté considered the Koyukon (or Ten'a as he called them)[7] to be deeply superstitious with what he considered to be a "strong and irrational fear" of the spirits in nature (Jetté 1911). Jetté carefully documented these "superstitions" of the Koyukon yet as a Christian he considered their beliefs to be false and border on devil worship (ibid).

> Omens [of the Koyukon] imply an obscure idea of causality, inasmuch as the omen is taken not as merely foreboding what is going to happen, but as being in some manner instrumental in bringing it about (ibid).

Nature taboos as these are characteristic of northern natives and indigenous people throughout the Americas. According to Athabascan scholar VanStone (1974) the single most common trait of Athabascans throughout North America is their "magico-religious" belief system of which taboos are a major feature that ordain the relationship between animals and humans. Unlike Jetté's almost blanket dismissal of taboos playing any sort of functional role in Koyukon society, VanStone and others saw the function of

[7] Also, early missionaries and anthropologists referred to the Koyukon as Ten'a, which was a misspelling of the Athabascan word for "the people" *denaa*.

these taboos as a way to temper the exploitative relationship of humans toward animals and nature (Nelson 1983; VanStone 1974). The Koyukon ideology was based on a "moral code" or environmental ethics that governed human behavior toward nature and included conservation methods such as avoidance of waste or excessive use of resources (Nelson 1983; 1986).

When visiting a Koyukon village today, in conversations with the Elders, one will soon hear the term *hʉtlaanee*. The Koyukon Athabascan dictionary, which used the writings of Jette as the foundational text of the language, defines *hʉtlaanee* as a taboo item, or a bad omen (Jette & Jones 2000). The meaning and system of taboos based on this principle is a very intricate set of rules for how humans are to behave. It could be compared to the Ten Commandments in Christianity, yet it is a far broader set of principles and rules that encompasses not only respect and proper treatment toward other people, but respect and the proper treatment of the whole of the natural world. In the documentary film by Richard Nelson *Make Prayers to the Raven* the narrator states: "Nature is not governed by God as in Christian tradition, Nature is God" (KUAC-TV 1997).

Traditional Koyukon spirituality is based on *Kk'edon ts'ednee* or Distant Time stories (an oral version of the Koyukon "bible" so to speak) that explains the origin of living things (Attla 1990). The *Kk'edon ts'ednee* stories were passed down through the generations orally and tell of a time when all living species were humans before turning into animals. The transformation of humans to animals in this Distant Time explains why animals have certain characteristics that are human-like. Distant Time stories endow the Koyukon people with a foundation for understanding their nature-based world and the relationship of humans to it (Nelson 1983). These stories also provide a way for passing down *hʉtlaanee* – i.e., the rules and codes that dictate proper behavior. Stories of Distant Time were told during the long, dark, cold nights of winter, and could take weeks to tell. At the end of each telling of a part of the story, the storyteller would say:

> *Et'eghł hʉydo hʉtaaldlet yeenslenh de hʉyh ghon' naaltlgus* – "I thought the winter had just begun and now I have chewed off half the winter."

"Saying this after each storytelling expresses the hope that the winter won't be so long" (Jette & Jones 2000).

It is this tradition that binds Koyukon to a strict moral code of responsibility toward the environment, and this is perhaps one of the reasons why their homeland remains largely undamaged today. Koyukon Elders took care of the animals by only taking what they needed so that the animals would still be around in the future. This embodies the concept of reciprocity in that if the animals give themselves to the hunter it is a direct effect of the hunter's demonstration of respect and self-restraint. Therefore, *hʉtlaanee* can be understood to mean self-restraint or restrictions on personal and group behavior.

Hʉtlaanee are methods not only for self-restraint but also for mental acuity. They serve a spiritual purpose, but also very functional role, which is that of maintaining focus. When one is not giving their full attention and awareness to the task at hand, the goal, and perhaps most importantly the process, one becomes more vulnerable to one's own mistakes, mishaps, accidents, or worse in the sometimes harsh and unforgiving environment of the Subarctic – death. Death might come immediately from falling through the ice, getting caught in a bad storm, freezing to death or it can come via the lack of harvest success and ultimately starvation. To the Koyukon it is all directly related – if you violate the rules of *hʉtlaanee* you will have no luck and no harvest success. This is one of the reasons that many of the Elders today talk about safety so much – because they are worried that the younger generations aren't paying attention to the signs, observing *hʉtlaanee,* and, therefore, more at risk for accidents while out on the land.

The belief that an animal would move away if respect was not shown is central to the animal-human relationship in the mind of the Koyukon.

> *Why we are taking care of animals and like moose - they used to tell us another thing about moose, don't throw that anyplace. Like take it back to the lake for the water animals. But moose, you can take it back too, but you put it on dry land. 'Don't' burn*

> *moose bones' they used to tell us. Even when we cook it, you're not supposed to burn it over the fire. Moose doesn't like that. They move someplace else where people take care of them better.*(Bill Williams, Hughes 2004)

Caribou are another subsistence species in particular that this affected as it is a herding animal that changes its migration patterns (Skoog 1968). Because animals don't like blood on the trail the Koyukon always made sure to clean up the camp.

> *Like caribou you're not supposed to drip blood all over the trail. Caribou doesn't like that. Like this old time story that I was telling you about. He said me I'll come back! In certain years, they said, if you don't take care of me, I'll come back in a few years* (Bill Williams, Hughes 2004).

The Elders know that the younger generation will survive in the bush if they "keep the old ways" because that is how a person and a community as a whole keep their luck. If you don't respect the land and animals and keep the land clean you will be "out of luck with it" (Beatus 2004). This way of thinking with respect to the natural world has persevered, especially among the Koyukon Elders. The Elders today especially adhere to the belief that proper treatment of an animal by a hunter is required, lest its "spirit" be offended resulting in refusal of that animal to be caught (Huntington & Reardon 1993).

Webster's New World Dictionary defines luck as "the seemingly chance happening of events which affect one; fate." The notion that luck occurs by chance comes from an antithetical Western Euroamerican ontology that contradicts that of the Koyukon worldview. In fact, the western definition of luck is much more superstitious than that held by the Koyukon because it implies some higher power or on the other hand nihilistic and random universe, whereas the Koyukon embodies the notion of human agency and action-orientation in creating their own fate. This cause-effect viewpoint expresses a realistic, pragmatic, and wise understanding of the interrelatedness of humans to their environment. Superstition is defined by irrational, unfounded fear or belief not based on reason or knowledge. *Hʉtlaanee,* on the other hand, is a system for determining luck either good or bad and is based on thousands of years of close participation with nature and understanding human interdependence with nature. It was obtained through observations and a deep wisdom time-tested through survival regarding how humans must relate to their natural world in order to succeed. In my view *hʉtlaanee* is not superstition; rather it is a code of respect and self-restraint for sustainability.

Luck then is not fatalistic, nor is it predetermined. Each human individually and collectively has a responsibility in determining how their luck will manifest based on their thoughts and actions. This is a core belief of the Koyukon. And it is this belief system and the rules that follow that have allowed them to live, survive, and prosper or fail in this rugged land. The legacy of which is a landscape that appears to have been barely touched by humans, and that still provides valuable ecosystem services such as providing food and materials without extensive human manipulation. This is why the Koyukon do not think or talk badly about or disrespect animals or the land. They know through hundreds, perhaps thousands of years of experience, that to do so will bring bad luck and misfortune. Conversely, to act, think, with respect will bring good fortune, even with the weather.

> *What I've noticed in the weather from long time ago, when we were kids they used to tell us, "don't talk about animals or don't talk about fish. Say 'we'll do this, we'll do that' I think that's what makes the difference in the weather. Because like in springtime when we first catch our fish, we don't say 'I caught it!' we say 'enaa bassee' (thank you) I think that's how we took care of the weather a long time ago. Same thing with geese and ducks, moose and caribou. I think a part of that too, part of the way we were trained.* Madeline Williams, Hughes (Williams & Williams 2004)

To an outsider, comments such as this one might seem on the surface to be mere superstition. However, there is a deep wisdom contained in this statement about the link between a human's lack of humility toward the awesome power of nature and changes in weather. This thinking is much more expansive and encompassing than Western notions of a direct and observable cause and effect. For it reaches beyond the immediate-term to the ultimate outcome in the link of events leading to Man's hubris toward it's support system – i.e., the Earth and it's living and nonhuman interconnected system. For it is exactly this hubris that supports the attitude that we can, and in fact are entitled to, exploit nature for our own selfish needs and without limits (Bennett 2005). It is the understanding of these limits that are contained in the Koyukon wisdom about our relationship to Nature.

There is concern among the Elders and more traditionally-minded among the Koyukon that these customs are fading. However, from my own personal experience, I first learned of the meaning of *hʉtlaanee* while riding bicycles to spring camp with five-year old girls who explained to me that it was not okay to speak about Big Animal (grizzly bears) because it is considered *hʉtlaanee.* It is a mistake to think of Koyukon traditions as disappearing in a linear fashion, though with modernization and youth who are seemingly increasingly influenced by television, video games, music, and "outside" culture generally there are variations in how these concepts are integrated on individual, family, and household levels.

Man on the Moon is *Hʉtlaanee*

Violating the code of respect toward all entities considered to be greater than humans is equivalent to breaking the highest law of the land. Huslia Elder, Catherine Attla, has likened it to U.S. Supreme Court law (KUAC-TV 1997). One example of this sort of violation was man going to the moon. To the Koyukon Elders it represented a most egregious violation of this respect relationship to the natural world, which includes the moon. On a small scale Catherine believes that they have more accidents (i.e., bad luck) because they are losing their adherence to the old ways, and because laws of human-nature relationships violated. For her, there are now more accidental deaths as a result of this imbalance.

One of the most talked about and respected Elders in the region, the late Chief Henry, was known to be extremely wise and a phenomenal storyteller.[8] He (along with other Elders at the time) was very disturbed in the 1960s when scientists started sending satellites and then people to the moon. This violated the *hʉtlaanee* that decreed that people should "never mess" with the moon because it was greater than humans. He warned that this act was going to create a great imbalance in the world, and he predicted future changes in weather and other difficult changes for the Koyukon people. Chief Henry told them that the "cold weather will grow old" meaning it will change and lose its strength. In an interview in 2005 Koyukon Elder and scholar, Eliza Jones, told me:

> *Because we were taught at a very early age to respect the land, respect the world, respect anything that was bigger than us and we should never try to mess with nature. And it's like breaking a taboo I guess. By the scientists going to the moon and doing things that man isn't supposed to do* (Jones 2005).

Eliza and other Koyukon Elders see that Chief Henry's predictions are now coming true. They see the recent changes in weather, climate and their environment as signs that man has violated this taboo to respect nature and the Universe, and now mankind is paying the price through an imbalance in the world. The moon like all they interact with in their natural world is a sacred entity to the Koyukon. They would pray to it often for good weather and harvest success. Because the moon was sacred humans should not be traveling there and walking on it according to the Koyukon view. There is also an understanding among the Elders about the physical relationship of the moon the Earth and how it affects tides and weather. They used to use the moon and the stars to tell the weather. This is why they associated messing with the moon as changing the weather. "Everything has changed" since man went to the moon. Going to the moon symbolized man going too far with technology and how he treated the earth and the skies (McNeeley

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[8] He was and still is known as "Chief Henry" because he was the first "chief" of Huslia when the United States imposed a political "tribal" system on the Alaska Natives Frank A. 2004. Personal Interview with Alda Frank, July 8, 2004. Galena, Alaska.

& Huntington 2007). The act of Man going to the moon symbolized this disrespect for the sacredness of the earth and skies; and so today's Koyukon Elders repeatedly talk about this whenever discussing their observations of a changing climate.

To the Koyukon Elders on a larger scale, the whole of humanity has violated these codes of respect toward the natural world that is greater than humans. And they see that now we as a human community, which includes the Koyukon, are experiencing the consequences of that across all scales through changes in weather and a world out of balance. The Elders see global climate change as a result of this violation scaled up to the global level where humanity as a whole has violated these highest of laws by disrespecting the land/Mother Earth/nature and an observable manifestation of this is that seasons are now out of balance.

Chapter 4: Observations of Climate Change

Climate Change and Sustainability

Humans have changed their natural environments for millennia, sometimes to their benefit in the short-term, but also degrading it to their own detriment over the long-term as well (McGovern et al 1988; Redman 1999; Winterhalder 1994). What is different today is that humans are changing global-scale biogeophysical processes at unprecedented rates, with unprecedented population growth and density consuming natural resources beyond the capacity for ecosystems to recover, regenerate, or continue to provide essential natural capital for supporting human systems (Costanza et al 2007; Crumley 2007; Millennium Ecosystem Assessment 2005a) Such problems are exacerbated by a global society that is interconnected through financial markets and a globalized economy. Regardless of whether we are talking large or small societies and economies, it is now clear that all are situated globally, with vulnerabilities even greater than anticipated with the global economic downturn in 2008-2009. We have arrived at a time in human history where the complexity of human societies combined with rates of resource consumption and environmental change are threatening human quality of life at best and survival at worst – but on a scale heretofore unrealized.

The transformation of natural resources to material and energy for consumption by humans is occurring at unprecedented rates and magnitudes; the ability of ecological and social systems to satisfy human needs also are now compromised by a changing environment and by human wants, with the provisioning of basic services unevenly and differentially distributed across the globe and across the developed, developing and so-called undeveloped world (Bennett 1996; 2005; Millennium Ecosystem Assessment 2005a). Because human population growth is inextricably linked to economic growth, and because both are tied to consumption and limitations on resource extraction, this cycle is inherently unsustainable in the long term (Brown 2008; Costanza et al 2007;

Hornborg & Crumley 2007; Millennium Ecosystem Assessment 2005b; Steffen et al 2004).

The ongoing cycles of population and economic growth are fundamentally linked to climate change as well with energy and material production, transportation, agriculture, and technology all dependant on the burning of greenhouse gas-causing fossil fuels until humans find a feasible way to satisfy our energy and material consumption habits as a species. More importantly perhaps, as a species we must adapt to this realization that our pace of consuming the world's resources has outpaced the absorptive, regenerative capacities of the Earth; and, therefore, we must proactively change our relationship to it in order to be more sustainable for generations to come.

In the meantime, we are committed to warming for many decades into the future, which means that as a global society we must pay serious attention to vulnerable people and places to implement measures to reduce vulnerability and strategize for collective anticipatory adaptation measures that sustain ecosystem services and livelihoods. The Arctic and Subarctic regions of the world are among the first to experience the effects of warming, and Alaska is one of the fastest warming places on Earth (Hansen et al 2007); and the indigenous people who live there are at the frontline of observing and experiencing the effects of global warming as they still depend on harvesting natural resources from their environment to sustain their livelihoods and well-being (Krupnik & Jolly 2002).

Climate Change and Variability in the Arctic

It is well-established now in the world scientific community that the Earth is warming. Regardless of what we do now to mitigate this through greenhouse gas reductions, we are still committed to at least another century of future warming, if not longer (Hare & Meinshausen 2006; Solomon et al 2009; Wigley 2005). The Nobel Peace Prize-winning Intergovernmental Panel on Climate Change (IPCC) made up of over 2,500 of the world's leading climate scientists from more than 130 countries agree that human energy consumption of fossil fuels is responsible for planetary warming through anthropogenic greenhouse gas emissions such as carbon dioxide into the atmosphere (IPCC 2007). The 2007 IPCC assessment [9] concluded that 11 of the previous 12 years are the warmest on record since instrumental observations began in 1850, and that the average temperature of the Earth has increased by 1.3°F (0.74°C) over the past 100 years (IPCC 2007). Similarly, the largest scientific society in the world, the American Geophysical Union, stated in 2007:

> The Earth's climate is now clearly out of balance and is warming. Many components of the climate system—including the temperatures of the atmosphere, land and ocean, the extent of sea ice and mountain glaciers, the sea level, the distribution of precipitation, and the length of seasons—are now changing at rates and in patterns that are not natural and are best explained by the increased atmospheric abundances of greenhouse gases and aerosols generated by human activity during the 20th century (AGU 2007).

The Arctic is expected to experience some of the largest and most rapid climate changes of any region on Earth, with major physical, social, economic and ecological impacts (ACIA 2005; Chapin III et al 2004; IPCC 2001; Serreze et al 2000; Walsh 2005).

In 2005 the intergovernmental Arctic Council released the groundbreaking synthesis, "The Arctic Climate Impact Assessment (ACIA)." Hundreds of leading Arctic climate researchers and indigenous experts concluded:

> The Arctic is now experiencing some of the most rapid and severe climate change on Earth. Over the next 100 years climate change is expected to accelerate, contributing to major physical, ecological, social and economic changes, many of which have already begun. Changes in arctic climate will also affect the rest of the world through increased global warming and rising sea levels (ACIA 2005).

[9] 2007 was the fourth assessment report conducted since the IPCCs conception in 1988. The IPCC is an intergovernmental body established by the World Meteorological Organization and the United Nations Environmental Program.

The Arctic land areas (with the Arctic defined the same here as in the Arctic Climate Impact Assessment to include are areas north of 60°N), and together with the Antarctic Peninsula, have experienced the greatest regional warming of any place on Earth in recent decades with average annual temperatures increasing by about 3.6 to 5.4°F (2 to 3°C) since the 1950s and up to 7.2°F (4°C) of average winter warming during the same time period (Huntington & Weller 2005). Global climate change is amplified in the Arctic region because of positive feedbacks that include decreased albedo (reflectivity of the sun's energy) with melting snow and ice, cloud dynamics, and temperature anomalies that trap heat at the Earth's surface (Euskirchen et al 2007; Overpeck et al 1997). General Circulation Models (GCMs) that simulate future climate project an annual mean temperature increase of approximately 3.6 to 5.4°F (2 to 3°C) by 2050 for the Arctic as a whole, with large seasonal and regional variability anticipated (Kattsov & Kallen 2005).

Observational records of precipitation in the arctic region are not as reliable as are temperature, in part because of the limitations of measuring rainfall and snowfall in very cold environments (McBean 2005). The observations for the region show an overall increase in precipitation over the last century, with greatest increases observed in fall and winter (Serreze et al 2000). Though observations also indicate that the fraction of annual precipitation falling as snow has diminished, with anticipated significant effects on terrestrial wetlands (such as bogs and fens) where spring snowmelt is an important factor in the water balance of the hydrological cycle (McBean 2005). Freshwater arctic ecosystems are particularly sensitive to climate change because their habitats depend upon the interactions between temperature, precipitation and permafrost (Huntington & Weller 2005). Recent warming trends and changes in the biophysical systems have already caused changes to supporting hydrological and ecological services (Hinzman et al 2005).

Point measurements of snow accumulation are somewhat unreliable in the cold, windy Arctic region as conditions make gauges highly inefficient and snowdrift can contaminate gauge measurements; even accurate gauge measurements cannot capture the regional variability of snow conditions in areas of heterogeneous topography and vegetation (Walsh 2005). Since the 1960s satellite measurements provide more accurate observations of snow cover, but generally cannot measure snow depth or water equivalent (ibid). Satellite measurements averaged across the Northern Hemisphere show that spring snow cover has declined by about 2% per decade since 1966, with little change in fall or early winter (Lemke et al 2007). The decrease in snow extent for the Northern Hemisphere from 1927-2003 was 10% overall, but with high seasonal and regional variability (Walsh 2005).

The most significant biophysical effects of decreased snow cover are on the surface energy budget (i.e., soil temperature, permafrost, and albedo) and on the surface moisture budget (i.e., runoff and evaporation rates). However, these effects differ among seasons. Because of the insulating properties of snow, decreased snow cover in winter causes ground cooling, but decreased snow means greater radiation absorption (lower albedo) and therefore greater ground warming. Changes in snowfall ultimately have large effects on freshwater ecosystems where snowmelt is often the most important hydrological input (Wrona et al 2005). This affects freshwater species through changes in the chemical composition of freshwater ecosystems such as lakes, wetlands, and ponds (e.g., pH, dissolved oxygen, dissolved carbon) and could have deleterious long-term effects on areas such as Interior Alaska that are dominated by wetlands.

Climate Change in the Northern Interior of Alaska

Analysis of mean temperature anomalies throughout the world show that Alaska is one of the fastest warming places on Earth (Hansen et al 2007). Within Alaska the Interior region has shown some of the most marked warming statewide over the last six decades (Alaska Climate Research Center 2008). Instrumental observations indicate that Alaska's mean annual temperature increased 3.4°F from 1949 to 2007, with local wintertime mean temperature change that range from 7.5°F to 9.6°F in the Interior region (Alaska Climate Research Center 2008).

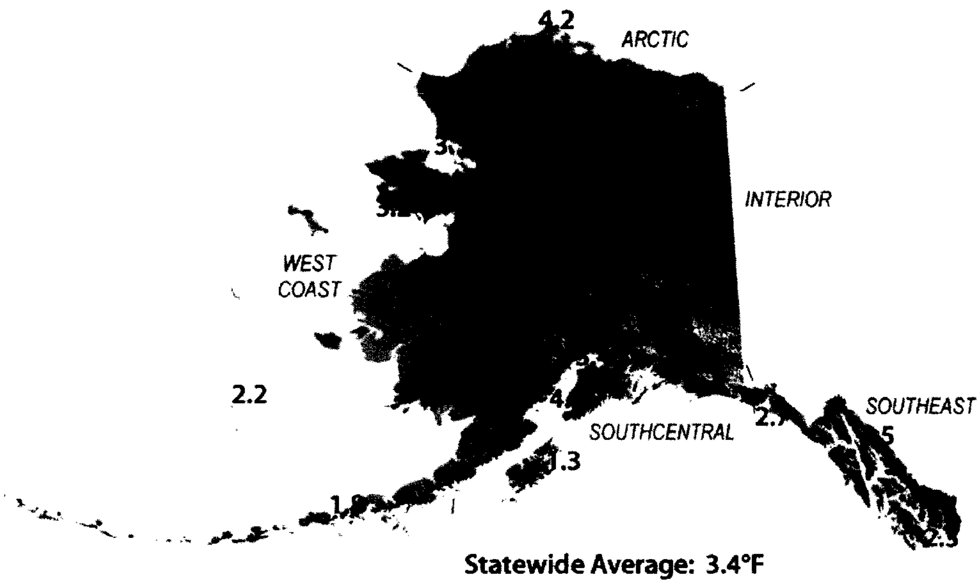

Figure 6 Total change in Alaska mean annual temperature (°F) 1949-2007 Courtesy of the Alaska Climate Research Center, University of Alaska Fairbanks

Table 2 Total change in mean seasonal and annual temperature (°F) 1949-2007. Courtesy of Alaska Climate Research Center, University of Alaska Fairbanks

Region	Location	Winter	Spring	Summer	Autumn	Annual
Arctic	Barrow	[illegible]	4.3	2.9	3.0	4.2
Interior	Bettles	[illegible]	4.7	2.1	1.5	4.2
	Big Delta	[illegible]	3.5	1.5	0.2	3.7
	Fairbanks	[illegible]	3.8	2.4	0	3.6
	McGrath	[illegible]	4.8	2.9	1.1	4.1
West Coast	Kotzebue	[illegible]	1.8	2.7	1.8	3.3
	Nome	6.0	3.9	2.7	1.0	3.2
	Bethel	[illegible]	5.3	2.5	0.7	3.9
	King Salmon	[illegible]	6.0	2.0	1.1	4.2
	Cold Bay	1.9	2.1	2.0	1.1	1.8
	St Paul	1.3	2.8	3.1	1.6	2.2
Southcentral	Anchorage	[illegible]	3.6	1.9	1.6	3.4
	Talkeetna	[illegible]	5.4	3.4	2.6	5.2
	Gulkana	[illegible]	2.2	1.1	0.2	3.0
	Homer	[illegible]	4.1	3.6	2.0	4.2
	Kodiak	1.2	2.5	1.5	[illegible]	1.3
Southeast	Yakutat	5.1	3.1	2.0	0.3	2.7
	Juneau	[illegible]	3.2	2.4	1.4	3.5
	Annette	4.1	2.7	1.9	0.3	2.3
	Average	*6.3*	*3.6*	*2.3*	*1.1*	*3.4*

Warming over the last several decades in Alaska corresponds with a shift in 1976 of the Pacific Decadal Oscillation (PDO) from a negative (cool) phase to a positive (warm) phase (Hartmann & Wendler 2005). How the PDO and other ocean-climate oscillations (AO/NAO/ENSO) are related to planetary warming is not well understood (IPCC 2007). Currently scientists are trying to determine if the PDO is shifting back into a cold phase, which could result in an ameliorating effect on the recent warming trend for Interior Alaska. In general for Alaska, the closer the proximity to the Pacific (Ocean), the stronger temperature correlation to PDO cycles; and winter temperatures for Interior Alaska correlate strongly with the PDO cycles (Figure 7).

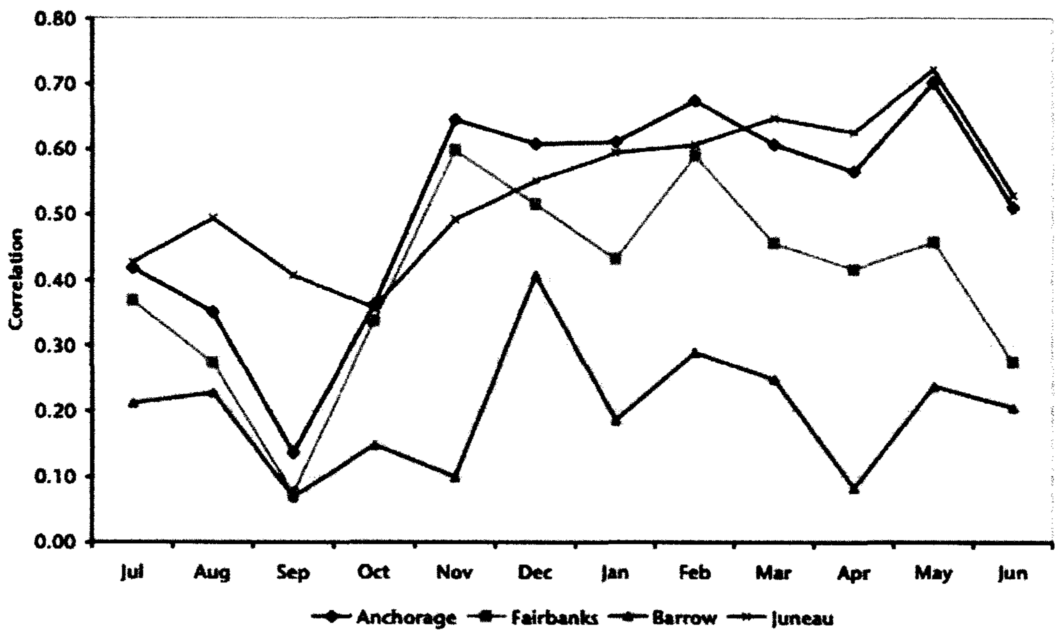

Figure 7 Alaska monthly mean temperature correlation with PDO Index. Note the relatively strong correlation for the Fairbanks station, especially during winter months, and the relatively weak correlation for the month of September. Courtesy of Richard Thoman/National Weather Service (Thoman 2009)

Climate variations such as these are important to consider when examining climate changes. Climate change is defined by the IPCC as:

> a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (Baede 2007);

whereas climate variability is defined as:

> variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events (ibid).

When analyzing climate data it is important to consider how these large-scale oscillation patterns like the PDO affect regional climate. The Alaska climate has definitely changed over the last century and effects are being observed and felt on the ground. Changing climatological trends and weather patterns have altered hydrological processes that support ecosystems, with major implications for both subsistence and land and resource management, (Hinzman et al 2005); and indigenous people in Alaska who are directly experiencing those changes are excellent partners for understanding how recent warming trends are manifesting on the ground.

Indigenous Observations of Environmental Change

Instrumental climate data and observations are relatively sparse in the Interior region of Alaska. Downscaling observations and resolving model data at appropriate spatial and temporal scales is what matters for real-time decision making and policy; efforts in this regard are underway, but results are still inadequate because of course-grained model resolution that does not account for important aspects of variability across space and time in accurate or useful ways (McCarthy & Martello 2005).

Alaska Native Elders and hunters who possess traditional ecological knowledge and have by necessity and inclination made keen observations of weather and environmental change are concerned about what they perceive to be dramatic changes in their biophysical milieu (Huntington & Fox 2005; Krupnik & Jolly 2002; McNeeley & Huntington 2007). Alaska and Arctic Native livelihoods are particularly vulnerable to recent significant climate change and seasonality shifts because some traditional knowledge and subsistence practices are not as effective as they were in the past (Ford 2006; Ford et al 2006; Krupnik & Jolly 2002; McCarthy & Martello 2005; Nuttall 2005). Natural resource-dependant societies, here meaning direct subsistence harvesters, who rely on the predictability of weather and snow and ice conditions, are affected by warming trends that alter hydrological and ecological systems to which their lives are closely connected.

Alaska Native livelihoods are attuned to the seasonal cycles characterized by patterns and timing of break-up, freeze-up, snow and storm conditions for travel, timing of animal migrations, and phenological changes. This tight coupling between human performance, subsistence behavior and seasonality includes knowing when and where and how to hunt, fish, gather, and to trap the various species scattered across land and seascape, and along and around the major waterways. In the past, adaptations to either expected or unusual environmental changes depended on a flexibility to move across time and space depending on the fluctuations throughout the year, and from year to year. Extant patterns of land ownership and regulations that determine where and when they can hunt have restricted their ability to move across time and space as they did in the past to adapt to changing environmental conditions.

The Koyukon Relationship with Weather

> *My late father - I talk about how he used to tell weather - well, we grew up with it. That's all we hear. We're not going to school, we didn't have no education. Everyday that's all we listen to is our native way.* (Alda Frank, Huslia Weather Workshop, May 2003)

> Even the weather is aware: if a man brags that a storm or cold cannot stop him from doing something, "the weather will take care of him good." It will humble him with its power, "because it knows." "In fall time you'll hear the lakes make

> loud cracking noises after they freeze. It means they're asking for snow to cover them up, to protect them from the cold. When my father told me this, he said everything has life in it. He always used to tell us that" (Nelson 1983).

Of all the biophysical elements in the Koyukon word, weather is one of the most personified and revered (Nelson 1983). Like everything in the natural world, the Koyukon Elders believe that one must not talk about the weather with disrespect or arrogance lest its spirit be offended and bring bad luck when traveling or hunting. The weather is aware and "will take care of him good!" if a man has an arrogant attitude that the cold or storms cannot deter him; the weather will humble him with its power (Nelson 1983). There is even some trepidation among some of the Elders today that perhaps public forums to discuss changes in weather and climate might offend the weather and bring harmful conditions (Natcher et al 2007). During an interview with the greatly respected Elder, Rose Ambrose, of Huslia, when discussing a workshop on weather changes recently held in the village she told me:

> *Something heard us. We froze all the winter. Spirit is hearing us! He heard us making big noise, we complain, we complain about warm, global warming and we froze out all the winter. I don't know how much fuel wood we burned.. That's what you call in the old days in our own language hʉtlaanee. That's why the Indian people say hʉtlaanee. They say don't talk too much. Some of the things you don't want to talk about because its hʉtlaanee. You see we talk about we're too warm, and too warm and we're too warm and look at that. We froze all winter* (Ambrose 2004).

This deep reverence toward weather is the result of decades of experience with unpredictable, highly variable, and at times brutally harsh subarctic weather conditions that can humble humans with its extreme cold and tempestuous behavior. The consciousness of the Koyukon is tightly attuned to weather conditions because they have no other choice given the nature of their day-to-day subsistence practices, which all require an ongoing awareness of the conditions. This combined with the Koyukon characteristic of frequent travel across a landscape where the roads are waterways and snow trails require them to have a constant eye on weather patterns, snow and ice conditions, and navigable waters sloughs and rivers. The knowledge about what kind of conditions to expect during any given season (climate) and how to read the signs of the sky to know immediate and near-term conditions (weather) are part and parcel of a long-standing, close relationship with their environment.

> *...as for the weather – it's just nothing like when I was growing up. Come September you'd expect it to get cold, and it got cold. I remember in the late part of September; well sometime in September we were in camp and we had fish net. Our parents had fish net in as late as possible. And we used to take pikes out of the fish net while there was still ice on the water and ice on the net. That was cold. And when it got cold it stayed cold...* (Jones 2002).

An ability to depend on the persistence of weather conditions was always important to subsistence livelihoods as it enabled planning and preparedness for conditions to the best of their ability. This was especially true during the fall season when preparations for a long, cold winter required the stockpiling of food and wood before conditions became more hostile for travel and resource harvest opportunities dwindled. So much work had to be done between returning from fish camps before the ice would start to freeze, hindering mobility until the ice became thick enough to travel over. Similarly, spring break up was observed with great anticipation as it meant freedom to travel to hunting grounds for fresh meat. A time long ago, this time period could present high risk as the later the ice went out, the longer the time until access was increased. Sometimes people would run out of food and starve before the ice went out, so observations of ice break up were very important.

Communication to ingratiate themselves to the weather and related phenomena was common during these former times. People would try to influence the wind, an often formidable foe on the landscape, with songs and offerings to bring good conditions for hunting and traveling (Nelson 1983). One Elder in Koyukuk told me how her mother used to make offerings to the river ice in the spring to encourage it to break nicely and not jam causing floods.

> *You know, mom used to* ghetenoyh yoonggu *('to talk to ice') back at spring camp.* Tl'odogge do'ehoyh. *('She go out to the bank.') and she pick out nice pieces of calico - she pick up all the nice fancy stuff cut it all in pieces and put it in the bag. I said "what you gonna do with that mom?"* Eenaa, dotegheeleel eeydee? beesnee. Haa nedaakoon koodee¬kket. Seneen¬'aanh ts'e hogho ees hukk'aategheelneyhtl," se¬nee.
> *I said to her. A little good food like dry fish and piece of fat with a little tea. She go out to the bank and she throw that on the ice.* Nodo h¨dokkaakk'et k'ee¬k'aanenh noho tl'ok etltonh, ne¬nee. Netooghe ne¬nee nee dehoono *she threw that stuff on the ice. I said* "Debaa eey beye¬ heneehaayenh? Beesnee" *('Who are you talking with?') she tell me "well, that's the way the ice there wouldn't be enough food the ice will keep on going. If the ice stops it's gonna be flooded". She tell me. Nowadays I haven't heard anybody who ever do anything like that. She'd say "there's a pretty lady down at the mouth that's waiting for you."* Tl'ok noho etltonh. *('she has a dish of food waiting for you.') so the ice wouldn't jam up you know. That jam up is what make the flood go high too. (Koyukon Elder)*[10]

Before the days when radios and televisions carrying weather forecasts became commonplace in rural native villages, people had to read the signs of the sky and land to know what the weather would likely be. They watched animal behavior, with behavior

[10] Keeping with Koyukon culture, I have not used the name of the Elder here because this person passed away within the last year as I write this.

providing indicators of whether winter would be long and cold, A common technique was to observe the beavers to see if they had a lot of feed in their houses. This meant a long winter was coming. Another was to observe the gray jay (*zuhge)* who would puff out its feathers when cold weather was coming. As such, the Koyukon developed a deep and intricate system of reading signs in nature to know the coming of intense cold, wind, storms, and snow. Today most people rely on the forecasts from TV and radio, but some natural indicators are still used, and most often, it is a combination of meteorologists' forecasts and their own weather knowledge that guides weather-related decisions.

> *They used to read a lot of things about weather. Every morning that was the one thing that people talked about. They would go out and look at the weather and they'd say 'I think it's gonna be windy today' or 'the weather is doing this.' And they had all the different words for all the different things. They were so observant* (Jones 2002).

Elders all throughout the Arctic and Subarctic report that their traditional ways of telling the weather are less effective now (Krupnik & Jolly 2002). There are multiple reasons why some of these environmental cues or indictors do not work as they used to. Some attribute this to a more variable, and therefore unpredictable climate and weather, which is also heard throughout the Arctic indigenous areas (Fox 2002; Huntington & Fox 2005). Another reason is that they don't have some of the birds or animals in abundance like they used to such as snowbirds, mink, and blackfish, which they watched for signs that would foretell weather conditions. Furthermore, features of modernized life prevent them from being able to use these cues from nature such as the electrical lights in the village that prevent seeing the night sky as well, and snow machines make so much noise as to drown out sounds in nature. Another reason is that they are not outdoors all the time like they used to be. Now they live in houses, many of which have indoor plumbing. Despite these changes, the Koyukon Elders and active hunters, trappers, fishers, and gatherers are still astute observers of their environment and its changes.

Koyukon as Observers of Climate and Environmental Change

A livelihood that is heavily dependant on wild foods requires that Koyukon hunters are keen observers of the natural world. Whenever a hunter or trapper returns from being out on the land or rivers he or she recounts the experience and what they observed on the landscape or in the water. This type of conversation is ongoing in the villages, so there is a continual updating and confirmation of the collective understanding of environmental conditions, especially weather and climate-related conditions such as quality and quantity of snow, stream conditions, animal populations and behavior, and ice conditions. Although total amount of time spent on the landscape has decreased to some degree with the cash-subsistence economy, the conversation is ongoing throughout the village as information is passed along from household to household in a continual monitoring of the people and their subsistence activities. Through this process their indigenous observations and knowledge as a body of cultural understanding endures while continually adapting as necessary to changing conditions.

Indigenous knowledge is a body of knowledge built up over generations by people who live in close connection to their natural surroundings (Berkes & Berkes 2008). Indigenous Elders provide the "corporate memory" of the land, animals, people, and climate and as such provide understanding about what qualifies as unusual or strange weather phenomena or animal behavior related to such phenomena (Berkes 1999).

Anthropologists, natural resource managers, and even Alaska Native scholars (Kawagley 1995) use a variety of terms to describe various types of indigenous knowledge. Traditional ecological knowledge (TEK) is the most commonly used term when referring to environmental knowledge. TEK has been defined in many ways, typically with considerable polemic discussion about appropriate terms – traditional knowledge, indigenous knowledge, local knowledge, and more (see chapter one, page 19); there is no need to elaborate here, or to contribute to this "in-house" conversation among professional academics. When talking specifically about ecological knowledge I use the definition by Fikret Berkes (1999) who defines TEK as a "cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationships of living beings (including humans) with one another and with their environment."

Koyukon Indigenous Observations and Understanding of Climate (IC)

What I describe in this dissertation for the most part pertains specifically to local observations about climate and weather variables, and I restrict myself to the term Indigenous Observations and Understanding about Climate (IC), avoiding as I do much of the intellectual baggage and implications present in the literature on TEK. Using this term helps me to more effectively communicate climate and related observations to a wider audience and across the social, natural and biophysical disciplines. It is also appropriate to use when communicating with rural communities, tribal offices and corporations, along with agency scientists and managers. **"Indigenous"** speaks to a knowledge that is particular to a culture and a landscape – in other words, it is a knowledge born from place that evolves *in situ*, and does not necessarily require one to be of a certain genetic or ethnic descent, but rather a life-long relationship with the landscape and its people. **"Observations"** speaks to awareness and monitoring of an individual or society's natural and social milieu. And **"Understanding"** encompasses both knowledge and wisdom, which is important to account for not just knowing things, but understanding the larger context and proper application of that knowledge and the interconnections therein.

The depth and breadth of the Koyukon IC comprises not only their natural environs, but also the social and cultural milieu as well; it includes the interconnections and interactions of the social and cultural to the natural in the context of an integrated social-ecological whole. In this framework the distinctions between weather and climate do not exist as they do in academic science. Yet an implicit understanding of **"Climate"** exists in the sense of knowing what weather conditions should be expected, and in knowing when anomalous conditions occur. Similarly, they have keen insights and observations about the timing of weather events with ecological variables, and some are experts at observing environmental cues important to subsistence activities. One environmental cue they used was in the spring time when the birch leaves became the size of beaver ears, it was time to "stop killing the animals" as this was the time that muskrats would give birth. Such use of a phenological cue based on observation is but one example of an indicator that the Koyukon use to understand their climate and ecology. It is also one of the many indicators that is becoming less reliable now with the seasons shifting in unanticipated ways.

> *The one thing we have in fall time was they used to say [in Native], you know in the fall time it get to autumn and all the leaves fall down and the wind is supposed to blow it down. A lot of the leaves were still up into the winter [this year]. And then fall time the water, rise and the water is supposed to take all the leaves down, that never happened either. There's a lot of change in that.* (Madeline Williams, Hughes 2004)

Koyukon IC and Identifying Climate Variability and Change

Variability is well understood by the Koyukon Elders as they have grown up in a land where high variability of weather conditions, resource abundance, and animal behavior is the rule. They are fully aware of both seasonal and inter-annual variability because of their decades of practicing hunting and observing the plants and animals, land and sky. Elders provide the collective memory and historical record for the biological and physical landscape with an astute capability to recognize conditions that are outside of the normal range of variability and can point to weather-related anomalies of concern.

Some argue that climate is an abstraction compounded from a number of variables (temperature, precipitation, air pressure, snow depth, wind speed) that are isolated for purposes of measurement, and that weather, by contrast, is about what it feels like to be warm or cold, drenched in rain, caught in a storm, and so on (Ingold & Kurtilla 2000). I agree there is an element of truth to this – i.e., that climate as an object of science is largely based on statistical abstractions and when climate is thought of strictly in this sense, it is very different from the phenomenon or experience of weather. But, climate change is in reality a shift in the expected range of weather events or conditions over some geographic area such as the expected temperature range during any given week, month, season or quantity of rain and snow, for example. This is where the local observations of climatic and environmental changes are valuable and do not fall into this polarization of climate as statistical abstractions, versus weather as direct and interpreted through story and action by a hunter, herder or fishermen. Hence, climate change is about what is considered to be abnormal in terms of the range of expected conditions, the variability within that range, and the extremes on either end of this range.

The Koyukon Elders understand that, even though the climate over the last several decades is generally trending toward warming, there can still be great variability, and that it can get very cold unexpectedly. Recent cold snaps are present in living memory. All of the Elders recall the cold snap of 1989 when temperatures dipped to as low as the negative 80s°F, and in some locations it stayed this cold for several weeks and stayed extremely cold throughout the winter season. Villages were running out of fuel and food because the bush delivery planes do not fly below -40F, as this is when machinery starts to freeze and malfunction. All they can do during these cold snaps is chop wood for heating stoves and keep the power plant running for electricity until the temperature warms up again.

Some climate-related stories told are those more mundane life experiences related to a more recent past. These stories are passed down through recent generations and trace back to at least the mid- to late-1800s if not earlier. One example of a common story that I heard in the KMY villages was about a time when it was so brutally cold that the sled dogs' tails would literally freeze and snap off (see Eliza Jones' quote in chapter one, page one). Elders estimate on the basis of their own knowledge and experience that it must have been in the -80s°F and even -90s°F for this to have happened; living Elders have seen persistent -80°F in their old village of Cutoff as well as up in the village of Allakaket during the 1940s, 50s, and 60s (as well as during the extreme cold event in 1989) and people were still hauling wood without any mention about dog tails freezing off. This particular "long time ago story" is said to have taken place in the mid- to late-

1800s. The implication of this is that instrumental records in Alaska do not capture the amount of change in cold temperatures from the last 100 to 150 years. Elders also observe how, as a whole, they have acclimated to warmer temperatures. This is a problem when the weather suddenly turns to extreme cold, because they have become acclimated to recent climate trends and now have changed (or changing) perceptions of "cold." In Hughes I asked an Elder, in the past how warm would it have to get for people to go back out again after a cold spell?

> *About 30°F or 40°F below; 40°F below was not too cold for them [in the past]. Right now even 30°F below is really cold for us - for everybody, I think. At 60°F below we used go to Huslia with dogs because we want to be down there for a good time during Christmas. We did one time me and my husband with little baby. Right now all the young people they don't know about it [the colder climate] because they didn't see it. They don't think about how we used to live long ago. They didn't see it so it's just like they don't believe it. But us [Elders] we went through it so we know how tough it was. We didn't think it was tough though.*
> ~ Alice Ambrose, Hughes (Ambrose 2005)

Acclimation to warmer temperatures is of big concern as villagers are less prepared for extreme cold today. Many of the Elders speak of safety issues for their communities, especially when out traveling in the bush and of the risk of being caught in cold weather unprepared. In Huslia, Rose Ambrose spoke of her concern regarding this issue and especially safety issues with younger generations:

> *It's more danger [nowadays]. It's pretty important for them to know what's going to happen tomorrow because it can turn cold. So kids should be educated about it. They should always have very warm clothes for themselves. Even extra so they could help other kids if they got stuck. Yeah, they should be educated about it. Lots of young people they don't like to take extra stuff because they think they*

have too much load but they should have it anyway. They try to go out as light as they could. It's danger! (Ambrose 2004)

Social-ecological vulnerability to climate change is not just about climate, but also about the socio-economic, cultural, and political underpinnings of the system of interest, which I will discuss in chapters five and six. Changes in the Koyukon livelihoods over recent decades cannot be understood without putting into the larger social, political, economic, and cultural changes that have resulted in a people going from a highly mobile livelihood to a village-based, mixed cash-subsistence society as I discussed in chapter two.

Now, environmental changes that seem uncharacteristic of the region add an element of difficulty in procuring natural resources from the land. This requires new awareness and strategies for responding or adapting to environmental changes in today's context, including the need to adapt to and participate in a perplexing wildlife and subsistence state and federal dual management system, which will be the focus of chapter six. But before that, chapter five will focus on observations of seasonality shifts, particularly in the early fall, that are increasing vulnerability to climate change.

Chapter 5: Changing Seasonality: Vulnerability during the Fall Moose Hunt

This fall it was so warm that the moose just didn't move...we just saw one moose track out of 70 miles because the animals were up in the hills, back in the lakes, so they just weren't moving.
(R.S. WIRAC Meeting October 4, 2005)

There is some agreement that additional data is needed before a determination could be made concerning that recent warmer than normal fall temperatures are part of a long-term climatic pattern. (P.D. USFWS OSM, WIRAC March 7, 2006)

A lot of mens [sic] didn't get their moose last fall....Because no moose. And whenever it closed [the regulatory hunting season] that's when sometimes they see lotsa moose track. But they can't kill it. The season is closed...That's first time nobody make dry meat this spring. Nobody, no dry meat! That's first time. All winter we're eating from freezer. Last fall people get enough to put in freezer for the winter. ~Alice Ambrose, Hughes (Ambrose 2005)

Introduction: Seasonality Shift and the Fall Moose Hunt

The quotes above illustrate an ongoing debate and often polemic discussion between the rural, predominantly Alaska Native, communities of Interior Alaska, and the state and federal agencies that manage wildlife and subsistence in the region. In recent years rural moose hunters have been reporting warmer fall seasons and lower water levels during some years, which decrease their opportunity to successfully harvest moose before the regulatory hunting season closes at the end of September. This, they say, results in an inability to meet their wild food subsistence needs for the year. In 2007 at the Western Interior Region Advisory Council (WIRAC) meeting, a local hunter from Ruby stated simply:

The weather's changed, people aren't getting their moose
(E.S. WIRAC October 11, 2007).

In the regulatory setting beginning as early as 2001, this debate about whether or not such unseasonably warm conditions constitute enough reason to change regulations or to grant emergency requests to provide more hunting opportunity has gone back and forth between the stakeholders. The villagers have claimed that they cannot meet their subsistence needs in years with warmer-than-normal falls. This is exacerbated by low-water-level years when boats with outboard motors can't access certain sloughs and rivers to reach key hunting grounds. By moving the hunting season later, locals say, they will have more opportunity to harvest moose before the regulatory season closes.

We need to bump the season back into the fall a little further... maybe 20 years ago the seasons that we have now worked for us, but with the way the weather is changing and how warm it is this fall the moose just weren't moving around.
(M.S. WIRAC meeting October 4, 2005)

Federal and state boards that make the regulations continue to question whether this reported warming is really part of a long-term trend due to climate change. Until now, there has been little systematic inquiry into the patterns of fall climate variability and changes that have occurred specifically during the fall hunting season in the Koyukuk-Middle Yukon (KMY). In response to this, we[11] examined patterns of temperature and precipitation variability and change in the KMY region of Interior Alaska through the integration of Indigenous Observations and Understanding of Climate (IC) with instrumental weather data.

The northern Interior region of Alaska has experienced some of the most pronounced changes in winter and spring temperature and precipitation recorded anywhere in the state (Alaska Climate Research Center 2008). According to indigenous

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[11] McNeeley, Shulski, and Lehmkuhl-Bodony

observers and scientists climate change-related physical manifestations of concern include decreased thickness of river and lake ice; timing of spring break up or fall freeze up of the rivers that can make travel dangerous or impossible during key harvest times; thawing permafrost and drying of important fishing lakes; and changes in the timing, quantity and intensity of rain and snowfall to name a few (ACIA 2005; Chambers et al 2007; Euskirchen et al 2007; Hinzman et al 2005; Huntington & Fox 2005). All of these physical changes have cascading ecological effects on vegetation, fish, and wildlife, and the linkages are sometime nuanced and very complex (Wrona et al 2005). One salient example of a recent climate change-driven trend is that in recent decades shrubs and thickets have increased in some areas, which may benefit moose by providing increased forage,[12] but it is also related to lake and wetland drying, which decreases fish, waterfowl, and small water-mammal habitats (e.g., beaver, muskrats, mink). Increased shrub cover combined with the recent trend of low snowfall decreases albedo (i.e., reflectivity of the sun's radiation), which means more heat is retained at the Earth's surface, possibly contributing to even more to local warming effects (Chapin III et al 2005; Hinzman et al 2005).

These biophysical changes have occurred in recent years/decades with an average of 3.4 degrees Fahrenheit warming for Alaska as a whole from 1949-2007, and Interior region wintertime mean temperature increases ranging from 7.5°F to 9.6°F for roughly the same time period (see Table 2) (Alaska Climate Research Center 2008). These observed changes in combination with projections of continued warming and impacts on local subsistence resources and harvest practices, all point to potentially serious negative impacts for rural Alaska villagers for decades to come (Kattsov & Kallen 2005; McCarthy & Martello 2005). Interestingly, "fall" temperatures as measured during the three-month period of September, October, and November show a weak warming trend throughout the state (see Fig. 3.2). This has left many wondering how to reconcile local observations of warmer falls in the Interior with the weather station data that seems to show a very small amount of warming. This leaves the question for decision makers – is

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[12] Though this is debatable and depends largely on if a particular population is density-dependant forage limited. In some regions of Interior Alaska this is not the case (pers comm.. Tom Seaton 2007).

there really a warming trend occurring during the fall moose hunt? Through the integration of ethnographic methods to record Indigenous Observations and Understanding of Climate (IC) with the analysis of weather data, we provide a more comprehensive picture of recent warming trends in the Koyukuk-Middle Yukon region of Interior Alaska, one that captures more than statistical analysis of means, averages and "norms" can provide. We will demonstrate how a small shift in seasonality has truly socially significant effects to people "on the ground" when the system sensitivity is high. In this case a seemingly small exposure combined with high system sensitivity results in vulnerability to this climate change-related seasonality shift because of a) how it affects moose and the ecological and social-ecological dynamics of the system and b) the importance of this time of the year to meeting annual subsistence needs.

One important aspect of IC is that it is predicated on traditional phenological knowledge (TPK), with this defined as an understanding of the expected timing of weather variables with ecological variables (Lantz & Turner 2003). Locals indicated to us that the timing of climatic conditions is critically important for fall subsistence hunting, i.e., the relationships between when it rains, when it cools down, starts to freeze, when the leaves fall, and when the moose go into rut. The observations gleaned from qualitative analyses literally "pointed" us to specific places to look in the instrumental record, challenged our assumptions, and helped us to ask the appropriate research questions. Because the biophysical changes in different parts of the typical 3-month "fall" season are different, this required parsing out the data accordingly to examine much more closely the phenomena of interest for this study.

Therefore, we looked specifically for changes taking place during the late summer and early autumn, and in particular, during the designated hunting season, which varies depending on the game management sub-unit.[13] Generally the hunt begins from between August 27th - Sept. 5th depending on the location and stays open to subsistence hunters until generally around September 25th. Weather data were analyzed for the four weeks

[13] And even into different areas within the various subunits. This will be explained in more detail in chapter six.

starting between August 25th and Sept. 25th.[14] Specific questions that came out of the interviews and IC included:

1) What temperature and precipitation shifts within the hunting season can be detected through analysis of the weather data?
2) When is the end of the growing season or first freeze in the autumn?
3) What is the variability in the length of time between first freeze and continuous freeze?

To place the analysis of hunting season period in the context of other changes taking place, a time series trend analysis of mean annual and seasonal temperature and precipitation was also performed. The four weeks during the hunting season (25 August – 25 September) were analyzed separately, as well as the season on the whole, to check for patterns of change or shifts in temperature and precipitation.[15] Before the research shifted to focus exclusively on the fall time, we examined seasonal trends throughout the whole year. I will briefly discuss some of those results in the next section in order to situate the fall time within the other seasonality shifts before moving on to the more detailed fall analysis.

Climate Variability and Change and the PDO Index

Temperature records in Interior Alaska show that it is characteristically a system of high inter-annual and interdecadal variability. Since 1949 the Alaska temperature record indicates a warming trend that started in the winter of 1976-1977 (Figure 8).

[14] We used August 25th as the starting date to have four 7-day weeks that included the time period between August 27th and September 25th.

[15] Linear regression analysis was performed on all the time series data, and statistical significance of the trends were determined at the $P = 0.05$ level.

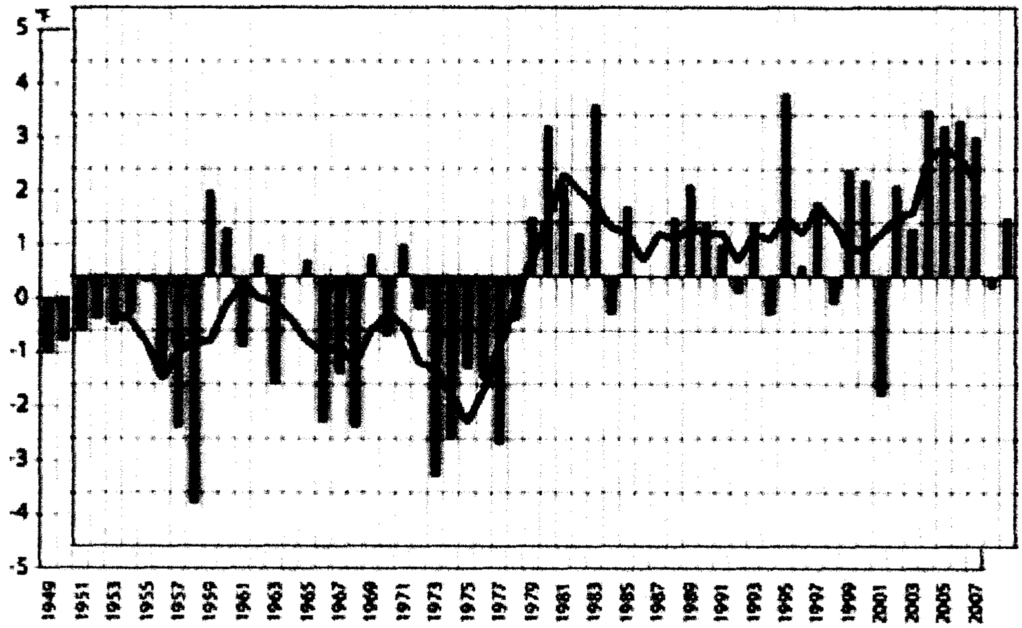


Figure 8 Mean annual temperature departure for Alaska (°F) 1949-2007. This shows the clear step-wise shift during the winter of 1976-1977 that closely corresponds to the PDO shift from a cool to a warm phase. Courtesy of Alaska Climate Research Center, University of Alaska Fairbanks (2008)

This 1976 shift corresponds with a regime shift in the Pacific Decadal Oscillation, which is a pattern of Pacific Ocean climate variability that shifts between warm and cool phases approximately every 20-30 years (Hare & Mantua 2000; Hartmann & Wendler 2005). During the years from 1925 (possibly earlier) to 1946, the PDO was in a warm phase until it flipped in 1946 to a cold phase that lasted until the winter of 1976-1977 when it went back to a warm phase (Biondi et al 2001) .

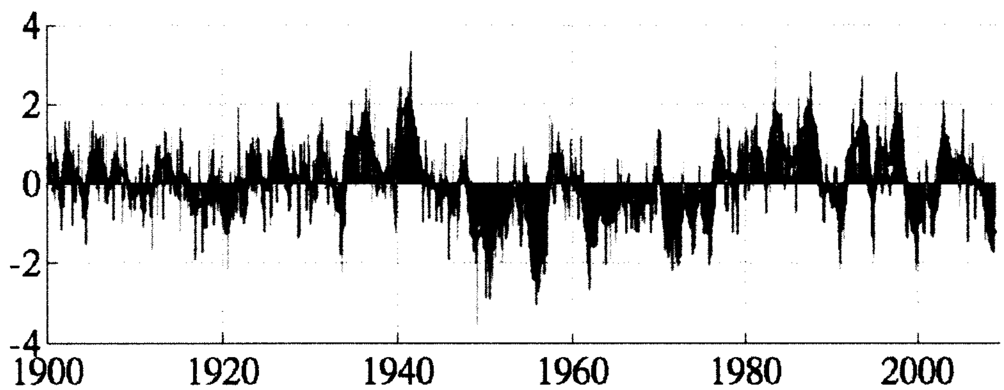


Figure 9 Monthly values for the PDO index: 1900-2008. This shows the oscillations patter of the PDO between warm periods (red) and cool periods (blue), which correspond to the Alaska annual mean temperature record. Used with permission from Nathan Mantua at the University of Washington's Joint Institute for the Study of the Atmosphere and Oceans http://jisao.washington.edu/pdo/

Air temperature at Fairbanks shows a relatively strong correlation with the PDO index, though the correlation is stronger in winter and spring and is very low correlation for June through September (see Figure 7) As such, it is especially important that any analysis of annual temperature records is situated and evaluated within the context of these larger-scale patterns of climate variability. Consequently, when interviewing Elders about climate trends, the interviewer must consider the person's age and how many of these phase changes the person has experienced. Those individuals with memories that include only the last cold to warm phase since 1946 have only seen an upward trend of temperatures, whereas those who were born earlier in the 20th Century may remember the earlier warm phase, when temperatures and related biophysical system elements were closer to the recent warming conditions.

Annual Mean and Seasonal Change for the KMY Region

The Koyukuk-Middle Yukon (KMY) region of west-central Alaska exhibits a subarctic, continental climate with typical characteristics of long, cold winters, short but relatively warm summers, and light and irregular precipitation coming mostly in the form of rain during the summer. Long-term meteorological stations are sparse in Interior

Alaska and are situated almost exclusively in villages along waterways at low elevation, where the human population of the region is concentrated. Weather stations used for this analysis are the three stations that sit within the KMY region – i.e., Bettles (66°55'N / 151°31'W, 642 ft. a.s.l.), Tanana (65°10'N / 152°06'W, 227 ft. a.s.l.), and Galena (64°44'N / 156°56'W, 120 ft. a.s.l.). Daily climatological data for Bettles, Galena, and Tanana were obtained online from the National Climatic Data Center (NCDC) from the Daily Surface Data (TD3200 and 3210) datasets. The Bettles site is a National Weather Service first-class observing station and has been in operation since April of 1944. It is located on the Koyukuk River south of the Brooks Range. The longest-running of these stations is Tanana, which began operation in 1902 and is located at the confluence of the Yukon and Tanana Rivers in central Alaska. In Galena, on the north bank of the Yukon River downstream of Tanana, the observing station has been in operation since 1941.

Missing observations were filled in where available from NCDC Serial Publications; Climatological Data and Local Climatological Data reports (http://www7.ncdc.noaa.gov/IPS/). Metadata for the stations are given in Table 3.

Table 3 Metadata for the four weather stations used in the analysis.
* COOP denotes cooperative observing station, AP denotes airport, CAA denotes civil aeronautics administration and ASOS / AWOS are Automated Surface / Weather Observing System.

Station	Latitude	Longitude	Elevation	Period of Record	Station Type*
Bettles CAA	66°54'N	151°43'W	856 ft	4/1/1944 - 4/30/1951	COOP
Bettles AP	66°55'N	151°31'W	642 ft	4/1/1951 - 2007	COOP ASOS
Galena AP	64°44'N	156°56'W	120 ft	12/1/1941 - 2007	COOP
Tanana AP	65°10'N	152°06'W	227 ft	8/24/1901 - 2007	COOP ASOS

Data for Bettles CAA and Bettles AP were combined for one complete record for the period 1944 to 2007. Daily maximum and minimum temperatures were averaged for all stations to obtain monthly average temperatures, then further averaged for each season and year.[16] Precipitation and snowfall were summed to obtain a total for each month, season, and year. Calendar years were used to generate annual average temperature and precipitation (Jan – Dec). Characteristics of winter seasons (such as snowfall) were identified using data from July through the following June to capture complete winter seasons. The best-fit linear trend and 5-year running mean were determined for the time series of monthly, seasonal, and annual totals/averages. The total change over the period of record was calculated for each parameter-station. Long-term averages were computed; periods of record for each station and the departures from average for each year were determined; and time-series plots were constructed. Seasonal and annual rankings were also calculated to identify the warmest/coldest and wettest/driest years. Changes in extreme low temperatures were identified by calculating the frequency of occurrence of minimum temperatures below thresholds of -70°F, -60°F, -50°F, and -40°F, as well as the absolute minimum per year.

The time series of mean annual temperature exhibit the clear pattern of predominantly below-normal temperatures until 1976, but since this time show warmer than average annual temperatures. As mentioned above, the clear step-wise shift in the mid-1970's correlates strongly to the Pacific Decadal Oscillation climate regime change in the Pacific basin (Hartmann and Wendler, 2005). The total change of mean annual temperature for Bettles, Galena, and Tanana is +3.8°F for the time period 1944 to 2007. Using a standard three-month breakdown for each season, it is evident that this trend is dominated by strong changes in temperature during the winter (Dec, Jan, Feb) and spring (Mar, Apr, May) seasons, with a total change in seasonal temperatures of +6.5°F and +4.5°F, respectively. The summer (Jun, Jul, Aug) and autumn (Sep, Oct, Nov) seasons also show warming, though lower in magnitude, of +2.5°F and +1.6°F, respectively.[17]

A predominant feature of the cold season in particular is the exceptionally high inter-annual variability, which is typical of a high-latitude continental climate location

[16] Monthly data were excluded from the analysis if greater than 10% of the daily data were missing observations. For annual and seasonal averages, if one month was missing then the long-term average was substituted. If more than one month was missing then the season/year was omitted from further analysis.
[17] Statistical significance of the linear regression at the 95% confidence level was found for all three stations for: mean annual temperature, winter, spring, and for summer at Bettles.

(Shulski & Wendler 2007). An indicator of this is the magnitude of the standard deviations for the various seasons: 5.8°F, 4.1°F, 2.0°F, and 3.6°F for winter, spring, summer, and autumn, respectively. The seasonal and annual time series plots show good agreement among the three locations of inter-annual variability, as would be expected given their close proximity.

It is important to note that there is large variability in the years and consistency of the historical weather data between the three stations. For example, the Tanana temperature record shows decadal periods of above and below average temperatures (Figure 10). Early in the record, from the 1920s to early 1940s, temperatures during some years were similar to those of recent since the mid-1970s (which correspond to the PDO), although the range of temperatures from 1977-2008 is clearly warmer than the earlier warm phase. A cool period happened between the mid-1940s until the mid-1970s when temperatures were mostly below average; this was followed by the current period of dominant above average conditions. Unlike Tanana, data for Bettles and Galena do not capture the early data time period since their records start in the mid 1940s.

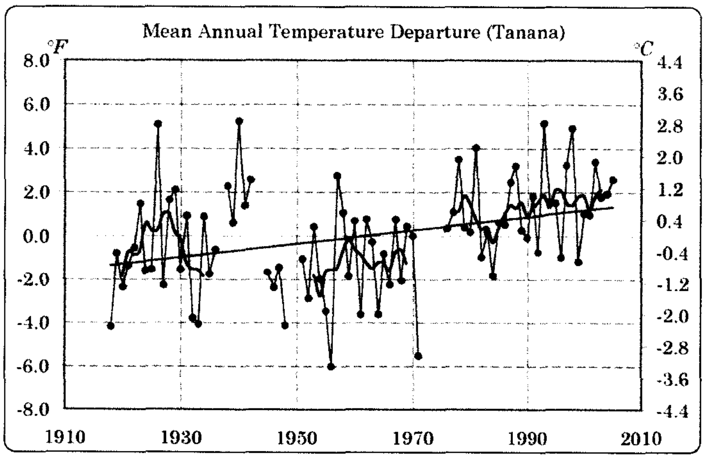
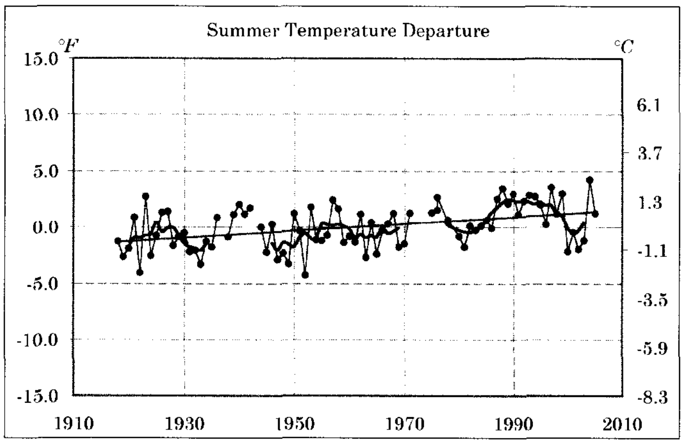
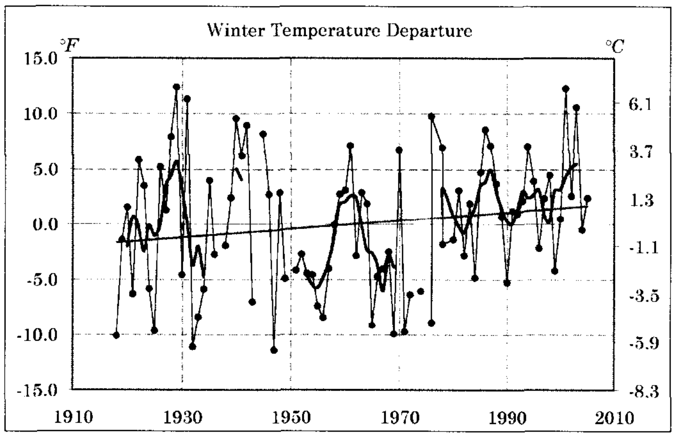


Figure 10 Time series plot of Tanana mean annual temperature departure at Tanana.

It is clear that inter-annual variability is strongest for the cold seasons, and much less for the summer. This is valid not only for these locations, but across the continental climate of Interior Alaska (Shulski & Wendler 2007). The plots of summer and winter temperature departure from normal for Tanana reflect this condition (Figures 11 a, b).



(a)



(b)

Figure 11 Time series of Tanana summer (a) and winter (b) temperature departure from normal. Figures are the same scale, although note the difference in the inter-annual variability between the seasons.

The top five warmest and five coldest years for Tanana were plotted as a number of occurrences per decade. The record illustrates that most of the coldest years occurred in the early part of the record, while the warmest years have occurred in recent history (Figure 12).

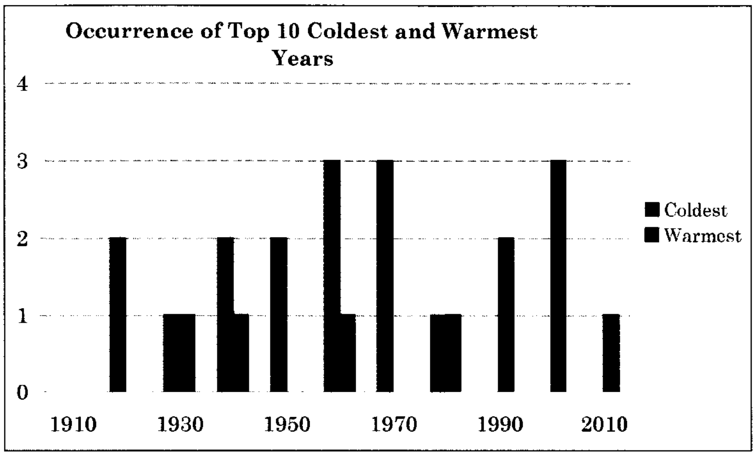


Figure 12 Number of occurrences per decade of the warmest and coldest years on record at Tanana. Note: the following years tied, or had the same annual temperature value (which is why the total number is 14 instead of 10): 1933 and 48, 1961 and 64, 1920 and 46, 1927 and 66.

Annual precipitation for the KMY region is light with a frequency maximum during summer and autumn. The trend analysis reveals relatively small changes in seasonal and annual precipitation totals for the three locations, none of which are statistically significant at the 95% confidence level. On an annual basis, precipitation shows a slight increase for Bettles (2.0 inches), very little change for Galena (.2 inch decrease), and a decrease of 2.1 inches for Tanana, with this primarily a function of drier than normal conditions over the last 7 years. The magnitude of change is small for the seasonal precipitation totals and is about .3 inches on average. As with temperature, the inter-annual variability in the seasonal and annual precipitation shows relatively good agreement among the three station locations.

Indicators of Shifting Seasonality

In this section we point out some of the most salient results from our analysis for each season before focusing on early fall changes during the moose hunting season. The integration of indigenous observations and understanding of climate (IC) collected through interviews with Koyukon Elders with instrumental data demonstrates that there are socially significant changes related to Koyukon subsistence livelihood activities, and shows how important it is to understand how climatic variability and changes manifest "on the ground" in terms of human experience.

Koyukon "seasons" as they are experienced in the region, are not the same as the typical breakdown of 3-month seasons that climatologists use. For example, March is considered spring in the conventional 3-month seasonal breakdown (March, April, May), but spring in the villages is characterized by the arrival of migratory birds, melting and crusting of the snow, and breakup of the river ice, all of which don't begin until April and May. Winter in its entirety to a villager might mean mid-October through mid-May (as this is the time period that the rivers are frozen; see chapter three). Fall can mean the last two weeks in August and the first few weeks of September. All of these designations depend on what is going on across the landscape physically and ecologically, as well as what human activities are happening in the context of subsistence practices and they can vary from year to year. In other words, a "season" to a scientist does not mean the same thing as a "season" to a villager to whom they are more fluid across temporal and spatial scales.

Climatologists have arbitrarily subdivided the year into four equal time intervals: the 3 coldest months, the 3 warmest months and two periods with intermediate temperatures. There is a poor correspondence between these climatologically defined seasons and the seasonal changes that impact people in the KMY region. This distinction is important when analyzing seasonality shifts from climate change that affect Koyukon livelihoods. Superimposing the arbitrary 3-month seasonal breakdown over a much more intricate and nuanced seasonality does not capture the level of detail required to understand seasonal shifts. This understanding is also the key to communicating about climate change with Koyukon Elders and community members for research and resource management.

Since winter temperature shows the largest changes with declines in the magnitude of the temperature trend in order through spring, summer, and fall, this is the order in which they are discussed here. Interestingly, though, while the "fall" (September, October, November) climatological season shows the smallest value for average temperature change using only a linear regression, this is the most important season when looking at climate-change vulnerability and adaptation for the region at present. This is because fall is the most important harvest time of the year and climate change decision making has already been established in the regulatory procedures. Therefore, fall changes are discussed in further detail in the subsequent sections, along with the implications for vulnerability. Barriers and opportunities for collective adaptation of the institution of wildlife management of the moose harvest are discussed in chapters six and seven.

***Hʉyh* (Winter) Climate Change**

Throughout most of Alaska the winter season as measured by December, January, February shows the most marked warming in general, and the KMY region is no exception (see Table 2). Winter season in the villages occurs between mid-October and mid-May, depending on when the river freezes and thaws (see chapter three). When the river is fully frozen becoming the winter highway – then winter begins. The Koyukon term *Ts'eyeets'en hʉyh kk'aatl'ot* literally means "from the canoe (travel) to the solstice," signifying the early part of winter from river freeze up (in October) until winter solstice around December 21st (Jette & Jones 2000).

The winter months are long, dark, and very cold with temperatures dipping into the -30°Fs to -50°Fs. Yet the Elders speak with nostalgia about what to most of us would be unbearable conditions of brutal cold. They describe current winters as "warm" compared to the past. Prior to the 1950s they were still living out on the land, moving to locate the animals seasonally for most of the year. During the1940s, 1950s, and 1960s conditions were considerably colder with temperatures regularly staying in the -50°Fs and -60°Fs for weeks on end.

> *We used to get 50 below for 2 or 3 months - from November all the way to February. We don't get more than one month of 50 below anymore. Maybe 2 weeks at the most. And seem like spring's coming early and freeze up's getting later, toward the end of October finally start freezing up. And then, we just get*

mild winters now. No more 50 below for 2 or 3 months at a time. And I think most of it is man made. ~Joss Olin, Huslia (Olin 2005)

This still was not the kind of cold that their Elders experienced. There is a common story told about how during the late 1800s it got so cold that the dogs' tails would freeze off when they were traveling by dog team. The living Elders now imagine this had to be in the -80s°F to -90s°F for stretches of time as they have never seen dogs' tails freeze off and have experienced cold as low as -80°F.

Temperature, ice conditions and snow quantity and quality are the important climate variables for winter from the Alaska Native perspective. The primary negative effects of winter warming trends are that conditions are more dangerous for travel with thinner and unsafe ice or changes in snow quality and depth. These are conditions that affect traction and trail conditions. Whether travel is by snow machine or dog team the increasing unpredictability of daily and weekly weather conditions, with more variability and less predictability, are now the norm.

The key Koyukon subsistence activities in winter are caribou hunting, trapping furbearing animals, and woodcutting for heating. Once conditions reach -30°F or lower, travel becomes less frequent and below -40°F the bush planes are sometimes grounded, cutting off supplies of food and fuel until it warms again. However, above this temperature villagers are often out traveling for wood and to check traps. Trapping has declined dramatically compared to the past, a response to the decline of the fur industry and the low price of fur, but it remains an important cultural activity to many of the Koyukon Elders in particular.

We used to have really cold weather too. 60(°F), 70(°F) below. That's not only for a week that's for a month! Months at a time. A Month or over a month sometimes. I remember this one time in 1950s me and my dad went out to winter camp and mother was supposed to come with an airplane. You know we stayed out in camp for 45 days. It was over 60 below all during that time. We never used *dog team that time it was too cold for their feet.* ~Bill Williams, Hughes (Williams & Williams 2004)

Multiple observations similar to this one above led us to analyze the frequency of occurrences for various low temperature thresholds for Bettles, Galena, and Tanana. All stations showed the same trend toward a decrease in the number of extreme cold days (Figure 13a). Similarly, there was also an increase in the absolute minimum temperature (Figure 13b).

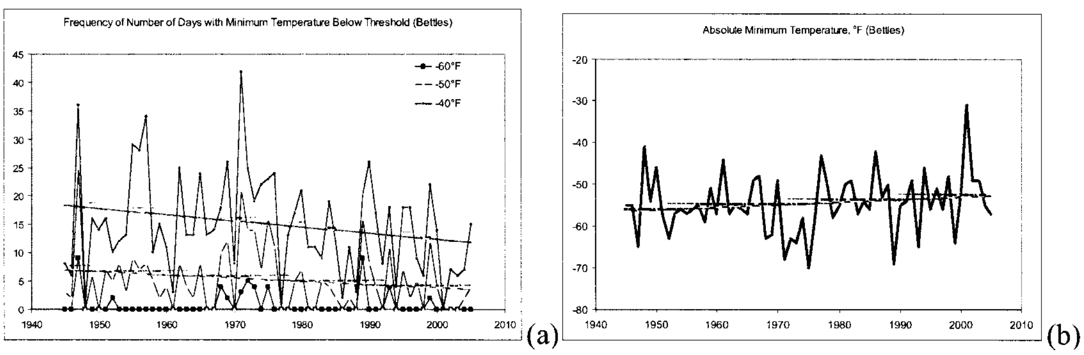


Figure 13 Time series of the number of days at Bettles with minimum temperatures below certain thresholds. (a) shows a decrease in the frequency of days below -40°F, -50°F, and -60°F; and (b) an increase in the absolute minimum temperature. Galena and Tanana show the same warming trends.

Overall, low temperature thresholds have increased, meaning less extreme cold, absolute minimum temperatures have increased, and the frequency of temperatures above freezing during the winter (October through March) has similarly increased. The increased tendency for winter temperatures to go above freezing causes dangerous ice conditions when rivers and lakes thaw and have open leads (i.e., large pools of unfrozen water usually along the bank). In January of 2004 I was in Galena and there was a large open lead on the Yukon River that the Elders said they had never seen happen before. The open water was contributing to ice fog that stranded people at the Galena airport for days. Melted ice in winter as well as additional ice overflow can result in unsafe ice for traveling by foot, dog teams or snow machine.

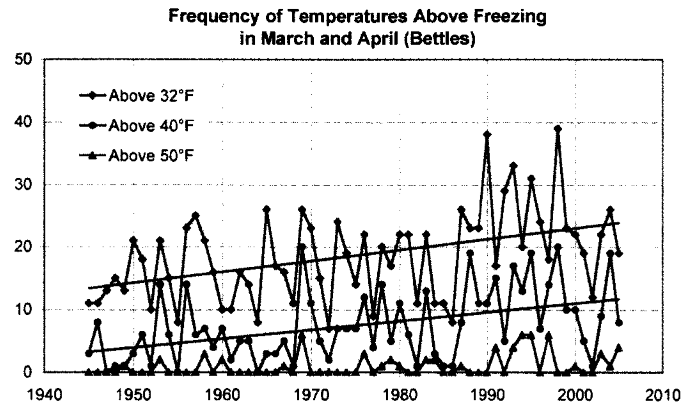


Figure 14 Frequency of days with temperatures above freezing (32°F, 40°F, and 50°F) in March and April has increased indicating an earlier spring thaw.

Snow cover has also decreased overall during the winter season with certain months staying fairly stable or increasing slightly. Locals have observed that snow is coming later, and the weather station records measuring the percent of seasonal snowfall in October show that since 1987 snowfall for this month contributes much less to annual snowfall (under 12% each year from 1987-2005) than it did during the 1970s and 1980s when it was frequently between 20-35% of annual snowfall.

This phenomenon also impacts how snow pack develops for snow machines trails, and therefore, when people can start traveling long distances in early winter. Little snow also means a lot of exposed tussocks, gravel and other obstacles, and is hard on equipment, which requires expensive repairs and being stranded sometimes. The most socially significant change is that today there is less snow and warmer temperatures at the end of winter/early spring (March and April), another important indicator of seasonality shift as the winter season has shortened by about one month during some years according to IC of Koyukon Elders.

Sonot (Early Spring When Thawing Begins) and *Hulookk'ut* (Late Spring at Breakup) Climate Change

The three-month seasonal breakdown for climatologists begins spring with March, but for the Koyukon "spring begins with the long days of April" (Nelson 1983). Subsistence spring begins when migratory waterfowl start to arrive (white-fronted geese, ducks, and swans), when the rivers break up making travel possible by boat again, and when some families go to traditional spring camps to hunt muskrats. One example of spring traditional phenological knowledge, which is part of IC and includes the understanding of the expected timing of weather variables with ecological variables, is that when the birch tree buds reach the size of a beaver's ear, this indicates the time to stop hunting muskrats because they are "having their little ones." Observations are that unseasonably warm spring temperatures result in earlier spring budding that is out of synchrony with the animals' cycles. To the Elders this is evidence of an unusual seasonality shift.

When there is less snow cover at the end of winter and beginning of spring, travel becomes very difficult with either dog teams or snow machines. Spring is the time when the travel-loving Koyukon make long trips to multiple villages for spring carnivals that celebrate the new season with various outdoor games and dog team races. When there is less snow cover in late-April/early-May waterfowl harvest decreases as travel (overland by snow machine) to hunt them is hindered or made impossible. Our analysis of Galena April snowfall as the percent of annual total snowfall has decreased by approximately 5-6% from 1949-2005.

Another spring seasonality change that the Elders observe is the unusually long springs where breakup often comes earlier than normal, with this followed by late cold spells that prolong the snow and ice melt. This phenomenon results in phenological shifts that affect spring waterfowl hunting.

> *The last two springs [2003, 2004] we couldn't go up to Fish Lake but during the summer time it [the water levels] comes up though. But that's the wrong time of*

> *the year to go there. We go there for fishing to get a few ducks. They are nesting about around this time [summer] so we don't bother them.* ~Bill Williams, Hughes (Williams & Williams 2004)

In this example provided in an interview in 2004 the spring duck hunting area became accessible too late in the season because of changes in water levels due to a late cold spell that kept water levels low until summer.[18] Spring breakup is still highly variable from year-to-year, but the timing range is moving earlier with "thermal" breakups occurring with more frequency. Thermal breakups occur with warmer temperatures and are characterized by weaker, rotting ice before the ice from upstream flows downriver, ice breaks into very small pieces, and no ice jams form (Rundquist 2009).

***Saanh* (Summer) Climate Change**

Subsistence summer begins when the rivers are ice-free and the salmon runs come up the Yukon River from the Bering Sea to return to spawning grounds in the various tributaries. As the salmon runs are an extremely important part of rural subsistence, some of the main questions about climate change center around warming effects to the salmon runs. However, little systematic scientific research exists to date documenting the results of observed warming effects on salmon or other fish species in the KMY region.

Temperatures have increased in June, July, and August through 2005 (+2.6°F, +1.6°F, and +2.9°F for Tanana, Galena and Bettles, respectively), and rainfall has decreased for the months of July and August, which creates more fire danger when soils and vegetation lack moisture content. The summers of 2004 and 2005 broke records as fire years, resulting in significant impacts on animals, habitat, property (native allotments with hunting and trapping cabins), travel, and human health (Juday 2005).

Lake drying resulting from degrading permafrost is another significant change and concern in the Interior (Hinzman et al 2005; Riordan et al 2005). Elders report many of their lakes they depended on for fishing have dried up and that decreases in water

[18] When it is warm the water levels rise from melting snow and glaciers upriver. Late cold spells cause the snow to melt later, which means the water levels take longer to rise.

mammals such as mink, otters, and muskrats as well as disappearance of blackfish are likely due to drying lakes. Beavers have been moving out of the lakes into the rivers and sloughs, which Elders say is unusual and link to lake drying. It is interesting to note that, while Elders and scientists have observed melting permafrost and the drainage of Interior lakes, many Elders mentioned a large earthquake in 1957 that drained many of the lakes. So it is possible that the Earthquake precipitated a process that was then continued or exacerbated by recent warming trends.

Huyts'e doghot **(Fall) Climate Change**

The Koyukon word for "fall" is the same as the word for freeze up as this is the most dramatic physical change on the landscape (along with spring break up) that separates the summer and winter seasons and determines whether the rivers are navigable by boat or are ice roads to be travelled on with snow machines. River freeze up is highly variable from year to year, yet observers notice that late freeze ups are happening more often and occurring later. One of the latest freeze ups in recent memory was in November of 2003 where the Yukon River near Koyukuk village didn't freeze until about November 10th.

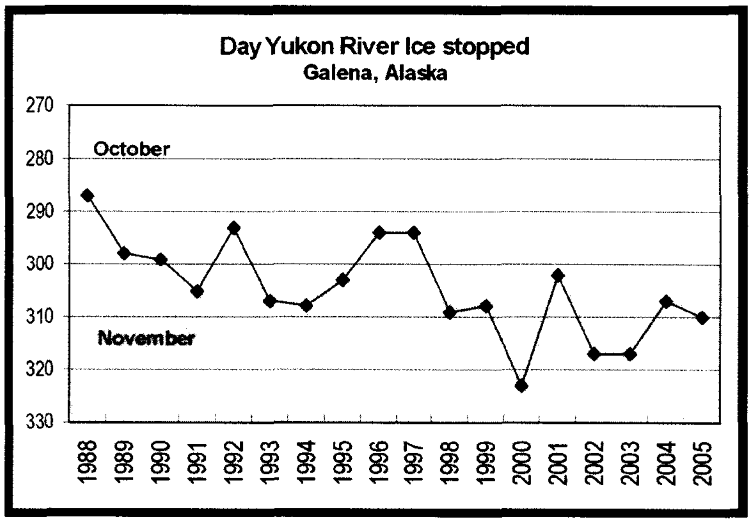


Figure 15 The day the Yukon River froze in the fall at Galena from 1988-2005 is occurring later ("ice stop refers to when the ice stops running and the river freezes solid).

Perhaps the most important aspect of freeze up is not when the river freezes, but rather how thick the ice is, and how this relates to the timing of snow. In the past, residents could rely on cold temperatures freezing the ice to sufficient thickness before it snowed to develop adequately thick ice before the first snowfall. In years with a warm fall and late freeze up the ice remains dangerously thin. If it then snows on top of that thin ice, the snow insulates the ice and ice conditions become extremely dangerous.

> *Well, we've had a lot of changes in the last 20 yrs I'd say as far as the weather is. It used to freeze up in October and freeze solid 4 inches before we'd get any snow. So we don't have any problems going out with snow machines. But nowadays it starts snowing before it freezes and it doesn't freeze very good so we have to be careful now.* ~Joss Olin, Huslia (Olin 2005)

Hunting for bears starts in September and continues through November; and after freeze up in October this requires travel by snow machine after the rivers and sloughs freeze and become roadways to familiar hunting grounds, mostly following long established and well used trails. Late freeze up creates an inability to go out and find the resource when timing is ideal when the bears are hibernating in their dens. In Huslia especially, hunting bears in their dens is still an important cultural event for the men.

Subsistence fall begins in late August or early September, depending on the year, but always when temperatures start dropping into the 40°Fs and 30°Fs, leaves fall off the trees, birds begin their journey south, and most importantly – the moose rut and hunting season commences. Compared to the other three seasons, the fall time as defined by September through November appears to have warmed the least (see Fig. 3.2). The fall season temperature trend is not statistically significant at the 95% confidence level in contrast to the other seasons. Yet because of the importance of the fall moose hunt to the Koyukon cash-subsistence economy and culture, a seemingly minor physical change assumes paramount importance. Changes during t*oo k'eelaanh te* – early fall time (mainly September) – are the most important to understand for current vulnerability and adaptation in the region. We discuss this in great detail in the remainder of this chapter, describing changes during the transition time when temperatures begin to hover or oscillate around freezing and the moose engage in their annual mating ritual ("the rut").

Saanh tl'ogots'en' **(End of Summer/Early Fall) Seasonality Shift and the Fall Moose Hunt**

Importance of the Fall Moose Hunt for Winter Food Security

Early fall time in the Koyukuk-Middle Yukon region is the most important time of the year for conducting the activities that maintain winter food security and thus is met with great anticipation and hopes for good seasonal conditions, a healthy moose population, and harvest success (see Figure 5.10). Of the wild foods harvested in the KMY region, moose is the most important big game animal in the region (Brown et al 2004; Nelson 1983). Overall, 92% of the households use moose (Brown et al 2004). Even in communities where no moose are reported as harvested, almost all households report using moose, confirming not only the vital importance of moose but also that intra- and inter-village sharing and food distribution continues to be an important trait of these subsistence communities (ibid). Despite the relatively recent arrival of moose to the Koyukuk River valley within the last 70 years or so, moose have become something the people are economically and psychologically attached to and that are deeply ingrained into the social and cultural fabric (Nelson et al 1982). Maintaining a healthy moose population and hunting access and opportunity is a top priority in the region. Moose are also the most efficient wild food to harvest in terms of pounds of meat harvested per unit of time, energy, and money put into the harvest effort (Feit 1987).

Social-ecological System Dynamics of the Fall Moose Hunt

Alaskan Moose (*Alces alces gigas*) are among the largest moose in the world, weighing from 800 to 1,700 pounds, and are the largest land mammal in the KMY region (Emanuel 1997). The population of moose in the KMY reached a peak in the early-1990s but has since declined as a result of increased hunting pressure during the late 1990s (Alaska Department of Fish and Game 2001). Predation on moose by wolves and bears is also a major factor affecting population dynamics (Boertje et al 1987). Indigenous observers report increased numbers of wolves and grizzly bears in the region.

Moose inhabit the boreal forest and muskegs of the Koyukuk-Middle Yukon region where their diet primarily consists of willow, birch, and nutritious aquatic plants during the ice-free seasons (Renecker & Schwartz 1997). During summer, the moose tend to spend their time in the higher grounds and wetland areas, thermoregulating from the summer heat, replenishing lost body reserves from the previous winter, and fattening up for the upcoming fall breeding season and winter (Renecker & Schwartz 1997; Schwartz & Renecker 1997). In the fall time they move out of those areas into open areas of valleys and riparian corridors where they perform the annual rut ritual (Bubenik 1997).

During the fall rut the bulls do not eat for up to three weeks if not longer; and the bulls begin to demonstrate rutting behavior typically around the end of August when velvet falls and antlers harden, and they start moving around, cleaning their antlers on trees, calling, and beginning to spar with other bulls for mating dominance (Bubenik 1997). Alaskan cow moose aggregate in harems, and the prime bulls compete for harems while keeping away the more immature bulls (ibid). Once a bull establishes a connection with a cow harem, he will mate several and sometimes with all members of the group. All of this is predicated on hormonal communication during the attracting phase when cows go into estrus, and bulls release their hormonally charged urine.

The timing of climatic conditions affects the social-ecological system dynamics of the fall moose hunt, and an intimate understanding of this transition time is central to the success of subsistence hunters. It is widely accepted among moose biologists that the fall breeding dates are determined by the photoperiod (Schwartz 1997). However, rutting *behavior* begins when the temperatures are cool enough that the bulls begin to start moving around, searching for cows to breed (Bubenik 1997). The exact process and temperature threshold that triggers bull movement is not well understood, though the initial attracting phase could be delayed by warmer temperatures (Jack Reakoff, pers. comm.). Warm weather affects the ability for the moose to thermoregulate without overheating or expending too much energy to do so (Vucetich & Peterson 2008). When a bull goes into rut he stops eating, so energy needed for rut activities such as moving, fighting other males, and breeding females, is reserved specifically for those activities. If the temperatures are not cool enough for the moose to begin these rutting activities, they become inactive and do not move around looking for cows to breed until later in the season.

This results in bull movement beginning just a few days before the cows are in estrus unlike in colder falls when bulls may be with cows for two weeks before estrus. Also, they will move around at night when it is too dark for hunters to see them, or they will stay in higher country away from the bugs that linger during warmer falls. Cold falls are virtually insect-free, and warm falls make it difficult even if a moose is taken because of blow flies that are still active and destroy meat. All of these factors reduce opportunity for hunters to harvest moose under optimal conditions.

Hunters rely on the bulls moving, making mating noises, and on coming down into riverine or open areas where they can see them and have access to them by boat. Transportation during this time of year is still by waterways before the fall freeze up, so boat travel into rivers and sloughs is how moose hunting grounds are accessed. The ability to travel overland is limited this time of the year in the bush, so when the moose stay away from the rivers in the lakes and higher ground, they are inaccessible to most hunters in areas off the road system. The best conditions for moose hunting are when temperatures are around freezing at night, and around 40s°F by day before it remains cold enough for a long enough period of time that the rivers begin to freeze. It is a window of about a month between the end of summer and the fall freeze up during which moose hunting conditions are ideal for successful harvest – in cool years. In warm years this time becomes much shorter, and more difficult to harvest successfully.

Of course, in addition to climatic conditions there are a host of other social and ecological variables that influence harvest success rates. Below in Figure 16 we show the necessary components for a successful moose harvest. All of the drivers on the left side of the diagram are climate factors and will be discussed in the next section with the weather analysis.

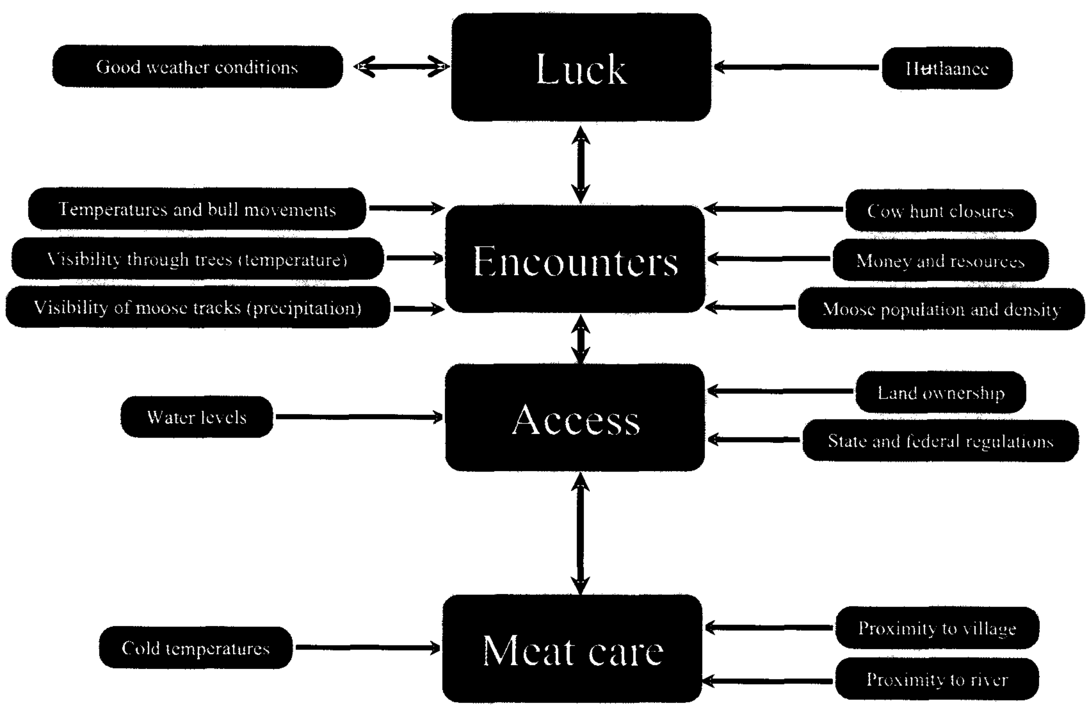


Figure 16 Necessary Components for a Successful Moose Harvest

Climate Change Effects on Hunter Behavior

In past decades and in cool years, rutting behavior typically began around the end of August/beginning of September (Nelson 1983). Research during the '60s and '70s suggested that good hunting season was mid-August to mid-Sept (Bane 1982; Nelson et al 1982). Local hunters now report that in some warm years the season has shifted by 2-4 weeks, depending on the year, with prime conditions now typically beginning in early- to mid-September during cool years, but mid- to late-September in warm years - a period that is out of sync with the regulated hunting season (discussed in chapter six).

Preparing for hunting trips is very difficult when the weather is increasingly unpredictable. The understanding of seasonal cycles and environmental cues allows hunters to accommodate year-by-year variations without wasting time, money, and energy through premature travel to distant harvesting sites (Turner & Clifton 2009). However, with seasonal shifts and lack of persistence (i.e., less predictability) of weather conditions compared to the past, the accurate assessment of when and where to hunt is further complicated.

> *Because of the high cost of fuel people have to be able to take the precise opportunity to harvest... this is getting down to the fine lines of the economics of subsistence, the economy of time, effort, and expense.* (J.R. WIRAC Meeting October 4, 2005)

Changes in precipitation patterns can result in low water levels at the beginning of the hunting season, which makes getting into key hunting areas very difficult or impossible when sloughs or rivers are too low to access by boat. Heavy rain during moose hunting can make hunting more difficult by dampening moose sounds, washing out moose tracks and scents, creating problems with keeping hunting equipment dry and functioning, and by causing difficulty in caring for the meat.

With unseasonably warm temperatures meat spoilage is also a significant problem. Moose are huge animals with hundreds of pounds of meat to handle. From the time of actually killing the animal the whole process requires many hours of butchering, packing, and transporting long distances from the kill site to the butchering, processing and camp site, and then to the residential location in the village and into the freezer. If it's too warm during this long process the meat will spoil. Meat spoilage is a key indicator for hunters as to whether or not temperatures are favorable as this was not the problem for them in past decades that it is now.

> *The amount of time we hunted in the fall didn't change, we'd go out for a week or so but we didn't have the freezers then so we'd wait until it started getting cold and then we'd go out, that's the appropriate time. Now, we can't do it because* ***we've got such a short window*** *that when that window's there everybody's got to go out and the other thing that happened is it would be staggered. If we knew somebody had been up the Northfork next week then, well, we'll wait a few days before we go up so we weren't all hunting at the same time.* ***And the seasons are really putting a crimp on traditional subsistence activities of going out when it's appropriate****, when the weather, you can take care of the meat and so on* (Mr. C WIRAC meeting October 4, 2005).

Patterns of Climate Variability and Change in Early Fall

An important question of the agency and scientist stakeholders in this case study is – what constitutes a "trend"? Climate scientists need very long time scales of at least 30 years to be able to say with confidence there is a "trend." However, villagers relate climate variables such as temperature, precipitation, snow quantity and quality, wind direction and speed relative to a whole range of variables in the system (see Figure 16) and ultimately consider how these combine to either hinder or help harvest success. Examples include temperature, freezing ice, vegetation changes, moose behavior, water levels that all interact as relatives as opposed to absolutes. In integrating Indigenous Observations and Understanding of Climate (IC) with instrumental weather data we had to reconcile these different, but complementary, ways of knowing and understanding.

Sometimes our results are not statistically "significant," but patterns in the data match patterns identified through IC. In our estimation, human or social significance (i.e., importance) to people on the ground helped bolster the statistical significance of weather data. Criteria for statistical significance can downplay social significance if viewed only by those criteria, for example, where a 95% confidence level determines whether or not a trend is significant. In other words, just because something is not statistically significant at that level does not mean it isn't a real phenomenon such as the subtle, yet important, changes in seasonality observed by hunters on the landscape. Conversely, statistical significance might not be important at all to people or animals on the ground. The strength of this analysis is in the integration of data and methods.

What is "too warm" for moose to move around? As mentioned above, the best weather conditions for moose hunting are cool and dry, with temperatures around 40s by day and 30s at night. Local observers said that moose can get their best footing for breeding when the ground starts to freeze. A big question in the villages is whether or not the warmer temperatures are actually causing the moose to copulate later in the season, yet scientists believe that the breeding dates do not change and are determined by photoperiod and not weather. For Alaska, scientific understanding on this issue is based largely on two studies from the 1980s on moose breeding dates in Alaska – one in the Kenai Peninsula area (Schwartz & Hundertmark 1993), and one in Denali National Park (Van Ballenberghe & Miquelle 1993). The latter study found October 3^{rd} to be the peak of moose breeding, and this is used to set the close of the fall moose harvest at September 25^{th} as the agency biologists feel strongly that any later than this is too close to the peak breeding date. I will come back to this in more detail in chapter six. For now, suffice it to say that the season ends per agency biologists' recommendation on September 25^{th}.

IC and Instrumental Observations on Hunting Season Trends

Temperature Trends

Koyukon Elders have indicated that September weather is often what August conditions used to be, i.e., warmer and wetter. Overall, in recent years the average temperature during the hunting season has shown a predominance of positive anomalies indicating a warming trend. Since 1995, eight of thirteen years (61%) have had warmer than normal temperatures, particularly in the three autumn seasons of 2005 – 2007. These years combined have mean anomalies of 4.0°F, which is greater than one standard deviation above average (>2.9°F) for this time period, which makes these years warmer than the normal range of expected variability. Combined, these three years represent the warmest consecutive three-year period of all hunting seasons in the historical records.

The total change in temperature over the period of record (1944 - 2007) for the hunting season (between August 25-September 25) ranges from 1.3°F for Galena to 2.9°F for Tanana. Each individual week within this month shows an increase on the order of .7°F to 4.1°F. An exception was found for week three at Galena, which shows no change. Further investigation of this particular time series revealed several cold snaps during the most recent 20 years that cause this week's time series from showing overall warming. One recent extreme cold autumn in particular (1992) can be seen as anomalous for all stations, especially for weeks 3 and 4, though this cold event is clearly evident throughout much of Interior Alaska and is a real phenomenon (as opposed to representing erroneous data). The interesting thing is that when this year is removed, the trend for week 3 at Galena does change from slight negative to a positive temperature trend, in line with the other stations, which is a testament to how a single extreme event can skew a trend line.

Calculation of Heating Degree Days (HDD) provides a measure of the relative warmth or coolness of a season by looking at how often temperatures were low enough to require the heating of homes (assuming a heating temperature of 65°F).[19] Heating Degree Days for the months of August and September yield totals on average of 1087 for Bettles, 956 for Tanana, and 959 for Galena. Each of these stations shows a decrease in the two month (August and September) HDD total since1944, indicative of a warming for this two month time period. The trend is statistically significant for Tanana with a total change of 137 units, but is not for Bettles and Galena with a total change of 131 and 75 units, respectively, though the trend for all stations is of similar magnitude.

As indicated by indigenous observers the time when temperatures start to oscillate around freezing is a key time period for the moose rut. In a community meeting with villagers in Hughes, one Elder told us:

> *Moose don't move until it starts to freeze and you get that crunch in the ground.* (Field Notes in Hughes, Spring 2007)

Similarly, during the fall of 2007 during a conversation with an Elder hunter in the village of Koyukuk I asked what temperature it needs to be for the bulls to start mating in the fall. He told me somewhere around freezing (32°F) because they need to wait for the right temperature to mate. The Elder said to me:

> *The moose need the ground to freeze a little bit to get a good foothold for mating. Right now the younger bulls have it okay but it is still not frozen enough for the more mature (bigger) bulls* (Field notes in Koyukuk September 27, 2007)

IC such as the statements above indicates that an important threshold temperature for climate-dependant moose and hunter behavior is 32°F. As such, we determined the designation of the end of the growing season to be the date when the minimum temperature was at or below 32°F at the end of summer. This date was identified for each

[19] The mean daily temperature is subtracted from 65°F and all the resulting daily values are added together for each month. This measure is often used for determining energy consumption required to warm a home to 65°F inside. Therefore, if the mean daily temperature is less than 65°F then it is a heating degree day because energy is needed to maintain the home's internal temperature.

station and year, and also served to mark the start of the freeze/thaw period, or the time when the minimum temperature oscillates above and below freezing and the ground begins to freeze. This date is also important because it signifies when the deciduous tree leaves that moose browse start to turn colors and fall off the trees, which also triggers the bull moose to stop eating and go into rut as well as provide visibility for hunters. The end of this freeze/thaw period was also identified as the date when the minimum temperature went below freezing and remained so for the duration of the winter. We determined the number of days in this period for each station and year as a way to characterize variability during a critical time for subsistence practices.

We found the end of the growing season, as determined by the date of first freeze in late summer/early autumn, to occur earliest at Galena relative to Tanana and Bettles. Over the entire period of record, dates for the occurrence of first freeze range from August 3rd to October 2nd with an average of September 1st. Galena showed a trend toward earlier occurrence of the first freeze with a change over the period of record of 8 days, which is statistically significant.

Once the minimum temperature dips below freezing, how long is the time period before the minimum temperature stays below freezing for the winter? The length of this freeze/thaw period ranged from almost 80 days to 0 indicative of high variability during this time period (a long season for the former and a short season for the latter), in which the temperature went below freezing and remained so for the duration of the winter. Galena and Tanana both show a trend toward lengthening of this time period by one week since 1944. Bettles shows only a slight change of one day. In addition, the inter-annual variability of this time period is high, yielding inconsistencies from year to year, which means less predictability as the Elders have also indicated from their observations. The occurrence of earlier first freeze dates seems to contradict the findings that interpret an overall warming trend for this season. However, the longer time period until persistence of temperatures below freezing indicates a longer freeze/thaw season. Local IC of early freezes frosting gardens concurs with this finding.

Our analyses of the temperature data for the four week time period during moose hunting suggests that the season in general is warmer, however, the end of the growing season and initiation of the freeze/thaw period is occurring earlier. The warming trend is pushing the fall season later, but there can be short but strong cold bursts of arctic air resulting in these early freezes. Perhaps the most important trend from the moose hunter's perspective is an increase in inter-annual variability resulting in less seasonal predictability, and more frequent temperature extremes, both of which can impede successful harvest of moose. Falls that are too warm are simply a detriment to hunters, so regulations that don't allow for adjustment to these conditions are problematic for subsistence livelihoods.

Precipitation Trends

Koyukon Elders and hunters note that fall precipitation patterns are shifting from the expected historic conditions. "August rains" were typically when precipitation was at its peak, and would recharge the rivers and sloughs water levels. September was typically cooler and drier than July and August, which creates conditions ideal for moose hunting. Local observations indicate that this is beginning to shift and "August rain" is coming more frequently in September.

> *Well, it's unpredictable [rainfall] this season moose hunting season it was really good, it was dry, but the year before that it rained, rained, rained in September. It usually rained in August.* ~Benedict Jones, Koyukuk (Jones 2004)

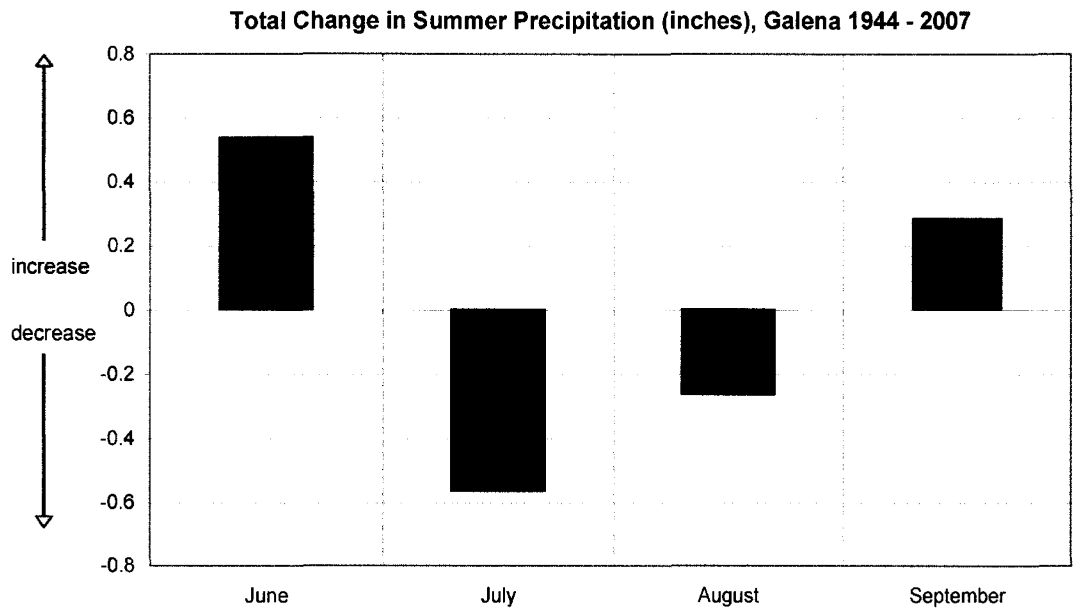


Figure 17 Changes in Galena average rainfall for June through September 1944-2007 indicating a slight decrease in July and August and a slight increase in September.

Analysis of Galena's precipitation data shows that precipitation has decreased in July and August but has increased in September. When we looked at the four weeks individually during moose hunting season, the first two weeks, August 25th to August 31st and September 1st through September 8th, show a slight decrease in precipitation, while the latter two weeks, September 9th through September 16th and September 17th to September 25th, show a slight increase. Therefore, within the hunting season at Galena, the first half is trending toward warmer and drier and the second half toward warmer and wetter, with the weather data analysis agreeing with local observations of change.

The analysis for Bettles shows the same trend, although Tanana shows an overall drying for each of the four weeks; although these weekly and monthly temperature and precipitation trends are not always statistically significant at the 95% confidence level the results do concur with local observations in the KMY region. Subtle changes such as these are occurring during the transition season when biophysical changes of import to people are taking place on the landscape. High inter-annual and inter-regional variability is such that an overall trend in the data is hard to detect, which is why local observations help identify nuances that are difficult to detect in statistical analysis of the data. Locals observed that there is high variability in fall conditions from year to year, but in years when a warming trend occurs, it negatively affects hunter success. Social significance to hunters is determined by harvest success, which has much more meaning when food security and vulnerability are at stake.

Anatomy of a "Closing Window" of Harvest Opportunity

Some extreme warm, dry, or wet falls may not matter much to the statistician if the overall trend is found to be statistically insignificant, but it matters a lot to the hunter trying to feed a family. What stands out about the fall temperature record is a very high level of variability in the system (see Figures 10 and 11b). This variability confounds decision makers when balancing a variety of factors to manage wildlife in a way that satisfies all the stakeholders involved. The high variability also leads people to question whether this is a trend to be concerned about (i.e., climate change), or just the "weather doing what it does" (i.e., variability). In this case, it is both climate variability and change, so all stakeholders need to be prepared for both.

The linear regression trend lines for the three stations we analyzed appear as if there is only a slight and sometimes even statistically insignificant warming trend. Upon closer examination of the departure from the mean temperatures we gain a better understanding of individual years in relation to others (Figure 18). In regard to climate, it is this relativity that matters most because it is what conditions hunters for what to expect each year. Climate is the range of expected or average conditions of weather during any given season in a particular place. A string of warm years in a row, which local observers perceive as a warming trend over the last two to three decades, can result in conditions that shift the coping range of the hunters as the cumulative effects of multiple, successive warm years affect the overall coping capacity of communities. When multiple stressors and regulations accumulate and/or converge to constrain the ability to move through time and space accordingly, social vulnerability increases.

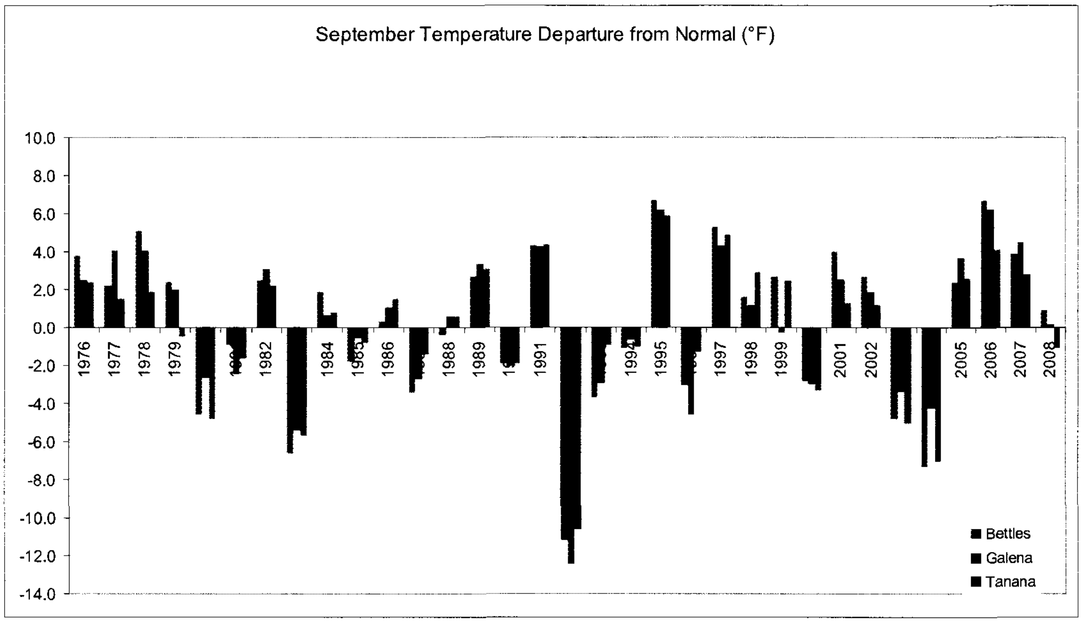


Figure 18 September temperature departure from normal (°F) for Bettles, Galena, and Tanana 1976-2008. The standard deviation for the years 2005-2007 are outside of the normal range of variability

The falls of 2005-2007 were three years in a row with significant temperature departure over one standard deviation, which for this time period is 2.9°F. Does seasonal warming beyond a standard deviation above average temperature provide a threshold for local or regional harvest success or failure? It is not enough to just look at average temperatures. We need to look closely to understand how all the variables in the system are interacting; and the cross-section of time and space of the analysis matters.

Combining this with qualitative sources of data we have a better picture of the "window of vulnerability." Windows of vulnerability are created when timing of events or periods in which hazards become more impactful because of the combination of circumstances (Dow 1992). This case demonstrates a closing window of opportunity for the successful harvest of moose under circumstances of shifting seasonality. When combined with the other socio-economic and biological stressors, specifically decreased moose populations, and increased gas and food prices, along with the decreased hunting opportunity through regulatory restrictions (discussed in chapter six), this "closing window" of opportunity creates the window of vulnerability for the rural communities of the Koyukon-Middle Yukon region.

Wind directional changes, moose moving into cover, and other factors affect harvest success during "normal" conditions. Good population structure (e.g., good bull:cow ratios) and moose in accessible areas increases the "luck" factor. If the window of opportunity is halved, so is the "luck" of harvesting a moose. Luck to the Koyukon hunters is expressed through their own behavior and showing of respect to the animals, but it is also dependant on a spectrum of favorable biophysical and ecological conditions, and the ability to hunt when and where their cultural methods dictate. When restricted by a small window of opportunity, the environmental conditions matter exponentially more. Examination of the fall season in 2007 gave us a better understanding of how the convergence of a very warm season with other factors creates this "closing window."

The Fall of 2007

The hunting season of 2007 is exemplar for understanding baseline vulnerability to fall seasonality changes. The 2007 fall season was unseasonably warm, as it had also been for the previous two years. Hunters in several villages with surrounding low density moose populations (e.g., Hughes, Koyukuk, and Nulato) had difficulty harvesting moose before the season closed on September 25th.

> *In our area, Galena area, there have been people who didn't get their moose, so I'd like to also have our moose hunting extended just a little bit longer. Sometimes the weather is too warm and there's a lot of wasted meat out there that probably could have been saved had the hunting been a little later* (J.P. WIRAC meeting March 6, 2007).

Water levels were low in many places because of low precipitation in late August, and so hunters were going out and coming back empty-handed for the first few weeks of the hunting season. Then it rained a lot in September. When I was in Koyukuk in

September of 2007 just after the moose hunt I was discussing how it went with Benedict and Eliza Jones. I asked them if rain affected the moose. Benedict said the bulls have a harder time tracking the cows because it washes away the scent as cows mark their scent by urinating on the ground (Field notes September 27, 2007). He said that this had been the wettest September he had ever seen. Both Elders remarked that the weather they were having then at the end of September – i.e., cool, cloudy, and rainy – was "August weather" in that it was wet and cool but not freezing with no frost on the ground.

Figure 19 shows August and September high and low temperatures compared to the mean highs and lows during the 2007 moose hunting season.

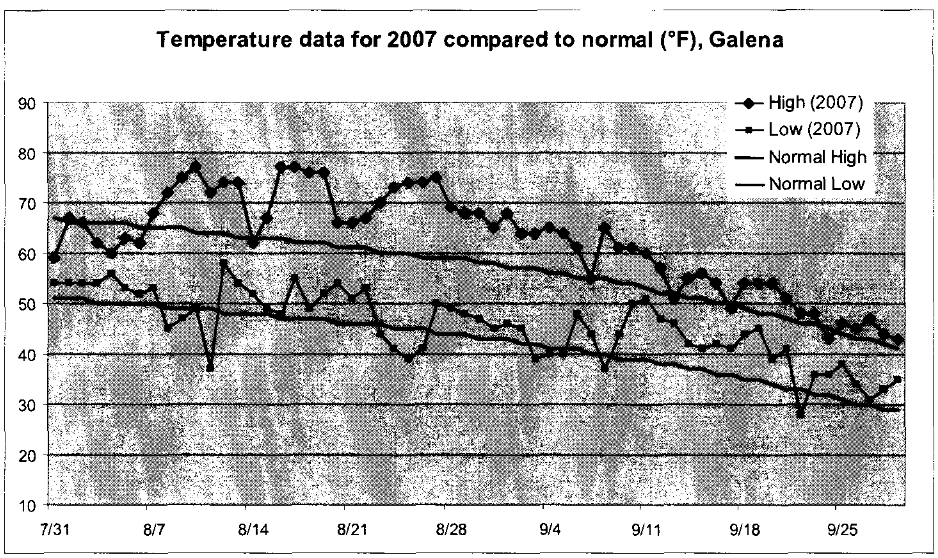


Figure 19 High and low temperatures for August and September 2007 compared to the 1999 decadal mean.

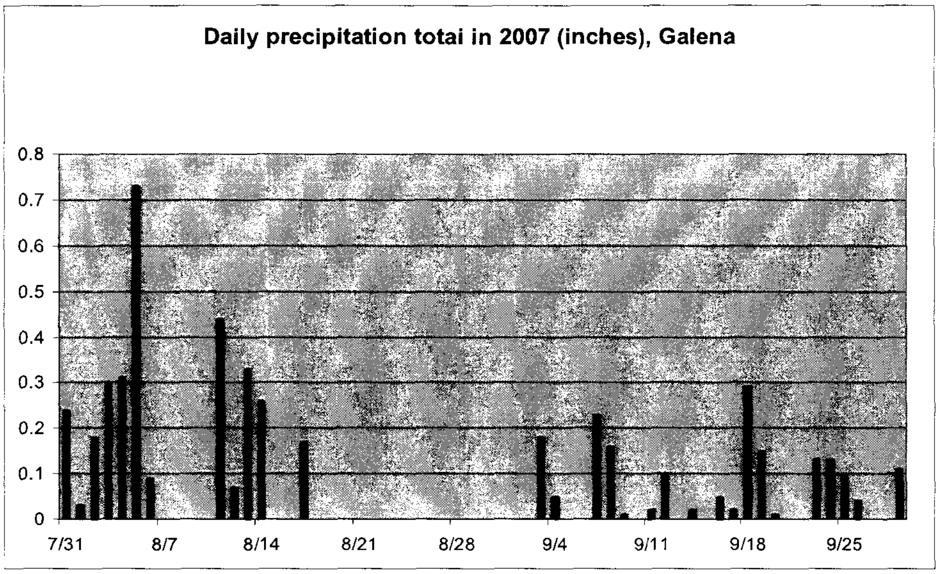


Figure 20 Daily precipitation total in inches for Galena August and September, 2007. This shows no rain during the last week of August, which resulted in low water levels in sloughs and rivers. It rained through September, which helps with water levels, but is not good for caring for meat or for moose mating.

The temperatures in the fall of 2007 were above average for most of the season. Most importantly, temperatures did not decrease into the 40°sF and 30°sF until September 19th and the first freezing temperature was on September 24th – one day before the close of the season. Additionally, the precipitation record shows that last week of August until September 3rd was dry. This resulted in low water levels in many places at the start of the season. Later on in the season it was quite wet, and very wet late in the hunting season for several days at exactly the time temperatures were opportune. Consequently, for many hunters in the region, there were very few days where conditions were suitable for hunting success.

If a warming trend on the order of one to two degrees Fahrenheit since the mid-1970s has pushed the hunting season back by weeks to a month during warm years, the continued warming projected by climate models (Walsh 2009) could eventually result in an even later seasonality shift, resulting in conditions too warm until during or even after peak breeding dates as determined by biologists. The long-term ecological effects of this are unknown, but in terms of moose behavior and hunting success, this could eliminate the fall hunting opportunity altogether in some years if the current window is not allowed to expand. Local individual and group adaptations notwithstanding, as long as the moose population numbers are of concern and breeding dates according to the one Interior region study (Van Ballenberghe & Miquelle 1993) are rigidly adhered to, this will mean continued conflict between the goals of protecting the moose populations for future generations, and the ability to harvest moose successfully in the present.

Conclusion: Fall Seasonality and Vulnerability to Climate Change

Indigenous observers all over the northern Interior region of Alaska report that warmer temperatures during early fall time (i.e., late August/September) are affecting the fall moose hunt some years. Changing seasonality results in difficulty harvesting moose in time before the regulatory moose-hunting season ends on September 25th. This decreases the opportunity to meet their annual harvest needs for the winter. Inability to access moose and/or harvest failures can cause hardship for families, households, and even entire communities. It means having to rely on more labor-intensive wild foods (e.g., salmon and other fish species, caribou, bear, beaver), and, for the most part now, on nutritionally inferior and expensive store bought food flown long distances from the urban hubs to the rural villages. Recent poor salmon runs (and in the late 1990s) on the Yukon River and its tributaries make salmon a less reliable substitute than it used to be.

In the thirteen years between 1995 and 2007, eight years show a predominance of positive temperature anomalies for the whole moose hunting season starting end of August through the end of September (and nine of the thirteen years show above-average temperatures for September), particularly in the three years 2005-2007. These three years have combined mean anomalies of 4°F, which is greater than one standard deviation above average, and, therefore, are outside of the normal range of expected weather conditions. Combined, these represent the warmest consecutive three-year period of all hunting seasons in the historical records. Given the context of the larger warming trend across temporal and spatial scales in Alaska over the last 60 years, and especially over the last 30 years, and the results of our analysis for the region, we conclude that this is likely part of a long-term warming trend.

Yet, when considering issues of social vulnerability and adaptation, whether or not this is part of a longer term trend is, in a sense, the wrong question. Determining this with 100% certainty is difficult given the limited amount of time series data along with the nascent state of scientific understanding of the role larger-scale climate oscillation patterns play in Interior Alaska. A more appropriate question is – given the relative certainty that the global climate will continue to warm, and predictions of how this will affect Alaska, how can we incorporate understanding of current and past vulnerability into our planning for the future?

Low Climate Exposure, High System Sensitivity

The system dynamics have created a high sensitivity to small shift in climate. Dramatic changes take place on the landscape during the short transitional fall season, and both moose and subsistence communities are quite sensitive to even slight shifts in the timing of specific events. Because of mandated state regulations, certain practices are limited in time to a specific window of opportunity, making seemingly insignificant climate trends or shifts quite critical for those dependent on the direct harvest of natural resources. In conclusion, even a statistically small change in temperature is enough to affect moose and people hunting moose during this very critical time of year, given the high sensitivity of the social-ecological system to the resulting shift in seasonality. This research demonstrates the importance of local observations and knowledge in helping to identify these *important* ***nuances*** *that might be missed in conventional scientific analysis from afar*. Timing of temperature and precipitation, moose behavior, and the regulatory window opening all combine to result in system where a slight shift in the temperature/precipitation had a high impact. If a family or household does not get moose, it causes stress for not just that household, but for the whole community because of the cultural expectation to share meat with those who are without (discussed in chapters two and three). A household that was successful might still end up with insufficient meat to meet their needs and are therefore food insecure as a result.

In summation, our analysis found the following evidence of shifting seasonality during early "fall"

a. Weather instrumental records agree with indigenous observations that there has been a small, but socially significant warming trend in the fall shifting both temperature and precipitation patterns some years;
b. This seasonality shift is likely part of a long-term warming trend for the region that is highly likely to continue into the future;
c. Individual seasons of 2005-2007 provide an analog and good baseline picture of vulnerability regardless of the long-term historical trend.

Seasonality Shift, Multiple Stressors, and Food Insecurity

The fall seasonality shift in combination with multiple stressors are affecting moose harvest and threatening food security The difficulty in fall harvest is also caused or exacerbated by many social, biological, economic, and political stressors. First, the moose populations have declined compared to past decades because of increased hunting pressure combined with an overabundance of wild predators (wolves and bears). Second, gas prices have gone up making it extremely expensive to hunt by gas powered boats, which is the main form of transportation to hunt moose. As of 2008, gas averaged about $7/gallon in the region, and one trip out could cost as much as $1,000 for boat oil and gas, food, and other supplies, or more if one travels by boat 80 miles each way looking for a moose, which is a common for the hunting patterns in some villages, especially since moose in low density areas like those near Allakaket and Ruby are harder to find in general. Third, traditionally Koyukon hunted in the late winter/early spring and to get moose when food supplies started running low. The February/March cow hunt has been eliminated by the state.

Therefore, there are socio-economic variables and biological variables underpinning the problem, and now climate change is added to the complexity of all of these multiple driving variables/stressors. This is all happening within the context of a subsistence and wildlife regulatory system that constrains movement across time and space for a local hunting society whose adaptability has long depended on great flexibility to respond to environmental change.

Chapter 6: Constraints on Sustainable Adaptation to Climate Variability and Change

Introduction: Responding to the "Closing Window" of Opportunity during the Fall Moose Hunt

The Alaska Board of Game (BOG) held their biennial Interior Region "spring" meeting from February 29-March 10, 2008, in Fairbanks to review proposals and set regulations for the upcoming two years for the region. Eight proposals were presented to the board to shift the fall moose hunt season later because of several years of warm falls that affected harvest success, with five proposals[20] submitted by the village stakeholder advisory committees to the Board of Game (BOG) for the Koyukuk-Middle Yukon (KMY) region ("Galena area"). This was not the first time that proposals were submitted to the Board of Game dealing with warmer falls and moose hunting, but it was the first time that multiple proposals were received from the KMY region.

The BOG heard public testimony on these proposals, along with presentations from ADF&G biologists on moose populations and weather changes. The board initially voted down all eight proposals, citing biological concerns for conserving the moose population, and the need to align with statutory requirements of the federal management system. One proposal (#63A)[21] was overturned two days later when the board revisited and adopted it with amendments to shift the fall hunting season to begin and end five days later (September 1st to September 25th) in order to give subsistence hunters more time to successfully harvest moose. The basis for the overturn was that more opportunity in the fall would alleviate potential pressure from noncompliance during the winter as the state had indefinitely closed down the February/March hunting period that provided approximately 14% to 21% of the annual moose harvest for the region from 1997-2003 (Andersen et al 2004; Andersen et al 1998; 2000; Andersen et al 2001; Brown et al 2004).

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[20] Proposal numbers 59, 63, 65, 66, 80

[21] Proposal 63A was the amended version submitted by ADF&G with the recommendation to change the hunt end date to September 25th instead of September 27th as per the original proposal submitted by the KMY village representatives.

Both conflict and cooperation among stakeholders are operative here, with context, multiple stressors, and specific events relevant for understanding the complexity of the problem, which are all working in combination to undermine the potential for positive collective action. There is tremendous potential for adaptive capacity in the form of social and institutional capital networks and trust relationships among state, federal, and tribal stakeholders in the region. However, the complicated relationships that have emerged from the system of dual management make realization of that capital challenging and sometimes impossible. The reasons are situated in the regulatory system, and in the institutional dynamics that breed conflict between the federal and state agencies, the rural Alaska Native villages, and nonlocal and sport hunters.

Constraints on Adaptive Capacity to Climate Change

Success in the wild food harvest requires flexibility across time and space to effectively respond to changing environmental, social and political conditions. Policies that limit the ability of natural resource-dependant societies (i.e., direct harvesters), with the Koyukon case described below but one example, to be creative, diversify, or innovate may lead to unsustainable resource use and exacerbate vulnerability to climate change (Thomas & Twyman 2005). Following Alaska statehood in 1959, a complicated dual Alaska state and US federal management system for wildlife and subsistence emerged from the Alaska Native Claims Settlement Act (ANCSA) of 1971, and the Alaska National Interest Lands Conservation Act (ANILCA) of 1980. Alaska Natives who were historically highly mobile and flexible across the landscape for their subsistence hunting, fishing, trapping, and gathering became increasingly restricted by the institutional morass of rules and restrictions imposed by the state of Alaska and the federal government. In chapter two I discussed the other drivers that led to a more sedentary people over the last century such as the Christian missions, trading posts, and legally required schools in villages, to name a few. But it was ANCSA and ANILCA that really *restricted* movement across time and space (as opposed to just changing patterns as did the other drivers of change) when it came to subsistence hunting practices.

In this case study I demonstrate the complexity and rigidity of the dual state and federal management system of the land and its ecosystem services (i.e., to provide food) to rural villages that creates barriers to adaptation to climate change and seasonality shifts. Participation in this complicated regulatory system is mandatory for rural, Alaska Native communities today, forcing them to respond within an imposed framework. This form of adaptation has been difficult and is one they continue to contest in the ongoing attempt to maintain their rights to land and wild food. However, this system is the rule of law, so here I investigate the opportunities and constraints within the system for collective, and perhaps even strategic, adaptation to climate change.

The important characteristics that underpin adaptive capacity for rural Alaskan Native community response to climate change include ecological knowledge and harvesting skills, along with social and institutional capital. Social capital describes the relationships and social networks, agreements, flows of information and other aspects of social organization such as trust, obligations and expectations and cultural norms that facilitate coordinated actions to achieve social benefits and facilitate well-being and security (Adger 2003; Coleman 1988; Dasgupta & Serageldin 2000; Fukuyama 2003). Communities in the KMY region and throughout rural Alaska continue to make use of cultural community mechanisms to distribute resources and food through their local and regional cash-subsistence economies by utilizing social networks and personal and family ties (Brown et al 2004; Magdanz et al 2002; Wolfe 2000). The Koyukon also maintain traditional environmental ethics guided by *hʉtlaanee* (taboos) to remain in balance with their natural environment and to sustainably harvest natural resources (discussed in chapter three).

Adaptive mechanisms (such as food and resource sharing or changing of hunting patterns and practices) operating at the community-level are often constrained by the institutional hierarchies in which they are nested, determining in part how adaptation to climate change manifests through the policy processes (Adger & Kelly 1999). Institutional responses to climate change are often best suited for mitigation of emergency situations and isolated events rather than to slower onset, cumulative or systemic climate-related problems leading to disruption of ecosystem services; the institutional and regulatory entities are even less well-suited to the working with underlying social factors that structure vulnerability (Handmer et al 1999). Where institutional rule making occurs in a compartmentalized and fragmented framework, responses to climate change have been either nonexistent in the worst case, case-based mitigation in the best.

The power and authority to make decisions in complex societies typically usurp what were formerly local decisions and differing viewpoints about risk, rewards, and priorities, a situation that often lead to decisions with disastrous effects on local resilience (Redman et al 2004). In wildlife management agencies such as the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service, biological paradigms and political and government agency priorities invariably dominate over local considerations, especially with respect to resource management issues relative to considerations of climate. Consequently, decision makers are often disadvantaged in devising responsible solutions to complex problems such as climate change in a complicated, cross-cultural setting such as this one. Decision makers lack comprehensive understanding about how fundamental social relationships and processes provide community stability, or about how their decisions create unintended consequences for system dynamics in surprising and sometimes negative ways. This dynamic can produce inefficiencies and feedbacks that result in maladaptation and diminishing community resilience over time (Rappaport 1978).

Policies that put too much emphasis on complex technical or biological solutions at the expense of peoples' ability to innovate or maneuver through space and time in either physical or political environments can lead to unsustainable resource use and inhibit adaptation to climate change (Thomas & Twyman 2005). In past societies, vulnerability to climate change increased when such climate perturbations came after a period of declining marginal returns on investment in complexity (McGovern 1991; McGovern et al 1988; Redman 1999; Tainter 2000). In other words, a social-political system can become maladaptive when its internal incoherence limits capacity of the system to respond effectively to stress (Rappaport 1978; Redman 1999). This is a classic illustration of what can make a system highly sensitive to climate change-induced stress, as I discussed conceptually in chapter one and in extant circumstances in chapter five. It is not always the magnitude of the external stressor, but rather is often the internal structure and functioning of the system or subsystem that make it sensitive to environmental disturbance.

In addition, impact-oriented climate research has been insufficient to help decision makers and resource managers adapt to climate hazards, in part because of a lack of appropriately scaled information that is necessary for effective decisions, and in part because assessments are made too far into the future for real-time decisions. Moreover, there is typically little to no consideration of the factors that determine vulnerability and adaptive capacity (Burton et al 2002; Fussel & Klein 2006). Where models of physical processes are uncoupled from social ones, projections of future climate change are of limited utility to resource managers, and of almost no use to stakeholders who depend on the resources being managed. Here I will show how adaptation to climate change in the KMY can only be understood within the context of the complicated dual management system and how this system has hindered adaptations.

Wildlife and Subsistence Management for Moose in the KMY Region

The Alaska Native Claims Settlement Act (1971) left a legacy of patchwork land ownership and management authority across Alaska that largely defines how the institution of wildlife and subsistence management has developed. In the KMY region there are four national wildlife refuges managed by the U.S. Fish and Wildlife Service office in Galena– the Koyukuk National Wildlife Refuge, the Nowitna National Wildlife Refuge, and the Northern Innoko National Wildlife Refuge (Figure 21) and the Kanuti National Wildlife Refuge (not pictured) near the villages of Allakaket and Alatna.

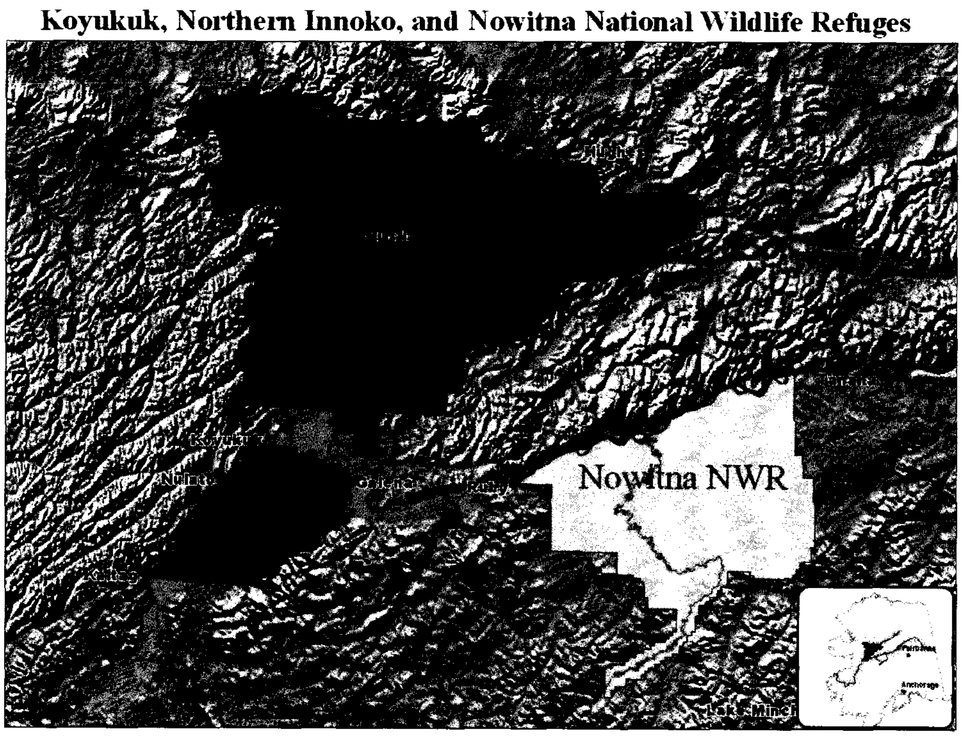

Figure 21 Map of the Koyukuk, Nowitna, and Northern Innoko National Wildlife Refuges

Within the three refuge boundaries the federal government is the biggest land owner with 6,044,478 acres of land, Doyon, Limited regional native corporation is second, with title to 756,839 acres. The state of Alaska, village corporations, and native allotments make up the remaining acres. Most of the lands surrounding the refuges are owned by the federal government, or managed by the Bureau of Land Management, or are owned by the state of Alaska.

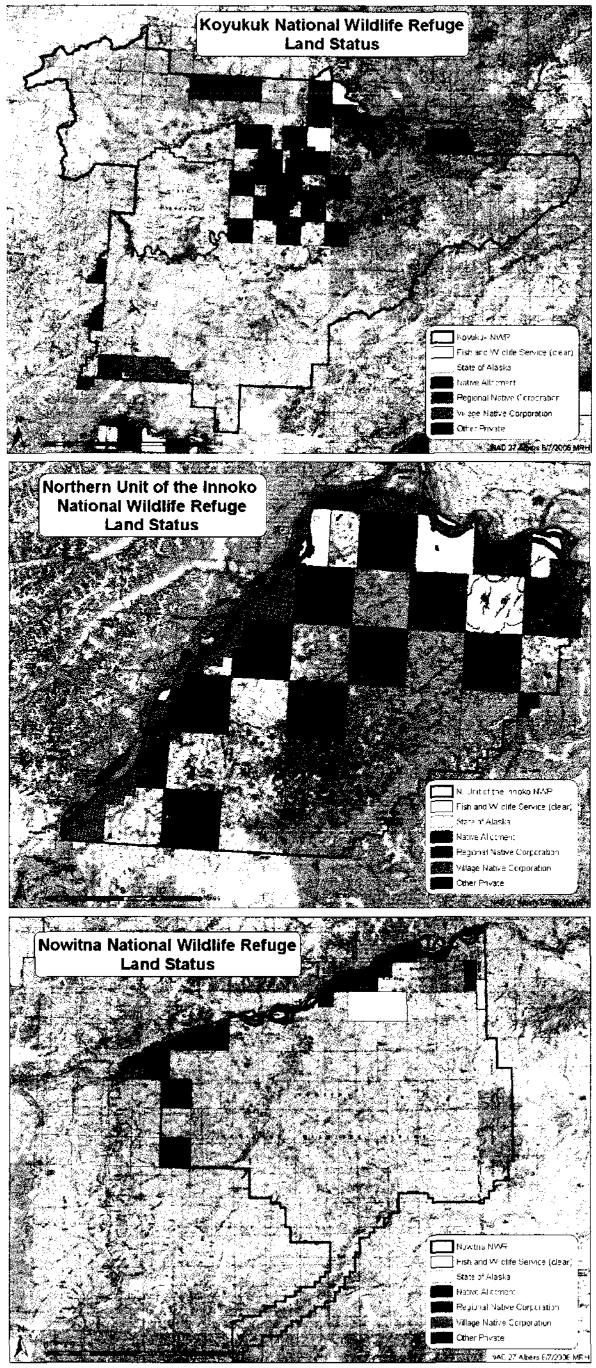

Figure 22 Maps of land ownership in the Koyukuk, Nowitna, and Northern Innoko National Wildlife Refuges. Courtesy of the U.S. Fish and Wildlife Service Galena office.

The Alaska state government has primary authority over management of wildlife and subsistence, meaning that the Alaska Board of Game, made up of seven people appointed by the governor and approved by the legislature, is the central decision making body. The composition of the BOG is critical to all decisions made. Rural needs are very different from non-native, urban, and commercial needs in many ways, and the BOG must evaluate the needs of all within a framework that is both legal and constitutional. Given the dominance of commercial interests in natural resource extraction in Alaska (Haycox 2002), the BOG is composed of primarily non-Alaska Natives, and is currently comprised almost entirely of urban males with commercial interests.[22] Tension between rural subsistence hunters and hunters from urban Alaskan centers, or from those outside Alaska, has been problematic since statehood, with tensions increasing since passage of ANCSA. There is probably no other forum where this is demonstrated more strongly than in the highly politicized Board of Game meetings where all the stakeholders negotiate the regulations that determine hunting access and rights.

The Alaska Department of Fish and Game (ADFG) answers to the BOG and to elected officials, and manages various regions of the state as Game Management Units (GMUs). GMUs 21D and 24 are the units within the KMY region and cover roughly 38,000 square miles. Figure 23 shows the Game Management Units 21 and 24, along with the USFWS refuges and the Controlled Use Areas (CUAs) in pink. The Koyukuk Controlled Use Area (KCUA) was established in 1979 to reduce hunting pressure from non-local hunters by banning the use of aircraft over this area. Approximately one half of the KCUA (4,791 square miles) lies in 21D, while the other half is in 24D.

[22] As of this writing in 2009 only one Alaska Native sits on the BOG and there is not one female representative.

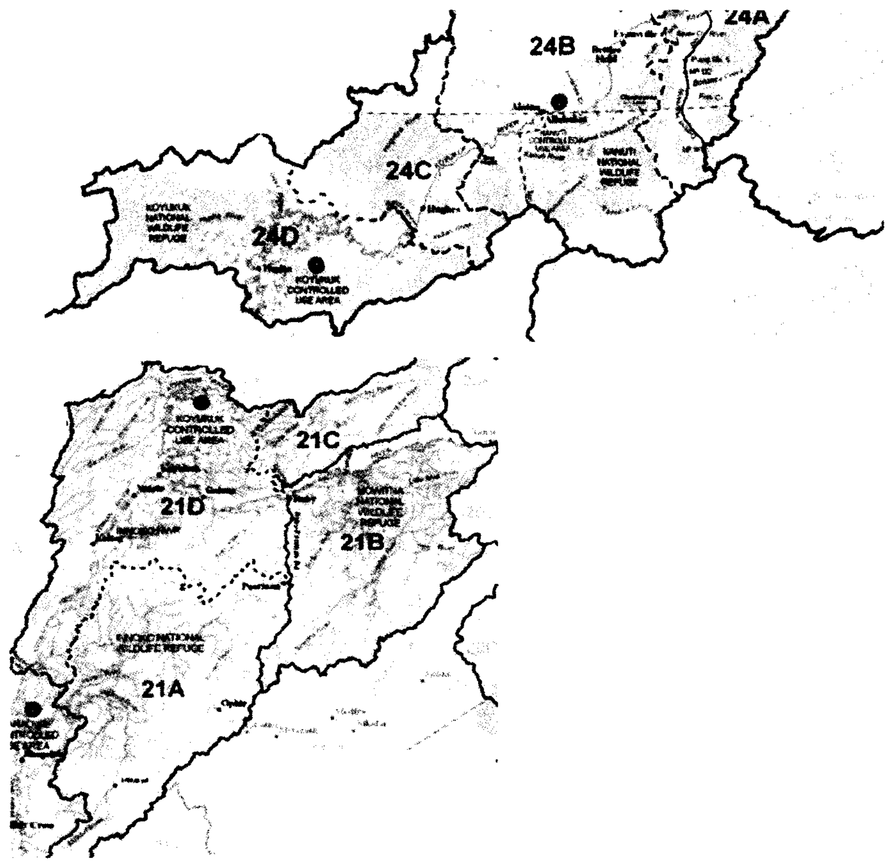

Figure 23 Maps of Game Management Units 21 and 24. Excerpted from the Alaska Department of Fish and Game, Division of Wildlife Conservation Hunting Regulations Booklet 2008 http://www.wc.adfg.state.ak.us/index.cfm?adfg=regulations.hunting.

The ADF&G Division of Wildlife Conservation manages the wildlife populations along with subsistence according to the regulations determined by the BOG. The ADF&G Division of Subsistence provides assistance through research on subsistence patterns and use throughout the state.

As the major landowner in the region, the federal government plays a very important role in the management of moose in the KMY. In an effort to address the complexity of the dual management system, there is an ongoing goal of cooperation and "alignment" between state and federal policies and regulations. State regulations for moose hunting apply on all state, private, and federal lands, with the exception of when there is a shortage and federal agencies may authorize additional subsistence harvest opportunities for local, *rural* residents, with authority for this applying only on federal lands, and *only* if it is determined on the basis of "scientifically acceptable" evidence that there is a shortage of harvestable moose. As discussed in chapter two, the issue of "rural priority" for hunting regulations (per ANILCA Title VIII) in Alaska continues to be the source of ongoing tension for wildlife and subsistence managers across the state.

The decision making body for wildlife and subsistence policies on federal lands is the Federal Subsistence Board (FSB) supported by the Office of Subsistence Management (OSM), another federal agency. The FSB structure and process for public input is similar to the state system in that they have regional citizen advisory councils (in this region it is the Western Interior Regional Advisory Council or WIRAC) and proposals for wildlife regulations are made every other year to the FSB.[23] The FSB is comprised of the regional directors from each of the five federal agencies,[24] with the sixth a member from the public appointed as chair.

All of the stakeholders including subsistence and sport hunters, rural and urban residents, state and federal managers and decision making bodies all have to operate together within the very complicated dual management system (Figure 24).

[23] The FSB changed from an annual cycle to a two-year regulatory cycle in 2008.
[24] US Fish and Wildlife Service, Bureau of Land management, US Forest Service, National Park Service, and Bureau of Indian Affairs.

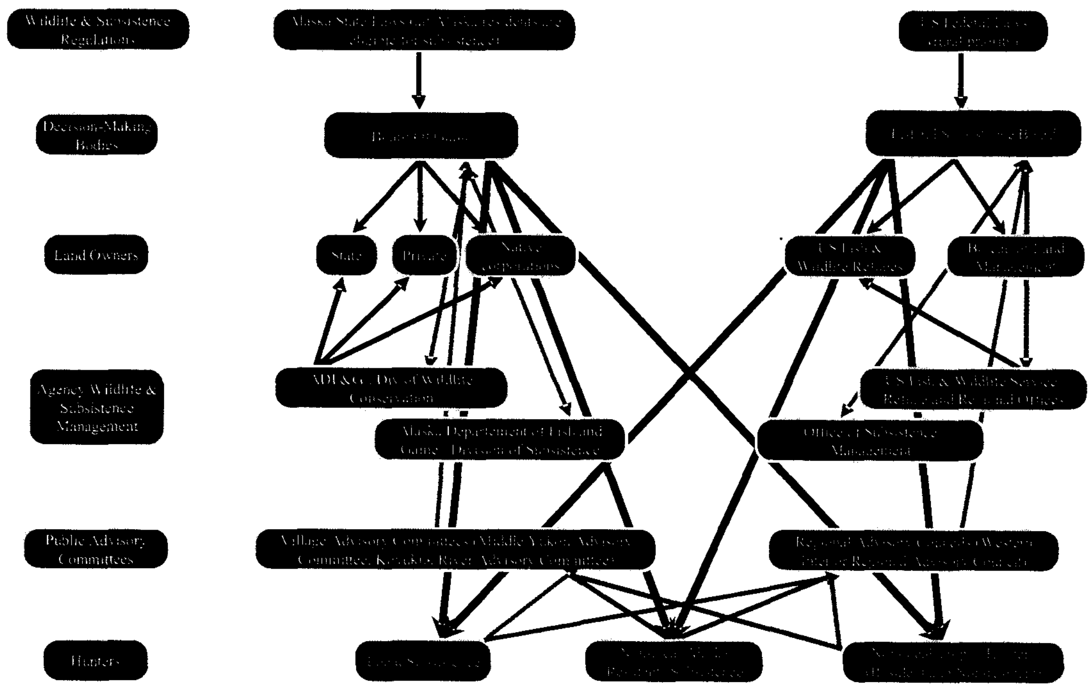

Figure 24 Diagram of the complex dual management system for wildlife and subsistence

As major landowners in the region, the regional Alaska Native corporation, Doyon, Ltd., along with the smaller village corporations, have a small advantage in defining hunting access on their lands. As private landowners they may legally limit hunting on native lands to native shareholders only, and may prohibit sport hunting and/or access by individuals from outside the region. Since Doyon, Ltd. is a state-chartered private (for profit) entity, this means that all corporate-owned lands are still governed by the state, including wildlife and subsistence law and implementing regulations. Village corporations were allocated a much smaller percentage of land and money than were the regional corporations through ANCSA, so in general they have less immediate influence (even though the managed resources are literally in their backyards).

In the KMY region there are two village corporations that are made up of several villages that merged to form corporations – K'oyitl'ots'ina, Ltd. is made up of the villages of Alatna, Allakaket, Hughes, and Huslia; and the Gana-A'Yoo, Ltd. Is comprised of Kaltag, Nulato, Koyukuk, and Galena. These smaller regional/village corporations have decision making authority on their lands that is similar to Doyon, but, as they are state-chartered entities (i.e., private corporations), wildlife and subsistence laws are still governed by the state.

The ADF&G and the US Fish and Wildlife Service have differing mandates, but they both put fish and wildlife protection before subsistence in terms of priorities. The ADF&G Division of Subsistence provides research and information on subsistence uses and needs, although, within ADFG it is biological considerations that take priority for management decisions. The village tribal councils and the agency advisory committees prioritize subsistence, but they have no direct authority over management of fish, wildlife and other natural resources. Tribal Councils do not technically have the legal authority to say who can hunt on village lands, and this is because the lands are owned by the village and regional native corporations.

The Koyukuk River Moose Management Plan (KRMMP)

After a growth in the KMY moose population during the 1980s and early 1990s, abundance decreased in the late 1990s, along with an increase in hunting pressure (U.S. Fish and Wildlife Service & U.S. Bureau of Land Management 2005). In 1999, 731 hunters were checked at Ella's Cabin check station[25] on the Koyukuk River, reporting a harvest of 367 moose, more than double the number of hunters (299) and moose than were harvested (181) just eleven years earlier in 1988 (Alaska Department of Fish and Game 2001). This happened in concert with a crash in salmon runs of the late 1990s, putting more pressure on local subsistence hunters and the resource to ensure regional food security.

Growing concern by the KMY communities along with state and federal agencies resulted in establishment of the Koyukuk River Moose Hunters' Working Group (KMWG) organized by the ADF&G Division of Wildlife Conservation and comprised of representatives from state fish and game advisory committee members, as well as by representatives from the federal advisory committee (WIRAC) and commercial operators.

[25] Ella's Cabin check station on the Koyukuk River is where hunters must check in with agency staff to show documentation and report harvest.

With state and federal agency representatives as technical advisors, the KMWG met multiple times over two years (1999-2000) to devise the Koyukuk River Moose Management Plan (KRMMP). Decision making was consensus-based, so all aspects of the plan had to be approved by all members before adoption. The finalized plan was presented to the Board of Game in March 2000 and was approved with only minor adjustments. Therefore, the 2000 fall hunt was the first hunt after implementation of the plan.

Local villages did have representatives on the board, but another grassroots tribal group was opposed to actions taken by the Board of Game. The Koyukuk River Tribal Task Force on Moose Management (formerly the Koyukuk River Basin Moose Co-Management Team) was formed prior to the KRWG in a locally-based attempt at co-management of moose that failed as it did not have the full buy in from locals or agency representatives. The village task force sued the Alaska Board of Game for issuing too many hunting permits for the KCUA, claiming a violation of the sustained yield principle of the Alaska State Constitution and legally mandated subsistence statutes; the Alaska Supreme Court subsequently ruled that the BOG was within its discretion in adopting a regulation to issue up to 400 permits in the KCUA (Koyukuk River Basin Moose Co-Management Team v. Board of Game 2003).

It is important to understand that the KRMMP was not formally a co-management effort since this would give some decision making and management authority to the village, authority to be shared with the federal and state agencies. The KRWG operated in an advisory role to develop the plan, but had no regulatory authority. The KRMMP was legitimized by the consensus decision making process, however, over the course of the implementation of the plan since 2000 conflict over the ADF&G's interpretation and policy recommendations has caused conflict between the local village and agency stakeholders within the group.

Management Goals, Implementation, and Current Status of the Plan

The KRMMP included eight goals with various recommendations for objectives and actions under each goal, the primary goal of the plan to:

> Manage Koyukuk River drainage moose on a sustained yield basis to provide both hunting and other enjoyment of wildlife in a manner that complements the wild and remote character of the area and that minimizes disruption of local resident's lifestyles (Alaska Department of Fish and Game 2001).

Limitation of hunting permits is the main tool used by the KRMMP for managing moose populations with the goal of reducing the number of hunters and hunting pressure on the moose population. This was to be accomplished through reducing antlerless hunts and changing the general hunt in the KCUA to a drawing hunt with separate resident and nonresident pools. Registration hunts for subsistence now required cutting the antlers and turning them in to destroy the trophy value. In 2000, the general registration hunt was changed to a drawing permit system with separate Alaska resident and nonresident pools (320 local/80 nonlocal), which has greatly limited the number of sport or "trophy" hunters coming to the area.[26] Since Alaska law considers subsistence eligibility applicable to all Alaska resident hunters, the plan does not have much impact on nonlocal hunters coming from places such as Anchorage and Fairbanks, so the local anxiety about too many "outside" (i.e., nonlocal) hunters continues, despite measures to limit trophy hunters.

The other goals and management tools are limited to habitat enhancement and predator control. While predator control is a high priority locally, it is not one that is politically advantageous because of ongoing protests by powerful conservation groups. Predator populations of wolves and bears have a large impact on moose populations, as black bears take approximately 40% of moose calves, and both wolves and brown bears take both moose calves and some adults. One study on predators in the region from the 1980s showed that black bears killed 40% of all radio-collared calves, followed by

[26] The subsistence registration hunt remained unlimited within the KCUA and the general hunt in GMUs 21D and 24 outside the KCUA.

wolves (9%), unknown predators (8%), grizzly bears (3%), and unknown causes (5%), with a total mortality rate of about 65% (Alaska Department of Fish and Game 2001). Data on predator populations, especially bears, is limited, but current local observations throughout the KMY region report that both wolf and brown bear populations appear to be growing. The KRWG recommended more aggressive predator control, including aerial hunting, as well as an Intensive Management Plan for predator control, which is in preparation by the ADF&G area biologist, with the timing and regulatory outcome uncertain.

The KRWG also recommended that it continue to meet annually, more often if necessary, to monitor plan implementation and make adjustments if necessary, with this depending on any positive or negative changes to the moose populations. Unfortunately, the financial and logistical resources necessary to support this effort dwindled and the group disbanded in 2005 when the KRMMP was supposed to expire. At their last meeting in 2005 they voted to continue the plan for two more years, which has since continued by default. As a result, the ADF&G, continues to manage on the basis of its interpretation of a five-year plan that will be nearing its 10th anniversary by the time the next Board of Game Interior region meeting happens in March 2010.

In addition to the need for the ongoing cooperation of the stakeholders to respond to changing moose populations, recent years of warm falls have resulted in a "closing window" on the moose harvest in some years as explained in chapter five. This necessitates a new planning process to revise a moose management plan that incorporates the best understanding of climatic patterns and seasonality shifts that are affecting moose behavior and hunter success (see chapter five). The only mention of weather (not climate as defined in chapter four) in the plan is the very last paragraph on page 36 that states simply:

> Periodic weather events are an unpredictable variable that will eventually require change to even the most perfectly designed decision making processes. Severe heavy snowfalls have been known to deplete high-density moose populations. It

should not be considered a failure of the KRMMP when drastic fluctuations occur in the population as a result of these unforeseen events.

As a result, the plan provides no guidance for dealing with climatic seasonality shifts as experienced in the region. In fact, implementation of the plan has had unintended consequences that now are in conflict with proposals to shift the regulatory window in accordance with seasonality shifts.

The Shifting Regulatory Window - Implementation of the KRMMP and Implications for Warmer Falls

When the KRMMP was approved by the Board of Game in March 2000, several actions were taken in response to proposals put forth by ADF&G and the Working Group. Action 1.2.2 of the KRMMP recommended a modification of the season for the subsistence registration hunt to begin and end five days *earlier* in order to provide more opportunity for subsistence hunters before the general season opened and the trophy hunters arrived to begin hunting.[27] This changed the fall regulatory window from September 1st-September 25th to August 27-September 20th (Alaska Department of Fish and Game 2001). This shifted the window of opportunity earlier, although this subsequently proved to be a mistake given the unpredictability of fall weather and seasonality shift.

The Management Plan also called for a gradual reduction in cow harvest over time if the population did not grow consistently with the stated goals of the plan. Because it is the cows that comprise the breeding segment of the population, conservation measures focus on protecting cows, with this the justification for reducing "antlerless" hunts throughout the year.[28] The first phase was to eliminate the fall antlerless hunt, and this was closed by emergency order in Units 21D and 24 for the 2000/2001 through the 2003/2004 regulatory years. The result of this action meant fewer encounters with harvestable moose during the fall season as only bulls could be harvested at that time.

[27] Not to be confused with the proposals to shift the season later, which come later after the unanticipated warmer falls.
[28] During the fall "antlerless" means cows, but in winter both cows and most bulls are antlerless, therefore, it is more difficult in winter to distinguish gender.

The second phase was to reduce the cow harvest during the winter hunt. The winter antlerless hunt was closed by emergency order during regulatory years 2002-2003 and 2003-2004, and in 2004 the winter hunt was officially closed by the Board of Game. This resulted in a reduction of subsistence harvest opportunity to only 20-25 days in the fall for most of the KMY region, with the result that added pressure was put on harvest success during the fall hunt. Locals were upset by the change as the KRMMP explicitly stated a goal was to maintain winter harvest opportunity for local subsistence hunters (Watson 2007).

Proposals to the Board of Game and the Federal Subsistence Board to change the dates of the fall and winter hunts in the Interior have been ongoing since the 1990s when there was food insecurity because of poor salmon runs combined with periods of severe weather that limited subsistence activity. In 2001 the first emergency petition submission to the BOG came from the Kaltag and Nulato Tribal Councils asking for an extension of the fall hunting season in Unit 21D because of a warm fall and the inability to meet harvest needs.

> *A request for a [sic] extra 5 day opening on moose hunting season [is requested]...[because] the weather is a little warmer than usual [and] most residents did not get a moose...the weather is warmer than usual [so] the meat will not last long* (Special Action Request to the USFWS from the Kaltag Tribal Council September 28, 2001).

The ADF&G Division of Wildlife Conservation advised the board against the extension stating:

> The vagaries of weather are a constant challenge to hunters and low hunter success should not by itself be considered reason to provide additional hunter opportunity. The area management biologist believes that harvest increased during the last days of September season, and feels that total harvest approached the levels desired.

The petitions were denied by the board because they did not feel that the request met the emergency criteria found in regulation 5AAC 96.625 of the Joint Board Petition Policy, with an emergency being defined as "an unforeseen, unexpected event that either threatens a fish and game resource, or an unforeseen, unexpected resource situation where a biologically allowable resource harvest would be precluded by delayed regulatory action and such delay would be significantly burdensome to the petitioners because the resource would be unavailable in the future." This demonstrates the inability for the emergency petition process to deal with or account for issues of climate change even though climate change-related phenomena are essentially unpredictable.

Local concerns about warmer falls were expressed earlier than 2001 in the institutional setting. Content analysis of transcripts from the WIRAC meetings showed that 2001 was not the first time warmer falls affecting moose was expressed as an area of concern. Since the WIRAC meetings began in 1994, the issue of warmer falls came up in those meetings starting in 1995 and following each fall where the temperature records showed above-average temperatures (1995, 1997, 1998, 1999, 2001, 2004, 2005, 2006, and 2007). However, it did not come up at all in the remaining years when temperatures were at or below normal for the season.

The next round of emergency requests from the region came in 2004 when village residents reported a "hot and dry summer" corresponding to the temperature and precipitation records for August, which were hotter and dryer than average.

> *Summer of 2004 has been a record year for wild fires within Interior Alaska as well as an unseasonably warm-dry summer and fall. Both of these have resulted in changing the fall movement of moose providing little opportunity for local subsistence users to harvest their moose for the year. In addition, many of the hunters have been working on fire crews for seasonal employment and have had limited time to hunt moose. Granting an emergency order now would prevent a burden on local villagers to delay providing for their subsistence needs. It would allow local subsistence users to harvest moose at or near their prime when*

> *weather conditions allow for the proper care, preparation, and storage of the harvested moose.* (Special Action and Emergency Order Request 5AAC 96.625(f) submitted by R.S. of Allakaket)

September was cooler than typical average temperatures for the month, but closer examination of the daily records show that daytime temperatures were unusually hot up until September 12th when temperatures dipped down to below average, which makes the result for September a negative average anomaly. Therefore, during the first 2 weeks or so of the hunting season, temperatures were unseasonably warm for moose hunting, shortening favorable harvest conditions to only about one week that year (September 12-20).

Emergency petitions to the BOG and Special Actions to the FSB (Federal Subsistence Board) were submitted in 2004 and 2005 to extend the fall hunting season in the KMY region after two record fire seasons, and warm and dry conditions in late summer/early fall resulting in low water levels that hindered access to hunting grounds and triggered later moose movements. In addition, because these were two record fire years many hunters were away fighting fires, so did not have the opportunity to hunt.

> *The other thing is water levels are really fluctuating so if we move it later that's all right unless it's like last fall when it gets drier and drier and pretty soon there's no water and you can't get ou*t (Mr. C. WIRAC meeting October 4, 2005).

Only one of the four requests/petitions from 2004-2005 was supported for an extension from September 25th to October 2nd in the Kanuti National Wildlife Refuge for the residents of Alatna/Allakaket (in 2004). The remaining three proposals were denied just as they were in 2001, because the boards did not find them to qualify under the conditions for emergency openings. The Federal Subsistence Board's reasoning was similar to the state's 2001 decision, with the request denied because it did not meet the criteria for Special Action requests according to federal regulations in 50 CFR Part 100, Section 100.19(c), stating that:

> A change in seasons, methods and means, harvest limits and/or restrictions on harvest only if there are extenuating circumstances necessitating a regulatory change before the next annual proposal cycle. Extenuating circumstances include unusual and significant changes in resource abundance or unusual conditions affecting harvest opportunities that could not reasonably have been anticipated and that potentially could have significant adverse effects on the health of fish and wildlife populations or the subsistence uses.

The wording of the regulations is such that the board could have considered warming falls to be an unanticipated event. However, the board was either unaware of the temperature changes that had occurred, or chose to interpret climate warming as predictable or expected inter-annual weather variability. Our analysis of the weather data (Figure 18) shows an anomalous stretch of warm years in comparison to the long-term average during the time period of these requests for a change in the regulated moose season. As mentioned in chapter five, since 1995, eight of the last thirteen years (through 2007) showed a predominance of positive anomalies for the fall hunting season. But it wasn't until the period from 2005-2007 (Figure 18), that the area saw the warmest three-year stretch on record, which exceeded the 2.9°F temperature standard deviation so were not within the expected range of variability as implicitly determined by the boards. Without having the analysis of the climate record to inform them, they were at a disadvantage for knowing their determination was, in fact, erroneous. In 2004, it was perhaps less evident to those outside the region (and even inside the region) that the fall season is experiencing a shift in seasonality. This demonstrates the difficulty of detecting the difference between inter-annual variability and climate change when operating in a knowledge vacuum without the focused statistical analysis combined with local observations. Though it was the locals who knew these were unusual conditions. Unfortunately, not the local stakeholders nor the agency managers had the research capacity at that time to present to the boards.

By 2006 all antlerless hunts in Unit 24 and 21D had been eliminated, putting intense pressure on hunters to harvest enough moose during the fall hunt to last through the winter along with heavy financial burdens as hunters had to spend more time looking for moose.

> *Interior Alaska has had a warm fall season resulting in reduced harvest opportunity due to the delayed movement of bull moose prior to rut...Middle Yukon River communities were unable to meet their subsistence needs. Local subsistence hunters spend more time and fuel searching for moose with a reduced harvest success. With extremely* ***high gasoline prices*** *this year, it was a financial* ***burden on local residents with limited employment opportunities and finances...*** *This change will allow local subsistence users to continue their traditional subsistence lifestyle to provide moose for their subsistence needs for moose. Supplemental food sources for winter food needs would be* ***difficult to afford with the high prices for heating fuel and gasoline.*** (WIRAC Emergency Order Petition 5AAC 96.625(f) November 15, 2006)

The first time that a *formal* proposal[29] to extend the fall hunt because of warmer falls came from the Koyukuk-Middle Yukon region to the BOG was in 2006 (see Appendix A for full proposal), with request for an extension to the state hunting season to include 6 additional days September 26th to October 1st.

> *Harvesting moose when temperatures are cooler will prevent spoilage. Bull/cow ratios are adequate to support subsistence harvests in these units. There should be little impact on the resource.... This extension will help provide for subsistence needs and allow users to allocate hunting resources to when the weather is cool and*

[29] Formal proposals are submitted to change the regulations, whereas the emergency orders and special actions are just to apply for special extensions during one season. In effect, the proposal changes, if adopted, are more "permanent" or "on the books."

when the bulls are moving. (PROPOSAL 95 - 5 AAC 85.045 from WIRAC to the Board of Game 2006)

The ADF&G staff recommendation was to "not adopt," citing concerns about the low moose population. The "not adopt" recommendation was supported by the BOG: "the board believes the conservation concerns are greater than the need to have a longer hunt" (Alaska Board of Game 2006; Alaska Department of Fish and Game 2006).

The Western Interior Regional Advisory Committee also submitted a formal proposal to the FSB in February of 2006 (Proposal WP06-34) to extend the fall moose hunting season on federal lands in Game Management Units 21 and 24 from September 26th until October 1st. The Office of Subsistence Management (OSM) staff draft analysis stated:

> Local concerns of moose population declines, restrictions on fall cow harvests, warmer fall seasons resulting in delayed bull movements, and high travel costs due to elevated fuel prices, have prompted the proponent's request for additional opportunity during the affected fall seasons. Local residents have stated that fall moose movements have been occurring later in recent years and that the onset of these movements occurs after the close of the regulatory seasons. The proponent feels that adoption of the proposed extensions would allow affected users to reallocate personal resources for gaining access to bulls at the onset of fall moose movements due to cooler temperatures (Western Interior Regional Advisory Council 2006).

The FSB did vote to adopt the extension, but with some modification of the exact locations.[30] This gave refuge managers the ability to open additional hunts on federal lands, but the additional opportunity was not guaranteed through this action because it was dependant on recommendation from the U.S. Fish and Wildlife Service wildlife biologists, and was totally at the discretion of the refuge managers. The document also states:

[30] To provide an October 1 season extension for those portions of Unit 24 north and east of, but not including, the Koyukuk CUA or Koyukuk National Wildlife Refuge.

> Local users in the affected areas have in recent years claimed that the onset of fall moose movements does not occur until after the fall regulatory seasons have closed. Agency resource managers agree that additional climatological data are needed before a determination can be made that the recent warmer than normal fall temperatures are part of a long term climatic pattern (Western Interior Regional Advisory Council 2006).

By the spring 2008 BOG meeting, the region had experienced 3 successive years of unseasonably warm fall temperatures, with overall departure in the KMY region of 4.0°F from mean temperatures. Five KMY region proposals were presented to the board to shift the hunting season back five days later from September 20th to September 25th (one of which was to provide a state hunt on native corporations lands to coincide with the federal extension as described above).[31] A five-day shift would return the season to the dates of the fall hunt before changes were implemented in 2000 per the Koyukuk River Moose Management Plan that had shifted the season dates to August 27th to September 20th.

A simple summary analysis of temperature data for Interior stations was presented to the board by one of the ADF&G wildlife biologists (Alaska Department of Fish and Game 2008b).[32] The analysis concluded that there had been a slight statistically significant shift to warmer temperatures during the first week of the hunting season, but not during the second. The board interpreted this as "really no change in the weather" and found it to be an insignificant concern compared to the more important biological concerns for conservation of the moose population in the region. They later reversed their decision on one (#63A) of the seven proposals to extend the season to September 25th to

[31] The rationale for the native lands proposals was that it would provide opportunity for native shareholders in the villages and not nonlocal "subsistence" hunters as corporations can exclude non-shareholders from their lands. The incentive for this is that native corporation lands are closer to many (but not all) of the villages so they would not have to travel longer distances to get to federal lands, thereby saving on costs of fuel, etc.

[32] Summarized data was provided by a National Weather Forecaster that examined temperature from 1960-2006 for September 1-8 as week one and September 9-15 as week two for Northway, Fairbanks, Tanana, Bettles, Galena, and McGrath.

provide more opportunity in the fall and hopefully take off the pressure to illegally hunt cows in the winter.

Knowledge Gaps and Decision Making Under Uncertainty

There are several areas where conflict arises regarding the issue of extending the fall moose hunt because of incomplete information and misunderstanding, differing priorities, elevating scientific knowledge to priority status over indigenous knowledge, and differing interpretations of data, including competing interpretations of the health and growth of the moose population, harvest success, and the effect of climate change on the moose rut and breeding dates. While hunters, biologists, and managers use various types of data and information to make decisions, given the gaps and lack of certainty, judgment calls include personal perceptions and cognitive and cultural models that guide decisions (March 1994; Plous 1993). Agency managers are forced to make difficult decisions today regarding moose populations, harvest data, and breeding dates based on past conditions with limited and often incomplete baseline data.

Knowledge Gap No. 1: Moose Populations in the KMY Region

KMY area wildlife biologists differ on interpretations of trends and numbers of moose in the KMY region. There is general agreement that the population is now relatively stable, but they do not have consensus on whether it is stable and declining or stable and growing. There is also some disagreement on the rate of moose population decline since the 1990s. Landscape heterogeneity and habitat quality across the landscape require different estimates for, high- vs. low-density areas. In an effort to manage at the appropriate scale according to the ecosystem patterns and dynamics, different management strategies operate in different areas within each of the GMUs; so the system of managing through uniform regulations across any given GMU has become progressively more complex.

The basic disagreement about moose population trends and status pertains to the uncertainty of the baseline data used for estimates, with different interpretations of the results. It is also related to a change in methods for aerial surveying to estimate populations that might underestimate the moose count substantially. Area biologists perform aerial counts annually and analyze Trend Count Areas (TCAs), which are used to look at population composition by observing ratios of bulls to cows, calves to cows, and yearlings to cows. These TCAs help biologists and managers make decisions about harvestable surplus (i.e., how many moose are available to harvest while leaving enough to sustain the population), and based on the assessment of trends, which indicate the health and robustness of the moose populations.[33]

Population estimates, on the other hand, are performed less frequently as they require more time and money to fly over larger expanses of the region for the count. Currently, the Geospatial Population Estimator (GSPE) survey method is used whereby the landscape is divided into one square-mile grids and moose are counted in each grid (Kellie & DeLong 2006). This method replaced the Gassaway method, which uses topographical contours instead of grids to guide the counting (Gasaway et al 1986). The new GSPE method does not share the "sightability" correction factor (SCF) of the Gassaway method, and recent observations by ADF&G researchers suggests that the GSPE method potentially underestimates populations by significant percentages (Boertje & Kellie 2007).

During the late 1990s ADF&G biologists estimated that, at its peak, the moose population was approximately 9,000 to 10,000 moose in Unit 21D (1997 estimate) and 11,000-15,000 in Unit 24 (1998 estimate) (Alaska Department of Fish and Game 2001). These population estimates were derived from limited TCA datasets, so should be understood as a best guess with potential for a large margin of error (pers comm. B. Scotton, 2007). They were derived by counting moose in a small area and extrapolating for much larger areas. Population estimates were subsequently completed in 2001 and 2004 using the GSPE method and TCA estimates using the GSPE method have been done annually since 2003.

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[33] These ratios provide biologists with indices about population status via productivity, calf survival, and the number of bulls available for breeding.

The difficulty with this is that the KRMMP management objective of growth as interpreted by ADF&G is based on estimates done in the late-1990s. The current ADF&G management objective is to grow the population back to the population estimates of the mid-1990s, but with current population estimates it would require a 5-10% per year growth over the next 10-15 years (pers comm. G. Stout, 2007). There are two issues of concern here: 1) possible error of the population estimates used to guide the management goals of the KRMMP and 2) possible error in estimated decline in population based both on a) the original estimates and b) a change in estimation methods that might add an additional error margin into the trend. Given these discrepancies it is very difficult to know for sure if the management objective for growth is overly conservative or not. There is no way to know for certain at present given that it depends on how one chooses to interpret the bias in the estimates. Given ADF&G's mandate for conservation of wildlife, the managers err on the side of conservation of the moose populations based on biological concerns.

It is important to note that opening subsistence hunting for locals also opens it to nonlocals since the state is bound by the equal opportunity clause for all state residents. This puts managers in a very difficult position where they are expected to both protect the moose population while providing enough opportunity for subsistence needs to be met. Yet when locals in the KMY are restricted by these conservation measures, the regulations (and regulators) are viewed with antagonism when perceptions are that those measures are preventing them from meeting their subsistence needs.

Knowledge Gap No. 2: Harvest Success and Subsistence Needs

From the late 1990s until today, locals in the KMY region have expressed difficulty in harvesting a sufficient amount of moose and to meet their basic subsistence needs. The ADF&G "Amounts Reasonably Necessary for Subsistence" (ANS) numbers are determined at the for each GMU rather than at the village level, which results in a mismatch in scale for understanding and managing for harvest success for rural communities. ANS numbers are linked to customary and traditional use patterns which are derived from documented local use patterns by the ADF&G Subsistence Division and decided on for GMUs by the Board of Game. Alaska defines "Customary and traditional" to mean "the noncommercial, long-term, and consistent taking of, use of, and reliance upon fish or game in a specific area and the use patterns of that fish or game that have been established over a reasonable period of time taking into consideration the availability of the fish or game" (AS 16.05.940). The ANS numbers are reevaluated periodically, and, where they have been reevaluated recently, they sometimes take into account nonlocal use in addition to local use. GMU 21 is one of those areas where it does account for nonlocal and local use. The ANS numbers for Unit 21 and Unit 24 are 600-800 moose and 170-270 moose, respectively. There are shortcomings in this system considering that villages differ in terms of their ability to harvest each year depending on many variables like the harvest success of other primary wild foods (e.g., salmon), but first and foremost, as it pertains to this discussion, where they are located in relation to high or low density moose populations. Hunters in the villages of Allakaket, Ruby, Hughes, Nulato, and Kaltag (see Figure 1) have a much more difficulty because of their proximity to low-density moose populations when compared to Galena and Huslia, which are located closer to high-density areas.

The ADF&G area biologist argues that locals are now feeling more stress in finding moose for two reasons: 1) moose populations have declined so there are simply fewer moose to encounter, and 2) with the decrease in nonlocal trophy hunters through a limited drawing permit lottery, less meat donated to villages by these hunters decreases the supply (Alaska Department of Fish and Game 2008a). These points are both valid to a degree, although the first is predicated on highly uncertain data, and the second is not based on any empirical evidence. There are no data showing exactly how much meat is or has been left behind by nonlocal hunters in the past, nor are there data showing how much meat is supplied or distributed through the communities for this region (see, however, work by Magdanz for Wales, Kotzebue, and Kiana villages) (Magdanz et al 2002).

The only documentation of nonlocal meat donation in the KMY comes from an ADF&G Division of Subsistence report on the big-game household surveys that were conducted in KMY villages during 1997-2003 (Andersen et al 2004; Andersen et al 1998; 2000; Andersen et al 2001; Brown et al 2004). Local guides were asked to estimate how many moose were donated by nonlocal hunters to communities with a best guess of 25 moose, a figure that has been repeated in subsequent reports (Andersen et al 2000).

There is no way to verify this number, and, given current political issues with guides bringing hunters from outside to communities, they could have been motivated to provide numbers for political reasons, regardless of whether higher or lower, and not based on empirical evidence. Also, it is often portions of moose instead of whole moose that are left behind, so one would have to guess at how those portions add up to full moose. It is undisputed that nonlocal hunters do donate some meat to local villages, but there is no evidence that such donations made a significant a contribution to meeting subsistence needs, nor do we really understand the mechanism in place for who receives the meat, or about how it is distributed. If this argument is to be used in policy decisions where local food security is concerned, then studies on meat supply and distribution are necessary to support it.

Recent increases in local moose harvest reports are interpreted by some managers in ADF&G as evidence that more locals are hunting to make up for this decline in supply of donated meat from trophy hunters, yet at the same time the number of people reporting rose (Alaska Department of Fish and Game 2008a). Modern subsistence patterns are inextricably tied to flows of cash so any significant increase in local village hunters would necessarily require increasing the allocation of money and hunting resources in any given community (Langdon 1986; Wheeler 1992). A hunting trip requires cash to pay for gas, boat oil and maintenance, food, hunting equipment, and the cost of owning a boat at all, or partnering with a boat owner, who receives gas money or meat in exchange. Each village has a finite number of boats to use, with more people typically needing or wanting them than there are boats available.

For more hunters to pick up the slack of fewer nonlocal trophy hunters supplying moose meat to villages, a substantial input of additional financial resources would be required compared to past years. As discussed in chapter two, villages in the KMY are well below the federally defined poverty level (with per capita income levels between around $10,000-$11,000), but have also experienced recent rises in gas and food prices; it is unlikely that they could afford to send substantially more hunters out during hunting season.

Subsistence research shows that harvest rates in rural villages in general, and in the KMY region specifically, have remained consistent over time despite fluctuations in extenuating environmental and socio-economic conditions. Household harvest surveys conducted from 1997-2003 in KMY villages documented a "remarkable consistency is found in the moose harvest numbers" despite annual resources fluctuations of other wild foods such as during the salmon crash of the late 1990s/early 2000s (Brown et al 2004).

The same household survey research found that, while harvest amounts were consistent across years, the effort needed to get moose had gone up considerably from an average of 7.8 days per each moose harvested in 1999-2000 to 10.8 days on average in 2003, but with great village-to-village variation from a low of 3.4 days in Huslia to a high of 17.8 days in Ruby (Brown et al 2004). This increasing difficulty in harvesting moose when measured in terms of harvest effort, and the insistence by locals that some households and communities are unable to meet their subsistence needs is perplexing in light of the harvest reporting that shows an increase in local hunters reporting that has increased.

The population of the KMY region has declined substantially over the last several decades. From 2000 to 2007 the region experienced an approximately 14% population decline (Alaska Division of Community and Regional Affairs 2009). Some of this decline is a result of outmigration from rural to urban areas. It is common for relatives in rural villages to ship wild foods to their family members living in urban areas, so a decrease in local population does not necessarily equate to a direct decrease in demand for moose meat or other wild foods. Although the costs to package and ship food to urban areas are high and have gone up in recent years, so in a region with low income levels a substantial increase in shipping meat is unlikely; there is no empirical evidence or data on the distribution of meat from rural villages to cities. What could explain the discrepancy between more reported local hunters on the one hand and local claims of inability to meet subsistence needs combined with increased hunter effort per moose?

Harvest Reporting

As an alternative to harvest reporting through harvest tickets, household survey methods that collect post-hunt subsistence harvest data through door-to-door surveys consistently result in more precise and generally higher harvest estimates (Andersen et al 1998). The ADF&G Division of Subsistence collected five years (and in some villages six years) of household survey data in the KMY region between 1997-2003 that provided much more detailed information about harvest use, patterns, and success rates than has the general harvest reporting format. By contrast, returned harvest reports do not account for 57% of the moose harvested in the 1997-1998 study (Andersen et al 1998).

A "Failure to Report" (FTR) state regulation was implemented in regulatory year 2005. "Mandatory" reporting already existed prior to 2005, but the FTR would now exact severe penalties (heavy fines and confiscation of hunting equipment) for non-reporting if caught. Reporting in the KMY region went up as a result, however, the assumption by the ADF&G biologist is that the rise in reporting primarily accounts for local, unsuccessful hunters.

It is widely accepted within the subsistence research community that harvest reports have long been problematic for use in management decisions as rural villages have historically had very low participation in the harvest licensing and reporting system (Anderson & Alexander 1992). A practical problem continues to be that licenses and permits are often not available in rural villages, and while this has been addressed for many villages, it is still a significant reason for lack of licensing and reporting in the past (Andersen et al 1998). Though it is the individual bag limit system that is culturally problematic because it conflicts with the custom of food sharing and the reality of community dynamics, where a relatively small number of hunters do the majority of harvesting for a village (Anderson & Alexander 1992). Throughout rural Alaska there is generally found to be a 30:70 subsistence rule with this meaning that approximately 30% of the community provides 70% of the harvest of wild foods (Wolfe 1987). In some regions that ratio is even lower such as in the community of Wales, Alaska where 20% of the households provide 70% of the community's harvest (Magdanz & Utermohle 1998).

The household surveys for the KMY region found a similar proportion to exist in the villages for moose harvest. In 2002-2003 of all the households surveyed in the region 42% of all households harvested one or more moose and overall 92% of the households used moose (Brown et al 2004). Regulations require individual bag limits meaning "one hunter per one moose," but where community harvesters hunt for multiple people, reporting any number at all might be incriminating and thus avoided (Andersen et al 1998; Anderson & Alexander 1992). In some cases, "proxy" hunters can apply to hunt for someone who is unable to hunt for themselves, such as an Elder, and community bag limits are being tested in limited locations (e.g., the village of Chalkyitsik in the Yukon Flats). Yet throughout Alaska individual bag limits are the rule. Because of the disconnect between reporting requirements and cultural patterns that distort the data, a heavy reliance on harvest reports for decision making is problematic, especially when community risk and vulnerability are concerned.

These are by no means new issues, as they have been ongoing for at least as long as the U.S. government and state of Alaska have been involved in subsistence and wildlife management. However, in the context of vulnerability to a changing climate, the problems become highlighted as they underlie community and institutional capacity to respond to climate change. Climate change compounds both environmental risk as well as the challenges of moose management in this complex system. What is new is the recent and growing need to incorporate climate change considerations into planning and management.

Knowledge Gap No. 3 : Climate Effects on the Fall Moose Rut

The short-term effects of warm weather on moose in the fall time are not disputed. Subsistence hunters and agency biologists have all observed the effect that warm temperatures have on moose, as well as the difficulty of finding and harvesting game, and on preserving the meat (Mowry 2007). It is known that hot temperatures are hard on moose, because they spend more time resting and less foraging (Vucetich & Peterson 2008). What is unknown is whether there might be any long-term effects of climate change on moose, with specific impacts on moose breeding patterns. Wildlife biologists state that moose breeding is triggered only by photoperiod, but indigenous observers question the conventional scientific understanding that warmer falls do not affect the rut in terms of the timing of breeding dates.

> *A lot of your data includes periods of times where we've had more typical weather where we've had a rut as we see a rut. The rut has been disrupted in recent years because of changes in weather. But your documentation that you use as the reason you don't want to change it is that that hasn't really occurred or shifted that. My perspective is that if you don't have a typical rut they've already shifted on their own. Their breeding season has moved later. They don't just start rutting just because it's the 25th. Their bodies have to get up to a point where they can breed and part of that is what we see "the rut." These animals quit eating, their stomachs are full of water, their necks swell and all of that and that's what gets them ready to breed. They don't just say "okay it's the 25th I'm not ready yet, but I'm going to start breeding because it's the 25th." The weather has changed.*
> (R.S. Middle Yukon Advisory Committee Meeting February 13, 2008)

It is very difficult to determine the exact date of breeding under natural conditions, and few studies provide detailed data (Schwartz 1997). Studies on average breeding dates across North America show very little difference across years, suggesting that photoperiod, not weather influence rut timing (ibid). In Alaska, two studies provide breeding date ranges for moose. Schwartz and Hundertmark (1993) performed a study from 1987-1991 on the Kenai Peninsula with captive and road-killed moose, and determined a breeding date range from September 28th to October 12th, and a mean date of October 5th. The second study commonly cited on moose breeding dates for Interior Alaska was conducted in Denali National Park during 1980-1991, and through copulation observations estimated a median breeding date of October 2nd and a peak breeding date of October 3rd with a range from September 24th through October 7th (Van Ballenberghe & Miquelle 1993). This is the evidence used by ADF&G biologists to confirm peak breeding dates in the KMY region. This study also concludes that weather plays a minor role given the yearly variation in snowfall and temperature, and the consistency of breeding during a window of 14 days each year.

The problem is that this study accounts for variation in weather rather than changes in climate, and understanding the difference is important because they involve different time scales. Within the ADF&G Division of Wildlife Conservation, there is widespread acceptance of this range of breeding dates and the conventional wisdom that rut is determined by photoperiod, not weather; "changes in weather" are dismissed as having no possible effect on breeding dates. Climate concerns long-term trends and changes in average conditions, for which these studies do not account. Weather, on the other hand, is the state of the atmosphere in a specific time and place with respect to temperature, precipitation, wind, cloud cover, storminess, and barometric pressure. Both of the Alaska studies mentioned here were done in the 1980s before the more recent and continued warming trend through the 1990s and 2000s. [34] No studies have been performed to determine climate effects on breeding dates and it is unlikely that any will happen soon in the ADF&G, given the costs and time required of doing this type of research (pers. comm. Tom Paragi, 2008). Because of the confusion between inter-annual weather variability and climate change, it is questionable whether the evidence available is precise enough to support the claim about static breeding dates under conditions of a

[34] It is also worth noting that the moose population in the Van Ballenberghe and Miquelle 1993 study is characteristically different than in the KMY as it is an unhunted population tolerable of human presence in Denali National Park that made for a good study population, but might have implications for different rut and breeding behavior and timing.

changing climate, or even to use these data as the only basis for making management decisions. When management decisions are rigid and have such widespread implications on food security and community well-being, the burden of proof is on the research community to pursue rigorous inquiry into the topic.

The Alaska Department of Fish and Game also observes that calving dates in the spring are consistent, with this taken as evidence that they are breeding at the same time in the fall (Schwartz 1997). The agency concern is that, if breeding is disrupted by hunters during this peak breeding time, that cows will be bred during the second estrus cycle three weeks later and that those calves will be born three weeks later in the spring and will have less time over the summer to get in prime condition for survival. It is unclear whether calf mortality of a second cohort is compensatory or additive mortality from predation of bears and wolves.

While it is certainly plausible that breeding dates have not changed dramatically, local observers have a different perspective, which leads to conflict between locals and agency representatives. There are obviously large gaps in knowledge and understanding for decision making to be made with greater certainty. It is often not possible to fill the gaps in knowledge given budget constraints or simply the difficulty of the nature of certain kinds of studies as mentioned here. It is important for devising appropriate solutions for these very complex problems that where there is uncertainty in the science this must be made explicit.

Regulatory Constraints on Adaptation to Fall Climate Change

The complexity of the dual management system is a major barrier to adaptation to fall seasonality shifts, especially where collective adaptation requires working within this system. The confusion in villages about the regulatory system takes on many forms. First, many people have a hard time distinguishing between the Alaska Department of Game and the U.S. Fish and Wildlife Service land, rules, and regulations, and they are commonly referred to interchangeably. It requires substantial time, knowledge, and understanding to navigate the political system and legal system. Often it is the same village representatives who attend all of the regulatory meetings and "burn out" is an ongoing problem, especially when meetings interfere with labor intensive subsistence practices.

The checkerboard pattern of land ownership (see Figure 22) determines jurisdiction across time and space yet is not demarcated on the physical landscape. Therefore, knowing when one is hunting on federal, versus state versus native corporation land is often impractical to impossible. Someone can step across property lines multiple times in a single hunt and be unaware – going between being legal and illegal as they travel.

Since the inception of the Koyukuk River Moose Management Plan, the KMY region went from having a general hunt to only two different registration and two drawing hunts to 14 overlapping registration and drawing permit areas and a multitude of different regulations within sub-regions of GMU sub-units. As the regulatory system becomes increasingly complex with respect to when and where village residents can hunt, decreasing marginal returns in agency investment into those regulations come in the form of noncompliance with the regulations (Tainter 2000). This is not a system in which hunters or managers can maneuver freely, and it is one that restricts innovation and creativity to adapt over time, and to maneuver successfully through physical space and the policy arena. This has resulted in a system that lacks legitimacy from the perspective of local stakeholders in the region.

The FTR (Failure to Report) system might result in more reporting, but it cannot prevent noncompliance without law enforcement. Law enforcement is costly in the bush, and is viewed with high anxiety and resentment by villagers. In the end, noncompliance thwarts managers' ability to control the system, with realization of the desired goals and outcomes difficult to realize.

Cultural Disconnects within the Regulatory System

For the Koyukon the highest law of the land is still respect for nature, especially for the animals they depend on (as discussed in chapter three). To disrespect animals is *hutlaanee* (taboo), and for the hunters this guides not only how, when, and where they hunt, but even how they think and speak about the animals. I cannot emphasize enough how important this still is to the communities of the KMY region, and how important this understanding should be for regulators, while fully acknowledging that those who do not ascribe to these cultural conservation ethos jeopardize the trust of managers for local compliance. For example, during the March 2008 Board of Game Interior region meeting Tom Huntington, son of Koyukon Elder Sydney Huntington, made a powerful testimony to the board about the Koyukon relationship with bears that illustrates this point that this ethic of *hutlaanee* lives on. He began his testimony by telling the board:

> *I come before you at great risk, I would say, in that this issue of traditional use of harvesting bears amongst our people we don't talk about. And I'm surprised that the Middle Yukon Advisory Committee brings it forth, but it has to be because all these years we've been criminals, we're illegal and it has to be addressed to make us law-abiding citizens that we want to be.*

It is important to note that he knowingly came and spoke before the board at great risk as this act of speaking publicly about bears in this way is in and of itself *hutlaanee* to his people. He risked not only reprimanding from his Elders, but also possibly losing favor as a bear hunting partner for making this speech. Koyukon people are not supposed to talk publicly about animals, especially one with such power and spiritual import as the bear, and his talking about bears publicly could ruin his and his fellow hunters luck in harvesting bears and thus threaten the collective.

This testimony elucidated a very important disconnect in the system; the regulatory system as it is set up is not culturally appropriate for the Koyukon and others tribes throughout Alaska. It requires talking and arguing publicly, answering surveys and questionnaires, and filling out harvest tickets about animals, which fundamentally goes against many Koyukon beliefs and practices. If Tom Huntington was surprised that the village AC brought this forth, it begs the question of how many other taboo issues are not publicly discussed or contested because of the cultural rules that preclude such action?

The cultural insensitivity of the system structure and process is not unique to the Koyukon. Another example from this same meeting in 2008 came from a Yupik Eskimo Elder from the Lower Kuskowim region of the Interior. In his testimony he told about how some of his native people were adapted to the "white man's way" of participating in this proposal system for wildlife regulations. However, he and many like him, especially Elders who often do not read or write English do not even know how to make a proposal to the BOG without help from younger members of their families or tribes. Again, this demonstrates how the system is set up in such a way that does not account for cultural or language differences. This is a system that lacks procedural equity (Watson 2007).

Procedural Inequities

At the spring 2008 BOG meeting Tom Huntington (and others) also mentioned that they could not possibly share all of the knowledge that they should or could about these management issues within the five minutes they are given to testify. Because the BOG must review over one hundred proposals on a myriad of highly complex issues of different regions in one two-week meeting, it makes it very difficult to make time for all the testimony that could be shared.[35] However, the structure of the Board of Game agenda is set up so that all public testimony is heard up front with each speaker having five minutes. Dozens of citizens and AC representatives go one after the other, testifying on all the proposals across all species and regions for that two-week meeting. Then, when the proposals are actually discussed, the conversation is typically between the agency staff (usually biologists for the particular region) and the board members. As such the local, rural, and native voices are not voiced when the various proposal arguments are

[35] Note that this is only for one of several regions in Alaska and other meetings of similar complexity and duration happen throughout the year.

discussed with and decided on by the board. This can have very serious implications when the complexity of these issues has many perspectives and nuances that are not well understood or even represented in the discussion.

Disagreement on Management Goals and Priorities for Adaptation

Opposition by ADF&G to the opening of federal lands within the region to provide additional hunting opportunity is an unfortunate point of contention between the state and federal agencies. This division is unavoidable given the conflicting legal mandates for providing subsistence opportunities to all Alaska residents per the state mandate versus providing additional subsistence opportunity when necessary for rural residents. Though alignment of state and federal regulations is a priority goal and is more often the rule than the exception, it is inevitable that differing perspectives on what constitutes "need" and who reserves the right to certain hunts instigates contention over this issue and will be ongoing as long as a dual management system that does not appropriately incorporate local views, perceptions, and practices is in place.

The Koyukuk River Moose Management Plan still guides management decisions for the KMY. The plan was written as a five-year plan (2000-2005) with the working group continuing to meet to update and adapt the plan as conditions changed over time. The working group disbanded in 2005 and the five-year plan will be in effect for 10 years by the time the next Interior BOG meeting happens in the spring of 2010. Since the inception of the Management Plan in 2000 there have been substantial state and federal regulatory changes, some changes in the moose population dynamics, and changes in the socio-economic and environmental conditions that warrant updating of the Plan. Yet at present no funding or plan exists to continue or renew the planning process to update the KRMMP.

The biologists who mange the region consistently repeat that the "management objective is growth" of the moose population. While the population growth objective is likely shared to some extent by all the stakeholders, interpretations differ on exactly how "growth" is defined and what the steps should be to attain that goal. To assume that all stakeholders are in agreement about this is at best naïve to uninformed. However, without resources to continue the process with the working group, the KRMMP remains the guiding document with its goals and objectives up for interpretation by the federal and state decision makers with ascribed authority. In an uncertain and changing social-ecological context, however, with nothing less than health and livelihood at stake, the opportunity for miscommunication and conflict grows and management problems inevitably increase, and the rural window for effective response closes.

Lag Response Time for Adaptation Measures

At the moment the only "in-season" mechanism to respond to unusual conditions is through the emergency petitions and special actions requests. Thus far, most of these petitions to address unusually warm fall seasons have been denied. This has fueled a cycle of unintended stress and mistrust, which delegitimizes the systems for local stakeholders and breeds more resentment between tribes and agencies, which in turn breeds more incentive for noncompliance with the regulations.

The two-year proposal cycles for the Board of Game and the Federal Subsistence Board build in a nonresponsive lag time for implementing changes in the regulatory system. Effective response through this proposal system occurs in hindsight after a climatic disturbance, yet in a climate system with high variability from year to year. "In season" management responsive to seasonal conditions as they are occurring would be more supportive of subsistence hunter success. However, as the system currently operates conditions that change because of inter-annual variability and shifting seasonality have resulted in this back and forth emergency petition and proposal cycle to proposal cycle where changes happen after the fact. Climate change is not linear and will still mean significant inter-annual and interdecadal variability. A more responsive system that is flexible and accounts for high variability will be necessary for sustainable adaptation.

Conclusion

In conclusion, continuing to restrict hunter access creates a positive feedback loop that encourages exactly the opposite result through noncompliance. The locals want to be in compliance, but when a system that controls their access restricts ability to feed their families, their cultural mechanisms and needs are going to take precedence over the written law. By understanding and nurturing the intrinsic adaptive capacity of local communities to use flexible and innovative harvesting measures when needed, more legitimacy of the system will result. Sustainable adaptation will, therefore, require more cooperation and strategic planning for future climate variability and change particularly in light of the nature of temperature variation and warming in recent falls. It will require ongoing cooperation and communication among the stakeholders as well as continued monitoring and documentation of environmental changes.

Biologists must generate numbers to justify their decisions, and they do the best they can in providing estimates based on the best information they have. Yet if they result in regulations that are perceived by local stakeholders to prevent subsistence needs being met, conflict ensues as it has in the KMY region. This is especially true when conditions change in a way that requires revisiting and changing the regulatory window, and scientific arguments against doing so are presented as fact, when they are in reality very uncertain.

Practical measures for collective adaptation must include not only a strengthening or nurturing of communities' cultural adaptive capacity, but also necessitate strategic action for ensuring that the capacity or potential can be realized via adaptive measures that promote rather than hinder adaptation strategies. Two of the most important characteristics defining these communities' adaptive capacity are 1) community sharing practices and patterns combined with 2) flexibility across time and space. Adaptation is going to require a system that enhances, not hinders these characteristics.

Finding ways to rise above the areas of conflict toward a more collective, cooperative relationship among all the stakeholders will be the key to adapting to future climatic and seasonal shifts. Without a recognition of this and concerted effort by all stakeholders to achieve this, collective and sustainable adaptation to climate change could remain a concept instead of a reality. Wildlife management policies that erode social capital, restrict flexibility, ignore cultural mechanisms for adaptation, lack understanding of climate and weather knowledge, don't acknowledge procedural inequalities and assume shared management goals hinder adaptation to climate changes. However, where these shortcomings of the system can be acknowledged and addressed sustainable adaptation policies are possible, which will be discussed in chapter seven.

Chapter 7: Conclusion – Toward Sustainable Adaptation to Climate Change

This research demonstrates a complex system where the effects of vulnerability to climate change depend on the *convergence* of social-ecological and climatological variables in a given space and time. The *relative* and *dynamic* combination of social, ecological, and climatological variables determine vulnerability and response capacity from year to year. High inter-annual variability in Interior Alaska adds to the uncertainty of how vulnerability will manifest at any given time. The integration of both weather station data and indigenous observations and understanding about climate (IC) provide invaluable insights and evidence of seasonality changes and shifts in each season of the year in the Koyukuk-Middle Yukon (KMY) region (see chapter 5, pages 105-132). The ethnographic, participatory approach that I employed for this research revealed multiple layers of understanding that could never be discovered with a conventional single-disciplinary, scientific approach. The ongoing experimental and flexible nature of this vulnerability and adaptive capacity assessment allowed for the research to evolve as conditions changed over time, thereby keeping it vital and relevant to stakeholders in addition to contributing to the academic understanding of climate change.

Instead of creating a set of indicators to quantify vulnerability I used what can be meaningfully quantified - i.e., temperature and precipitation records to establish trends and as determinants of seasonality shifts– but within a larger assessment of vulnerability which includes a range of qualitative sources of information and understanding. It is extremely difficult to arrive at any precise measure of vulnerability given its relative and dynamic nature and a limited amount of meaningfully quantifiable data in such a remote, sparsely populated area.

Wise use of a variety of methods, observations, and ways of knowing provide a baseline understanding against which future assessments can build and compare. Given projections for a continued warming trend, we can ascertain that the recent years of warming provide a good analog for how future warming will impact moose and moose hunting, and therefore, will very likely increase vulnerability of the Koyukuk-Middle

Yukon region if other strategic adaptive measures are not implemented to address food insecurity. If the season continues to shift and the window of opportunity closes even more, it could close altogether where no moose can be harvested without potentially causing conflict or more pressure to take moose at times less desirable for sustaining the population.[36] This is an extreme scenario, but is one worth serious consideration for sustaining livelihoods in the region, especially given the important role of moose in providing food security for residents. At present, there is no affordable or culturally acceptable substitute available in enough quantity to make up for what moose meat provides in annual caloric and protein needs of the human population.

Vulnerability over a certain time period will have some constants, but, given the dynamic nature of social-ecological systems, any analysis provides only a snapshot in time. During the initial interview period 2004-2005, certain issues arose as seemingly more important at that time (e.g., lake drying). However, between the years of 2005 to 2007 it was an especially warm time period for early autumn temperatures, and, through the collaborative and iterative stakeholder process with local indigenous observers and agency scientists and managers, we collectively identified the fall moose hunt as *the key* "window of vulnerability" to climate change. It was a convergence of multiple stressors such as socio-economic and regulatory changes along with changing climatic conditions that resulted in this dynamic change. Therefore, the "window of vulnerability" or "window of opportunity" changes depending on how these linkages and dynamics vary and change across both time and space.

Climate model projections indicate that climate change will continue into the future and cause seasonality shifts in Interior Alaska with the fall season experiencing some of the most intense warming (Walsh 2009). Seasonality shifts over the last two decades have already impacted moose harvest success in the Koyukuk-Middle Yukon region, which has resulted in vulnerability of the communities who live there through food insecurity. It is in the best interest of all stakeholders to recognize the shared goal of sustainable ecosystem services and livelihoods and to strategize to build adaptive

[36] For example, during the winter when moose are antlerless and more cows are killed.

capacity as defined by social/institutional capital and resources and the implementation of flexible wildlife and subsistence management policies.

Summary of Findings on Early Fall Seasonality and Impacts to Subsistence Moose Hunting

Most important to this case, weather variables such as temperature and precipitation coincide each fall with socio-economic (gas prices, wages, costs of living) and political ones (hunting regulations) to result in environmental and social conditions that can negatively affect moose and subsistence moose hunting for the natural resource-dependant Koyukuk-Middle Yukon communities.

In particularly warm years, such as the autumns of 2005-2007 moose movements occur later in Interior Alaska shifting the season and the "window of opportunity" for harvest later in terms of prime hunting conditions for moose harvest success. In chapter five and six I demonstrated how 2005-2007 provide a good analogue for understanding how unusually warm falls create a "closing window" of opportunity for subsistence hunters, and how this could have serious consequences with continued warming trends into the future.

Fall Seasonality Shift

The analysis of weather data combined with indigenous observations and understanding of climate (IC) in the Koyukuk-Middle Yukon region shows a small, but socially and sometimes statistically significant warming trend in fall. To summarize specific findings for early fall during the moose hunting season:

1) Total change in temperature during the fall hunting season (the four weeks from August 25th to September 25th) over the period of record (1944-2007) ranges from +1.3°F in Galena, +2.9°F in Tanana and each

week within this month shows an increase on the order of .7°F to 4.1°F.[37]

2) From 1995-2008 eight out of thirteen years early fall shows positive temperature anomalies indicating a warming trend.

3) The years 2005-2007 are the warmest three early falls on record with a combined mean anomaly of +4°F, which is greater than one standard deviation for this time period (>2.9°F) and, therefore, were outside of the normal or expected range of weather variability.

4) Each of the three stations Galena, Bettles and Tanana in the KMY region show a decrease in heating degree days (HDD) for the two-month period of August and September indicative of an overall warming trend for this time period.

5) "August rains" have shifted into September with the total change in summer/early fall precipitation shows a trend of dryer conditions in July and August and wetter conditions in September.

6) During the hunting season the first two weeks show a slight decrease in precipitation and the second two a slight increase meaning the first half (August 25-September) is trending toward warmer and drying and the second half (September 9-September 25) trending toward warmer and wetter.

Low precipitation in late August and early September results in low water levels making access to important hunting grounds via rivers and sloughs more difficult. Heavy precipitation later in September is undesirable because, while it helps to bring up water levels, too much rain during hunting complicates hunters' ability to keep hunting equipment and meat dry. The best conditions for successful moose hunting are cool and dry, which is what hunters were used to in past decades. Now September is warmer and wetter, shifting the season later and affecting ability to harvest moose in time before the

[37] With the exception of week three at Galena - see explanation in chapter five, page 121.

regulatory window closes. This "closing window" is condensing the time that hunters can successfully harvest moose within the legal regulatory time frame.

Low Exposure/High Sensitivity

Because of the importance of successful moose harvest to the food security of the communities in the region this makes them highly sensitive to changes in their environment that affect the moose and moose harvest. The social-ecological system experiences a relatively *low exposure* to climate disturbance in the early fall, but has a very *high sensitivity*, and therefore, increased vulnerability in terms of how the climatic shift negatively impacts the system by affecting harvest success and community food security. Climate vulnerability research often focuses more on the exposure side of a society's exposure/sensitivity matrix, but this case demonstrates the importance of social-ecological sensitivity where a seemingly small exposure can have serious consequences. This highlights the importance of integration of disciplines in climate research. It is through working closely with multiple stakeholder groups in the region and integrating IC with western social and natural sciences that I was able to identify key vulnerabilities resulting from multiple stressors and the high sensitivity to fall seasonality shift due to climate change in this system.

Importance of Recognizing both Climate Variability and Change

Perhaps the most important message regarding fall warming and regional impacts on moose hunting is that warming is not linear, the climate system is highly variable and uncertain, and, while the warming trend is likely to continue according to climate model projections, some years will still be more "normal" or favorable to successful moose harvest, and some will be colder than normal. It is important to recognize both climate variability and climate change when devising solutions, as avoiding a "preparedness paradox" where adjustments are made in a rigid fashion to warmer conditions, which have unintended consequences or catch people off guard when cool conditions return. A lack of this type of understanding and knowing how to integrate these considerations into preparing for upcoming harvest seasons as well as planning for subsistence management and policies is one of the multiple barriers to sustainable adaptation.

Barriers to Sustainable Adaptation

In chapter six I discussed the very complicated dual state and federal wildlife management system within which KMY region hunters must respond. The system suffers from a complexity and rigidity that is not well suited to the needs of local hunters or agency managers in responding to the fall seasonality shift. It is a system where government agency managers must make decisions with large gaps in a) knowledge about climate affects on moose populations and behavior, and b) a harvest reporting system that has major shortcomings for the needs of managers. This is a system that constrains necessary flexibility or the "room to maneuver" in both political and physical space of local stakeholders (Thomas & Twyman 2005). It is also a system that would benefit from more attention to the social life of subsistence that includes community mechanisms for the sharing and distribution of food and resources as well as particular patterns of hunting practices whereby around 40% of the households in the KMY region provide for approximately 90% of the households who consume moose (Brown et al 2004).

Regulations have changed significantly since 2000 with the implementation of the Koyukuk River Moose Management plan. However, while on the one hand nonlocal hunting has decreased as a result of the creation of drawing permits for trophy hunters, on the other hand, local subsistence hunters feel they have been increasingly regulated and no longer have enough opportunity to meet their needs for subsistence, especially in years when there is an unusually warm fall. One effect this has is the eroding of social and institutional capital because of a lack of trust between KMY communities and agency regulators. It also creates an increasingly complex regulatory system that becomes more cumbersome and slower to respond to the rapid pace of social-ecological and climatological changes. Because of these barriers for sustainable adaptation to fall seasonality shift, new and innovative ideas for creating a more flexible, responsive system are necessary.

Recommendations: Opportunities for Cooperation toward Sustainable Adaptation

Climate change concerns have largely been left out of regulatory planning and management to date. The stakeholders in the KMY need to implement collective, strategic action that brings climate change into focus in the context of subsistence and wildlife management. Successful or sustainable adaptation to climate change can be evaluated by strategic actions and their effectiveness (robustness to uncertainty and flexibility), efficiency (distribution of costs and benefits, nonmarket values, and timing of adaptation actions), legitimacy (extent to which all stakeholders view decisions as legitimate), and equity (Adger et al 2005).

In this case, efficiency would be achieved through streamlining the regulatory process, resulting in a reduction in regulatory proposals and emergency orders/special requests to the Board of Game and Federal Subsistence Board to extend the fall moose hunting season. From the agency manager's perspective efficiency would also come in the reduction in noncompliance and illegal harvest to better achieve shared conservation goals. This requires a system with legitimacy that addresses local subsistence needs and acknowledges local community conservation strategies. Equity and legitimacy from the local village perspective are based on ability to successfully harvest and meet subsistence needs of families, households, and communities. As long as locals feel they are being constrained by the system, noncompliance will continue defeating management goals.

Policy Recommendations

In-season Management

There is a great need for "in-season" management tools so that hunters and managers can take into account the changing climatic conditions each year. Currently, managers cannot proactively respond when conditions push the season back later in September, and the only recourse for hunters is to submit an emergency order or special action request to the state and federal game boards, which have been voted down the majority of times. An alternative to the current system could be explored whereby managers work with weather and climate forecasters and subsistence specialists to try to both anticipate and respond to both climate conditions and village harvest success during each season. Starting in August conditions could be monitored through both weather station observations as well as IC to assess temperature and precipitation and determine if the season has anomalous conditions that affect moose movement from warm temperatures and/or access to hunting grounds because of a lack of precipitation at the right time resulting in lower water levels. Climate scientists could experiment with managers and hunters by providing seasonal forecasts that could then be "ground truthed" by integrating actual observations made by local stakeholders and weather stations.

As part of the state of Alaska's Climate Change Strategy the Natural Systems Technical Working Group (TWG) is an advisory group to the Adaptation Advisory Group (AAG), which is providing recommendations regarding adaptation to climate change to the Governor's Sub-cabinet on Climate Change. In this role, the Natural Systems TWG recommended to the AAG that an adaptive management plan be implemented to include an in-season game harvest management option so that managers can respond appropriately to climatic change impacts such as the fall warming and impacts during the moose rut (NSTWG 2009). The plan outlines an idea for a working group to submit a proposal to the Board of Game to allow managers to have authority to extend the hunting season when conditions warrant the need for more hunting opportunity. The plan accurately acknowledges the problems for locals and mangers by identifying that hunting seasons

> Restricted to inopportune periods may hinder harvest success of wild game as a food source, complicate care of meat in the field, force unsafe travel, or encourage illegal hunting during closed periods, especially where subsistence harvest is critical in remote communities... some rural residents perceive a lack of concern

by management agencies and regulatory authorities, which will hinder the cooperation necessary for effective harvest management and wildlife conservation in remote areas.

In order to make this a viable proposal, however, the plan overlooks some potential roadblocks for making this a successful venture. Here I provide several constructive critiques and suggestions for how the plan might overcome these stumbling blocks.

First, it includes a list of the suggested participants involved (page 28), which includes the same stakeholders currently involved in proposal processes (i.e., hunters, state and federal wildlife managers, state and federal advisory committee/councils, and tribal organizations). Not included in this list are climate experts, social scientists/subsistence experts, local indigenous expert observers, nor indigenous knowledge experts. Inclusion of these other experts in addition to a professional facilitator (as opposed to facilitation by ADF&G staff) would help achieve a more balanced and interdisciplinary proposal that would include important cultural knowledge, and local decision making aspects that would enhance management decisions and outcomes.

Second, the plan states that "it would be feasible to adopt a state regulation allowing manager discretion to extend season length for harvest up to a sustainable quota that meets subsistence harvest needs for a rural community or communities; this would eliminate the need for additional hunts on federal lands" (page 29). This statement implies agreement between the managers and locals that the extension is warranted, which to date has more often been the exception rather than the rule as I discussed in chapter six. Discretion does not automatically translate into a regulatory season extension, so this would not *necessarily* eliminate the need for extensions on federal lands - especially considering federal land extensions provide opportunity for rural residents that state extensions are legally unable to do. Consideration of the history of extension requests and responses of managers as presented here in chapter six is necessary, otherwise, this will be yet another example of where adaptive capacity (i.e., potential additional opportunity) does not turn into adaptation. Sustainable adaptation as defined here would be a *fundamentally* changed system that becomes inherently flexible enough and responsive enough to actually provide that additional opportunity and help locals meet their subsistence needs.

The third critique and suggestion pertains to the wording (page 29) that "participating hunters will have to be convinced of the value of harvest reporting as a benefit to meeting their subsistence needs, because law enforcement alone is unlikely to be an effective means of change." An overreliance on the harvest reporting system as it stands could be ineffective given the problems with the individual harvest reporting system as I discussed in chapter six. There are many known reasons why rural villages have historically not had high participation rates in harvest reporting, and most of those reasons still exist. Unfortunately, in the KMY region where reporting has increased in the last several years because of the Koyukuk River Moose Management Plan process and a new Failure to Report law in 2005, the perceived agency misinterpretation of the increase in reported harvest as indicating that subsistence needs are, in fact, being met as opposed to reflecting an increase in the reporting itself has perhaps resulted in unintended consequences (i.e., a return to nonreporting or noncompliance).

Implementation of in-season management would also require devising ways to streamline not only the regulatory process but also the policy implementation. Additional hunting opportunity costs agencies money, yet typically does not come with an increase in budget. This acts as a disincentive for agency managers when already stretched and limited budgets are sapped by additional hunting opportunities. Another difficulty state and federal agency representatives face is informing the public about complicated regulations so it would be difficult to keep people updated on changing regulations within a flexible in-season management structure. Some mechanism for two-way communication between managers and hunters would need to be devised. One idea might be to have community village communication brokers who could act as the liaisons between agencies and hunters, and who would monitor hunting success to report to managers while updating villagers as to how the regulatory window was adjusting to seasonal conditions.

Through the incorporation of cultural understandings of human-environment relationships that include, for example, Koyukon views on *hʉtlaanee* and luck (chapter three) management and regulations would be more inclusive of local perspectives, which would improve the ability to meet management goals. This would include incorporating local ideas about what these views mean not just in terms of conservation outcomes but also for management and regulatory processes. If locals felt their cultural views and practices were respected and incorporated into management this would help build the social capital (relationships, trust, sharing of knowledge) so crucial for cooperative, collective action and planning to adapt to future climate change.

Updating the Koyukuk River Moose Management Plan

A strategic planning effort is needed to update the Koyukuk River Moose Management Plan to account for how social-ecological and climatological conditions have changed over the last decade. A planning effort must better integrate issues of climate and culture (than the KRMMP did) to cultivate and nurture social and institutional capital and build a more responsive, flexible regulatory and management system. This effort should include the ADF&G Subsistence Division in a leadership role and including climate experts - not just physical scientists but those who study, social-ecological impacts, vulnerability and adaptation and the important social and political issues that currently constrain sustainable adaptation. An improved system for collecting harvest data through a combination of household surveys and harvest tickets would be beneficial, but only insofar as there is some way to reconcile the differences, which would require adequate staff time and funding to support along with the other research and planning efforts here.

A planning effort would focus on not just shared goals but the *processes* by which to achieve those goals. Inattention to the latter is a source of conflict where interpretation of how best to achieve goals differs. *Processual equity* is as important, if not more so, than the outcomes as it determines those outcomes through fortifying social capital – a process that is culturally sensitive, inclusive, iterative, and transparent – in how decisions are made. Gaps in knowledge and understanding must be made explicit and transparent.

Research Recommendations

On Harvest Reporting and Subsistence Needs

Research on harvest reporting would help to reconcile the disconnect between what might look to some like an increase in or steady harvest, but could instead be increased reporting from the past. Conducting household surveys for moose and other big game as those carried out by the ADF&G Subsistence Division from 1997-2003 are critical for this effort. More attention placed on whether needs are being met as opposed to focusing just on how many moose are harvested would go a long way in helping managers make decisions that both conserve the moose population *and* help local stakeholders meet their subsistence needs. This would work toward the effort of building social capital through increased trust, communication, and implementation of actions toward shared goals.

Socio-economic research on how meat is distributed within the villages, between villages, and between rural and urban areas would be a step in this direction. This would necessarily include methods to estimate distribution of pounds of meat, not just harvested moose. This would give a more accurate understanding of sharing and distribution patterns of subsistence harvesters in the region and overall food security. Too many assumptions are made on anecdotal evidences such as how much meat is donated by nonlocal, trophy hunters, quantity of meat that leaves the region, or quantity of meat that actually ends up in household freezers.

On Moose and Climate

As the moose population and harvest data become more reliable, in theory, it would be possible to look at the temperature sensitivity more quantitatively. This could be represented by a frequency distribution by analyzing the changes in harvest success per unit of change in temperature similar to the example presented in Luers (2005). By combining as an integral the change in harvest multiplied by the temperature and weighted by the frequency of a given temperature, one could arrive at a more quantitative value for sensitivity of the fall moose hunt to warming temperatures. But this would only provide robust results with solid harvest data that were at least a decade if not longer. Currently the harvest data that are available would not provide robust results.

Closing Thoughts

It is difficult to understand environmental change to set sustainability adaptation policies without examining the big picture. That includes the larger-scale social-ecological context and dynamics within which the system operates and across appropriate scales from local to global, and from short timescales to longer timescales. The participatory stakeholder approach I used for this research was an invaluable method for understanding the subtleties and nuances that situate research on climate in a socially significant context. Climate research on vulnerability and adaptation processes must incorporate understanding of the social and cultural context, processes, and relationships in addition to the combination of social, ecological, and climatological variables that structure vulnerability and that hinder or provide opportunities for sustainable adaptation to climate change. By integrating ethnographic methods and participating with communities and various stakeholders, the research outcomes presented here demonstrate the effectiveness of such an approach.

Interestingly, the very concepts that I discussed here that are important to sustainable adaptation – i.e., flexibility, openness to different perspectives and worldviews, adaptability to changing conditions and circumstances – were necessary for me to embody as a researcher for the discoveries that came out of this work. The social capital that I built over time with all the various stakeholders was vitally important to accomplishing as much as I could here. The ongoing learning and iterative communication process allowed me to evolve the project with the changing circumstances as they transpired. Through the connections and collaborations I gained access and understanding in a way that I could never have achieved on my own or from afar.

Through this process I learned that the Koyukon notion of luck is fundamentally about respect and getting back what one gives. It is also about self-restraint in how we orient ourselves to the natural world and how we use natural resources in a way that we take only what we need and leave the rest to regenerate and continue to provide for us in the future. These are the very concepts that engender sustainability. How these concepts live or die or are reborn in a modern, fast-paced, rapidly changing world will determine not only the sustainability of Koyukon livelihoods, but the quality of life and sustainability for all humans on Earth.

Years ago at a lecture at the University of Alaska Fairbanks (circa 2004), I heard Richard Nelson say "It does not really matter if the Koyukon are right in their beliefs; we should act as if they are." I would expand on this to say that it is not really about the Koyukon being 'right' or wrong. It is about learning from them how to read the signs of the Earth because the Earth has more wisdom than all of the humans throughout history combined. The Earth is speaking at all times, and it is up to us as a human society to watch, listen, and learn from it. Like the Koyukon we must pay attention when the wind blows in new directions, when the waterways swell and shrink, when weather becomes more violent, when animals are behaving strangely, and when the trees die en masse. We must see the birds as messengers from another part of the globe bringing us tidings, good and bad, from afar. We need to learn to recognize when the seasons are out of balance. Then, and only then, will we be lucky enough to understand the Earth and its language like the Koyukon Elders of the remote Koyukuk-Middle Yukon region of Interior Alaska.

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Appendix A

Proposal from the Western Interior Regional Advisory Council to the Board of Game in the Spring of 2006

PROPOSAL 95 - 5 AAC 85.045. Hunting seasons and bag limits for moose. Amend this regulation as follows:

Units 21A, 21B, 21D, 21E, and Unit 24
Moose season: 1 bull, September 5 through October 1
All fall moose hunts for bulls only, the starting dates are to remain the same.

ISSUE: Because of moose population declines, restrictions on fall cow harvests, warmer fall seasons resulting in retarded bull movements, and high fuel costs, there is a critical need for additional bull harvest opportunity to meet subsistence needs.

WHAT WILL HAPPEN IF NOTHING IS DONE? Subsistence needs will not be met and local subsistence hunters will be more dependent on the winter moose hunts. This will result in more cow moose harvested further impacting the moose population. Also, an increase in illegal harvesting might take place in order to meet critical subsistence needs.

WILL THE QUALITY OF THE RESOURCE HARVESTED OR PRODUCTS PRODUCED BE IMPROVED? Harvesting moose when temperatures are cooler will prevent spoilage. Bull/cow ratios are adequate to support subsistence harvests in these units. There should be little impact on the resource.

WHO IS LIKELY TO BENEFIT? This extension will help provide for subsistence needs and allow users to allocate hunting resources to when the weather is cool and when the bulls are moving.

WHO IS LIKELY TO SUFFER? No one.

OTHER SOLUTIONS CONSIDERED? None.

PROPOSED BY: Western Interior RAC
(HQ-06S-G-018)

Appendix B

PROPOSAL WP06-34 from the Western Interior Regional Advisory Council to the Federal Subsistence Board 2006

DESCRIPTION: In Units 21A, 21B, 21D, 21E, and Unit 24, extend the fall moose season to close October 1. Submitted by the Western Interior Alaska Subsistence Regional Advisory Council.

COUNCIL RECOMMENDATION/JUSTIFICATION:
Western Interior Alaska: Support the proposal with the modification to apply the extended fall moose season dates to Units 21B and 24 Federal lands north and east of, but not including, the Koyukuk National Wildlife Refuge, and to require a Federal registration permit for the
March 1—5 season. This would allow moose hunting opportunity in the fall for bull moose where the moose populations can support that additional, but limited, harvest. The bull:cow ratio data for Unit 21B and the portion of Unit 24 show these areas can support this later, limited fall harvest. In addition, the winter cow moose seasons have been restricted for conservation concerns and elevated fuel costs have limited travel and hunter effort. The Council's recommendation provides for economy of subsistence harvest where it can be supported biologically.

Yukon-Kuskokwim Delta: Oppose. The Yukon-Innoko Moose Management Working Group and the State's GASH Fish and Game Advisory Committee did not support this proposal for Units 21A and 21E..

Eastern Interior Alaska: Support the proposal with the modification to extend the fall season to October 1 for Unit 21B – that portion of the Nowitna National Wildlife Refuge. The environment is changing and warming is occurring. Moose do not start moving until late September. Many subsistence hunters have not been able to get their moose during the current season. Moose are rutting later and later. The Council felt the regulations need to provide an opportunity for subsistence users to feed their family where the resource can support it.

North Slope: Support with modification to apply the extended fall moose season dates to Unit 24—Federal public lands north and east of, but not including the Koyukuk National Wildlife Refuge. The Council made no recommendations for Units 21A, 21B, 21D, and 21E.

BOARD ACTION: Adopt with modification as recommended by the Western Interior and the North Slope Regional Advisory Councils, to provide an October 1 season extensions for those portions of Unit 24 north and east of, but not including, the Koyukuk CUA or Koyukuk National Wildlife Refuge. The Board also aligned Federal regulations based on recent Alaska Board of Game actions that eliminated the State's December 1—10 season and added an August 22—31 season in Units 21B and 21D. A Federal registration permit will be implemented for the March 1—5 season for that portion of Unit 24B, north of the Koyukuk River except the John River drainage.

JUSTIFICATION: This action will provide additional hunting opportunity for Federally qualified subsistence hunters. Moose survey data indicate that these areas could support an additional but limited harvest during the six-day extension to October 1. The Board's action included a Federal registration permit for the March 1—5 season for Unit 24B north of the Koyukuk River except the John River drainage. A registration permit will allow Federal land managers to closely monitor antlerless moose harvest in accordance with the management objectives.

Appendix C

Proposal from the Huslia Tribal Council to the Board of Game in Spring 2008

PROPOSAL 63 — 5 AAC 85.045. Hunting seasons and bag limits for moose. Modify the season dates for moose in Unit 24 as follows:
Units 24C and 24D: Change the hunting season from [AUG 27 – SEPT 20] to September 1 –September 27.

ISSUE: Because of warmer weather, an early moose season is not realistic. The moose are not moving, and the meat will spoil in warm weather.

WHAT WILL HAPPEN IF NOTHING IS DONE? The village subsistence hunters are having a difficult time getting their moose.

WILL THE QUALITY OF THE RESOURCE HARVESTED OR PRODUCTS PRODUCED BE IMPROVED?
Yes, the local people would target smaller bulls and save the big ones for breeding.

WHO IS LIKELY TO BENEFIT? The local hunters/

WHO IS LIKELY TO SUFFER? No one.

OTHER SOLUTIONS CONSIDERED?

PROPOSED BY: Huslia Tribal Council (INT-08S-G-007)

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FAIRBANKS

Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

April 9, 2007

To: Shannon McNeely
Principal Investigator

From: Bridget Stockdale, Research Integrity Administrator
Office of Research Integrity

Re: IRB Protocol Application

Thank you for submitting the IRB protocol application identified below. I have administratively reviewed this protocol and determined that it meets the requirements specified in federal regulation for exempt research under 45 CFR 46.101(b)(2). Therefore, I am pleased to inform you that your protocol has been approved.

Protocol #:	07-19
Title:	*Climate Change Impacts and Vulnerability in Interior Alaska: An Interdisciplinary Approach to Data Integration toward Identification of Regional Patterns Relevant to Stakeholders*
Level:	Exempt
Received:	March 23, 2007 (orig) April 6, 2007 (rev)
Approved:	April 9, 2007

Exempt research does not require annual continuing review, but please submit any modifications or changes to this protocol to fyirb@uaf.edu for administrative review. Modification Request Forms are available on the IRB website (http://www.uaf.edu/irb/Forms.htm). Please contact the Office of Research Integrity if you have any questions regarding IRB policies or procedures.

Appendix E

Informed Consent Form

Circle of Knowledge
Climate Change Impacts and Vulnerability in Interior Alaska

Description of the Study:
You are being asked to take part in a research study about changes in weather and climate and related environmental changes in your area. The goal of this study is to learn how people in Interior Alaska are being impacted by recent weather changes and the problems or benefits this might bring. You are being asked to take part in this study because of your knowledge and interest in this topic. Please read this form and ask any questions you may have before you agree to be in the study.

If you decide to take part, you will be asked to participate in meetings or focus groups on this topic. Your ideas about the project and feedback will be requested.

Risks and Benefits of Being in the Study:
The risks to you if you take part in this study are minimal. We will simply be asking you about your knowledge of weather and related topics. It is up to you to decide whether to talk about any specific stories or experiences you have had with weather.

There will be no direct benefit to you from participating in the study, but we hope that you will have the opportunity to learn about scientific research on changes in weather just as we will be learning from you. You have the opportunity to tell what you know about weather, plants and animals and to have your knowledge recorded for others' benefit.

Confidentiality:
Your name will not be used in our study without your permission. Some people wish to be acknowledged for participating in this kind of study. Others prefer that their names not be mentioned in publications and reports. The decision is up to you.

If you wish to keep your name confidential, we will use a code number for the materials related to your comments. A list showing which code number goes with which individual will be kept by the researchers in case we have specific questions to ask you later. At the end of the project that list will be destroyed. The materials we compile during the interview (such as notes, maps, and recordings) will be used by members of the research team, but will not be available to others. At the end of the project we will preserve interview materials in an archive both in the community and at the University of Alaska Fairbanks. There may also be reports, publications, and/or audio/video materials that the interviewer will produce with the results of this research.

You can tell us whether anything you say should be deleted from the record. For example, if you say something that you do not want us to use, you can tell us to delete that statement or information.

Voluntary Nature of the Study:
Your decision to take part in the study is voluntary. You are free to choose not to take part in the study or to stop taking part at any time without any penalty to you.

Contacts and Questions:
If you have questions now, feel free to ask us. If you have questions later, you may contact:
Shannon McNeeley
303-918-7592 phone
303-497-8125 fax
shannon.mcneeley@uaf.edu

If you have questions or concerns about your rights as a research subject, please contact the Research Coordinator in the Office of Research Integrity at 474-7800 (Fairbanks area) or 1-866-876-7800 (outside the Fairbanks area) or fyirb@uaf.edu.

Statement of Consent:
I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been provided a copy of this form.

_______ YES - You may use my name along with the information I provide.

_______ NO - You may not use my name with the information I provide.

Signature of Subject Date

Signature of Person Obtaining Consent Date