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Indigenous Observations of Climate Change in the Lower Yukon River Basin, Alaska

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Natural science climate change studies have led to an overwhelming amount of evidence that the Arctic and Subarctic are among the world's first locations to begin experiencing climate change. Indigenous knowledge of northern regions is a valuable resource to assess the effects of climate change on the people and the landscape. Most studies, however, have focused on coastal Arctic and Subarctic communities with relatively little focus on inland communities. This paper relates the findings from fieldwork conducted in the Lower Yukon River Basin of Alaska in the spring of 2009. Semi-structured interviews were conducted with hunters and elders in the villages of St. Mary's and Pitka's Point, Alaska to document observations of climate change. This study assumes that scientific findings and indigenous knowledge are complementary and seeks to overcome the false dichotomy that these two ways of knowing are in opposition. The observed changes in the climate communicated by the hunters and elders of St. Mary's and Pitka's Point, Alaska are impacting the community in ways ranging from subsistence (shifting flora and fauna patterns), concerns about safety (unpredictable weather patterns and dangerous ice conditions), and a changing resource base (increased reliance on fossil fuels). Here we attempt to address the challenges of integrating these two ways of knowing while relating indigenous observations as described by elders and hunters of the study area to those described by scientific literature.

Key words: indigenous knowledge, Lower Yukon River Basin, Yup'ik, climate change

Introduction

Numerous natural science climate change studies are in agreement that the Arctic and Subarctic are among the world's first locations to begin experiencing climate change (ACIA 2005; Hinzman et al. 2005; IPCC 2007; Serreze et al. 2000). The effects include thawing permafrost (Jorgenson 2001; Osterkamp 2005; Walvoord and Striegl 2007), warming temperatures (Overpeck 1997; Serreze et al. 2000), and shifting weather patterns (Hinzman et al. 2005). Many of the studies concerned with climate change are conducted on a large spatial scale and recent temporal scale, and there is still a great deal of uncertainty concerning how climate change will manifest itself in specific regions (Duerden 2004). To address this uncertainty and better understand the effects of climate change, it is necessary to approach the problem from a smaller scale and incorporate the indigenous knowledge and understanding of the people of the Arctic and Subarctic. This method has been utilized in various studies throughout the Arctic (Ashford and Castledon 2001; Gearheard et al. 2010; Krupnik and Jolly 2002; Nichols et al. 2004; Turner and Clifton 2009). However, the majority of these studies have been conducted in extreme northern or coastal Arctic locations (Ashford and Castledon 2001; Gearheard et al. 2010; Krupnik and Jolly 2002; Nichols et al. 2004; Turner and Clifton 2009). There is relatively little known about what changes the people of the Subarctic Yukon River Basin (YRB) of Alaska are observing.

This study assumes that scientific findings and indigenous knowledge are complementary and seeks to overcome the false dichotomy that these two ways of knowing are in opposition (Agrawal 1995). Here, we attempt to address the challenges of integrating these two ways of knowing by relating indigenous observations as described by elders and hunters of the study area to those described by western scientific studies. There are inherent differences between indigenous knowledge and scientific findings that are both temporal and spatial in scale; it is necessary to consider both ways of knowing to gain a better understanding of the effects of climate change on the landscape and the people. Improvement in the understanding

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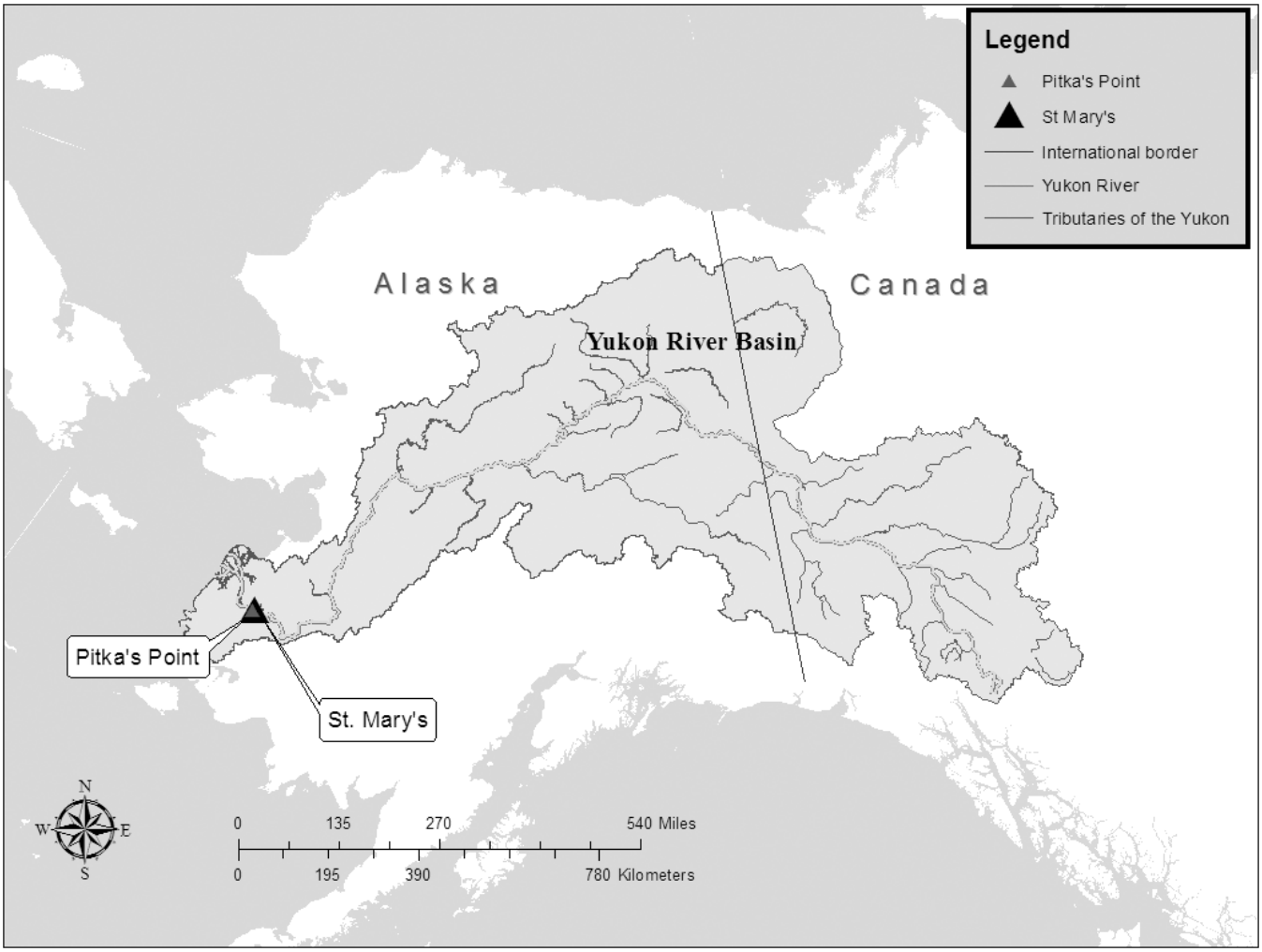
Figure 1. St. Mary's Alaska Within the Yukon River Basin



of the links between global scale and local scale phenomena and processes related to climate change is one of the great intellectual challenges of our time (Wilbanks and Kates 1999).

Study Area

St. Mary's and Pitka's Point are located in the lower portion of the YRB in the Subarctic of Alaska. St. Mary's lies on the north bank of the Andreafsky River 8 km from its confluence with the Yukon River (Figure 1). Pitka's Point is adjacent to St. Mary's, situated on the banks of the Yukon River 8.9 km west of St. Mary's. St. Mary's and Pitka's Point are Yup'ik communities that maintain a subsistence-based lifestyle of fishing, hunting, and gathering wild foods. Within St. Mary's are two federally recognized tribes, the Algaaciq Tribal Government and the Yupiit of Andreafsky. Pitka's Point also boasts a federally recognized tribe, the Native Village of Pitka's Point.

St. Mary's was chosen for this study based on the recommendation of a colleague and co-author from the Yukon River Inter-Tribal Watershed Council (YRITWC) as well as communication with a researcher from Alaska's department of Fish and Game. Members of the St. Mary's community work closely with the YRITWC on various projects including a collaborative YRITWC-United States Geological Survey (USGS) water-quality monitoring project (Schuster and Maracle 2010; Schuster, Maracle, and Herman-Mercer 2010). The previously established relationships facilitated the opportunity to approach key community members as guides/facilitators in the communities. The primary researcher, a USGS employee, was able to gain the trust of these key community members by virtue of the USGS relationship with the YRITWC, which was critical to the success of the study. The village of Pitka's Point was added to the study area after arrival in St. Mary's, based on the recommendation of our facilitator that individuals from that community should be contacted for interviews as well.

Methods

Observations of climate change were collected through semi-structured interviews (Schensul, Schensul, and LeCompte 1999) with elders and hunters indigenous to Alaska in the villages of St. Mary's and Pitka's Point. To establish a relationship with the community of St. Mary's, a letter was sent to both Tribal governments introducing the project and the investigator and seeking permission to conduct research in their community. A follow-up phone call was placed to each of the Tribal governments requesting assistance in recruiting participants for the interviews. This phone call led to a relationship with the environmental coordinator for the Yupiit of Andreafsky Tribal Council, in which he became our guide and facilitator in St. Mary's and Pitka's Point. At the time, we were unable to get a response to our letter to the Algaaciq Tribal Government, and several phone calls placed to their office went unanswered. However, a relationship was established at a later date following introductions at the YRITWC biennial summit meeting in the summer of 2009.

Participants were recruited based on the recommendations of our facilitator from the Yupiit of Andreafsky Tribal Council. Additionally, a snowball sampling technique was used, in which interview participants were asked to recommend someone else with knowledge of the issue to be interviewed (Biernacki and Waldorf 1981). Interviews were conducted with members of the Yupiit of Andreafsky and the Alaagciq Tribes. A total of 13 interviews were conducted; seven in person in St. Mary's and Pitka's Point, five over the phone, and one in person at the YRITWC summit meeting. Interviews lasted from 30 to 60 minutes and were recorded after the participant had given permission. In addition to verbal permission allowing for the recording of interviews, participants were given an information sheet which explained the purpose of the study, how information gained in the interviews would be used, and what rights they had as a study participant (Patton 2002). All interviews were conducted in English.

Limitations

This study was conducted over a five-day period in the city of St. Mary's and the adjacent village of Pitka's Point, Alaska. Time was the largest obstacle for this study, which was restricted by budgetary constraints. Although measures were taken prior to arrival in St. Mary's to establish relationships with key community members and arrange for interview times, the realities encountered on the ground dictated the number of interviews conducted.

Ten of the 13 interview participants were men. Our facilitator recommended mostly men for the interviews with their wives recommended somewhat as an afterthought. It became clear in the course of conducting interviews that this gender imbalance would lead to a lack of information about vegetation, as evidenced by the brevity of information related below. In future studies in the YRB, steps will be taken to understand the gender roles in each community and ensure a representative sampling of male and female participants.

Analysis

Despite the small sample size, interview participants began relating the same observations repeatedly towards the end of the fieldwork and are consistent with observations Yup'ik in coastal areas have made (Fienup-Riordan 2010). The interviews were transcribed in their entirety and data were reduced and organized by coding for common themes. Most of the codes were *a priori* as dictated by the question guide, while others were *a posteriori* as they arose spontaneously through the course of the interviews (Schwandt 2007). The results of this study are presented below and are organized in the way the interview participants spoke of their observations of climate change—weather observations, fauna observations, flora observations, and river observations.

Results

Weather Observations

> Those old people noticed it first. They're not around anymore, they're all underground. They used to tell me, "What's going on with this weather?" They noticed, sometimes it's too hot, sometimes it's too cold.[1]

Invariably the most common statement made by the 13 interview participants was that it has gotten warmer in recent years. Temperatures were perceived to be warmer in all seasons, though most notably in the winter months. In the recent past, winter temperatures dropped to 40° Celsius (C) below freezing, while in present times temperatures only reach 25°C or 30°C below freezing. Moreover, in the rare case that temperatures did drop as low as they had in the past, it was a brief cold spell, in contrast to historic month long cold spells. The above referenced quotation speaks to the temporal nature of indigenous knowledge, while scientific studies may demonstrate how temperatures have changed over the last 50 years (in places where such a long record has been kept), indigenous knowledge is based on observations made not just by the speaker in his or her lifetime alone, but also on the environmental history that has been passed on to the speaker and was passed on to those before him or her.

In addition to warmer temperatures, the weather was described as being less predictable by the people of St. Mary's and Pitka's Point. One interview participant, a hunter and resident of the area of St. Mary's for 66 years, commented on the unpredictability of the weather:

> Yeah, really unpredictable, you can't plan. You don't know what's going to happen, cause like I said, it will be bad a couple of days then clear up and you think it's going to be good, it'd be clear for a day or two and then just right back again. And you don't want to get caught out in the country in that weather.

Such unpredictability has a direct effect on the people that rely on subsistence activities for their way of life. One does not want to "get caught out in the country" when the weather suddenly changes. He continues:

> There's been times where we chat around and say, this winter's been really bad, like I said, depressing, you can't plan, can't take a walk or go hunting and feel safe, because you never know what's going to happen; this winter was like that. Before this you can kind of plan because normally that's how it works, but this winter was just jumbled up.

Furthermore, the accuracy and skill by which the people of St. Mary's and Pitka's Point once predicted the weather is less reliable than it once was owing to environmental change. Another interview participant, also a life-long resident and hunter in St. Mary's, said, "[You] used to be able to tell the weather by the moon, but now you can't because any kind of weather comes by." This point speaks of an ability to read the weather by noting the way the moon looks in certain atmospheres and, thereby, inferring the incoming weather. This skill in "reading" the moon has become less reliable in recent years as weather patterns have become irregular. A younger hunter of St. Mary's expands on this point, "I hear stories from the older people that they used to be able to predict the weather longer, a week I guess or so."

Changes in precipitation were also noted by eight of the 13 interview participants. Specifically, they commented on the month of August as the "month that it should be raining all the time and [now] either it comes earlier or it happens later on." Another participant agreed, "Yeah, usually we could get a good rain in August, but we don't hardly get it anymore." It was also noted by a majority of the interview participants that there has been a decrease in snowfall in recent years:

> I must have been about, oh seven or eight years old, when we first started living here and went to school up at the mission. Seems like every year we used to have lots of snow and really cold winters. I used to live down here in that old house, probably the oldest house in St. Mary's. Right outside our house, we'd get a really big snow bank, pretty big snow, kids used to jump off out there, you don't see that anymore.

He continues:

> Let's see, maybe in the 80s, late 70s, 80s there was this gradual change started, and it seemed like the winters were getting a little warmer, less snow, rain in December and January. It seems like there's hardly any snow, frozen tundra, ice.

Others also commented on the decrease in snow:

> Like I said, there used to be a lot of snow, really a lot of snow. This spring's the first time we had this much snow since, quite some time, I don't know when, I can't remember, we had quite a bit of snow. But, all these last few years we haven't had any, hardly any snow.

Less predictable and inconsistent weather patterns have numerous implications for the people. In addition to issues of safety (getting caught out in the country when the weather suddenly turns bad) the ecological patterns are also shifting due to the shifts in seasonal weather patterns which yield increased difficulty in subsistence activities.

Fauna Observations

> There's no more ptarmigan, we don't see even the birds like the ducks and geese, especially the ducks, you hardly ever see ducks anymore.

The general scientific consensus is that climatic shifts in weather patterns and river chemistry will ultimately manifest in changes to plants and animals. This phenomenon was found to hold true in the study area. People spoke of new influxes of species not previously found in the St. Mary's area, such as beaver (*Castor canadensis*) and moose (*Alces alces*), as well as a decrease in species that were previously plentiful, most notably ptarmigan (*Lagopus lagopus*).

When speaking of the changing animal population, the interview participants described a concept that everything in Alaska, the seasons and weather as well as the flora and fauna, moves from the east to the west. People did not seem surprised by the new influx of species that had not been in their area before; instead they seemed to associate it with the natural order of things. This is an important observation that is worthy of further exploration in future studies. It may be that indigenous communities possess knowledge about animal populations that has been handed down from times of historical climate change events that would help us to understand the way animals are responding to a changing climate today.

In regards to the increase of the beaver population in the St. Mary's area and the question of whether the population had truly increased or just migrated from other habitats one interview participant stated:

> Well, my dad used to tell us everything moves from east to west. They come down, everything comes down, normally he says if they're going to go extinct, that's what happens they start moving like that, leave nothing behind. And I think that's going happen too eventually, because there were no beaver here before, but there's lots and there's no more up there [north], and they're all down here; they got to keep going. Anything else, he says, like cold weather, fall time, comes from east, upriver interior cold weather come down here, same with the spring, warm weather comes from out east and comes this way, it's the same principle.

Others echoed this phenomenon in regards to the increased moose population in their area:

> From what I remember, you'd be lucky if you went out hunting and you'd see maybe eight. And today you can see eight in a bunch. So they're either moving from upriver, moving on in this way or, the elders say all animals and stuff, even spring and fall, winter comes from interior and goes down this way. The beaver did the same; they're everywhere.

Research with the Yup'ik in Southwestern coastal communities of Alaska found that the people attributed a decrease

in the black brant geese (*Brants bernicla nigricans*) population to inherent cycles or to the peoples' lack of attention to how the geese should be treated according to traditional Yup'ik beliefs (Fienup-Riordan 1999). Traditional Yup'ik beliefs state that animals control their own destinies, and that when they are treated poorly, they will not return; conversely, if they are treated properly, they return to the hunter year after year (Fienup-Riordan 1999). This theme of ecological reciprocity also arose in interviews with the Yup'ik of St. Mary's and Pitka's Point. The elders expressed a belief that animals may be becoming scarce because people were no longer treating them properly. An 86-year-old elder of St. Mary's stated in a phone interview, "The game is altogether different, we used to make a living catching animals, people don't take care of them like they used to." Another elder of St. Mary's said, "In native culture, they say that sometime in the future we'll have less, less everything, animals on the land and in the river too. It's here already." He continues:

> I really believe that native culture has known it from way back a long time ago, before everyone was born. Way up north they're getting less moose, they're having a hard time finding moose upriver; really few. So they're [the moose] going towards the Bering Sea, it shows that, we're going to have very, very few moose now on the land.

Although throughout the interviews only general questions were asked about the animal populations, the issue of the health of the animals was often brought up by the interview participants. The issue of animal health arose particularly in regards to the moose and the chum and chinook salmon *(Oncorhynchus keta* and *Oncorhynchus tsawytscha)* populations. One interview participant described what she has observed:

> I've noticed in the past, well just recently, that a lot of our moose meat or fish they begin to show, I don't know what, in the moose meat they look like warts that are in the fatty tissue, and also in the salmon, the chum, or chinooks, they start to have what look like pus pockets underneath the skin. And that's something really new that I have not seen before, the fact that I've been cutting fish just about my whole life.

This observation of pus pockets on the chum and chinook salmon was mentioned by other interview participants as well. Additionally, there was estimation by the interview participants that the population of these salmon species had decreased in size and number.

Flora Observations

> Yeah, it seems like they're [salmonberries] less and smaller.

Interview participants indicated that salmonberries (*Rubus spectabilis*), an orange berry similar to a raspberry (*Rubus strigosus*), were becoming scarce and smaller in size. One participant stated his belief for the cause of this change:

> Salmonberries getting fewer, that's due to lack of snow. See what's happening is, after the snow melts right away the tundra dries up. And that's one of the reasons for lack of salmonberries, the tundra is drying up and they can't grow when it's dry. That's lack of snow, that's one of the reasons, for lack of salmonberries also.

Irregularity in weather patterns has a direct effect on the people's subsistence. They are unable to know from year to year if the salmonberry crop and other vegetation can be relied upon. One interview participant characterized this as "playing catch-up with Mother Nature":

> The timing is a little off, we used to say, "Oh it's going be berry picking season coming up." We'd go out there and they're all gone, all dried up, got to go look elsewhere. Go out on the coast and we could find salmonberries out there.

Moreover, interview participants spoke of changes in the growing season. One elder stated that "…trees get green too fast, things growing underground too fast, so fast." She also mentioned that there are plants she had never seen before: "But once in a while we see something it seems like I've never seen before, the leaves some plants are growing…." New forms of vegetation were noted by other interview participants as well.

River Observations

> We don't see break up like we used to, the ice isn't solid when it starts breaking up, its needle ice, [break up] used to be really loud.

All of the 13 interview participants noted that the ice on the rivers (the Yukon and Andreafsky) has become considerably thinner in recent years, around 1 m thick in contrast to 1.5 to 2 m in the past. One participant recalled, "It hasn't been very thick since I was a kid growing up. My dad would set a net in the winter it would go through maybe 5, 6 feet [1.5, 1.8 m] of ice to set net and now maybe you're lucky if you have 3, 4 feet [1, 1.2 m]." Another member of St. Mary's for 30 years noted the recent thinning of the ice, "[I] used to spend the whole day chipping through ice to check fish nets. Now it only takes an hour." A resident of the adjacent village of Pitka's Point stated in regards to the Yukon River, "Three feet [1 m] we say is thick now, but it used to be 5, 6, 7 feet [1.5, 1.8, 2.1 m] thick."

Thin river ice becomes a socioeconomic issue because winter travel is mainly achieved by utilizing the frozen rivers as a transportation route via snow machines or sled dogs. Thinning ice shortens the winter travel season making it more difficult to trade goods between villages, visit friends and relatives, or reach traditional hunting grounds. Furthermore, it becomes an issue of safety as thin ice makes travel more dangerous.

When asked about open leads, places on the river that remain open and ice free throughout the winter, everyone that had knowledge of the river observed that the number of open leads has increased. Moreover, historical open leads, such as the confluence of the Andreafsky River and Yukon River, have

grown in size. An increase in both size and number of open leads is very dangerous for a culture that relies on river ice for transportation throughout much of the year.

Often when asked about open leads, people's first response was concerning how many lives had been lost in recent years when someone had fallen through the ice. An 83-year-old elder who has lived in St. Mary's for over 50 years, expressed her concern about open leads in a phone interview:

> Our river goes out to the Yukon not too far, about a mile [1.6 km] or a little more, and at this mouth to the Yukon, it doesn't freeze, it doesn't freeze, people keep drowning there. I don't know how many people now, especially young people. They've been falling in that hole, I don't know how many people now down there…because that place never freezes, we hate, I hate that, other people hate that.

In addition to observations of increased open leads, many interview participants reported an increase in sandbars on the Yukon River, shifting the flow of the water. This increase in sandbars may be contributing to the increase in open leads. As the sandbars shift the currents of the river, strong currents are created in new places that do not allow the water to freeze. In regards to the increase in open leads, one interview participant stated, "It [open lead] never used to be there…. Change in the currents I believe caused that, sandbar building up, current changes. Places that were private fishing grounds got eroded. People don't fish there anymore."

Both of the participants from Pitka's Point (located on the banks of the Yukon River) stated that there had been no sandbars on the Yukon when they were growing up. In the course of the interview, one participant from Pitka's Point pointed out a large sandbar in the middle of the Yukon River, which he stated had never been there before. When asked about water levels on the river, one elder stated, "There were hardly any sandbars in the Yukon when I was young. Now sandbars appear everywhere, lots of sandbars, lots of sandbars."

Additionally, all 13 interview participants stated that break-up has gotten "easier" in recent years. People described break-up as being an exciting event in the past, in which people would come down to the shore and watch the crashing of the ice. Today people hardly notice the event as the ice simply melts off. The loss of break up was attributed to warmer temperatures in addition to a lack of water. The ice is thinner because of warmer temperatures, but one interview participant stated that the river also lacks the pressure of high water behind it to cause the ice to break up violently.

There was uncertainty about whether or not the timing of break-up has shifted. Some people indicated that break-up was occurring earlier in the spring than it had in the past, while others felt that the timing of break-up varies year to year. When asked if the ice breaks up differently than when she was younger, one elder stated:

> Yeah, I guess it seems like it's getting longer in the spring time. The Yup'ik people, Eskimo people, say when we have a long fall and it never freezes even though it's supposed to freeze then we have a long spring. It's getting like that, it is. It's getting late, later, the break-up, it seems like. Every year seems to be because it never freezes on time, like it used to in the fall time, the spring is long. But I know I used to hear since I was little they say, "It didn't freeze this fall in the right time it's going to be a long spring." This year even it's kind of a late break-up.

This statement points to the fact that although people were unsure about whether the timing of break-up has shifted, they felt that the timing of freeze had.

Owing to what the participants described as lower spring flows on the Andreafsky and Yukon Rivers, people's ability to collect wood has become hampered. In the past, the high spring waters that arrived following break-up allowed people to collect logs flowing down the river from eco-regions up river. This resource is a critical socioeconomic driver in the form of firewood and building materials. In recent years, the high waters have not arrived and the wood that does come down river is trapped in the willows that line the banks where the people are unable to get it when the water recedes. This situation was related in an interview:

> Well, the water being low it affects us quite a bit. Springtime we count on high water to get our logs coming down the river, up the Yukon, collect our wood come spring. It comes down and then we go out there and collect the wood. We haven't done that; last spring it was a little bit, but water came and then dropped, just dropped and the wood end up back inside the trees and we couldn't get to them. Normally, high water stays and we can collect all our wood and water start coming down slowly, but not that spring, it just came and dropped down again.

This resource scarcity has placed a strain on the local economy through increased heating costs. The local ecology of St. Mary's is characterized by the surrounding tundra where suitable trees to harvest are scarce. The community is completely reliant on the high spring waters of the Yukon and Andreafsky Rivers to supply drift wood. The scarcity of drift wood for heating and other projects has caused an increase in socioeconomic pressure in an already depressed region. The loss in harvestable resources, in particular wood, has caused an increased reliance on expensive fossil fuels, prices of which can reach up to $8 per gallon.

Discussion

It is clear from the results presented above that the people of St. Mary's and Pitka's Point, Alaska are observing a variety of changes in their environment due to climate change. Observations related by the interview participants in the course of this study are synergistic with those reported in the scientific literature. However, as stated in chapter two of the Arctic Climate Impact Assessment (ACIA 2005:22), "The observational database for the Arctic is quite limited, with few long-term stations and a paucity of observations in

general…." This paucity of observations is especially true in the study area and the Lower YRB as a whole. This leads to a mis-match in scales when comparing observations of climate change as related by the interview participants of the study area with those documented in the scientific literature. Scientific studies often relate a global or hemispheric understanding of climate change. Indigenous knowledge on the other hand allows for a place-based understanding of climate change. Both understandings are important and valid; in order to gain a comprehensive understanding of climate change and its future impacts, it must be understood both globally and locally. However, we, as researchers and scientists, must be careful not to use the scientific literature to bolster the validity of indigenous knowledge. Indigenous knowledge has the strength to stand on its own merits. Below is a brief discussion of what the available scientific literature reports about climate change as near to the study area as possible.

Air temperature increases are the most obvious and arguably the most well documented change attributed to climate change that has taken place, not just in the Arctic, but globally. Serreze et al. (2000) report that the largest increase in temperature in recent decades has been over Northern Hemisphere land areas from about 40-70°N (our study area lies at 62°N). Moreover, the region surrounding and including the study area has experienced a steady average temperature increase of 1.0°C per decade since 1966 (Serreze et al. 2000). This time frame fits well with the observations of the hunters and elders of the study area who began observing that the temperatures were warmer than they, or their ancestors, had observed beginning in the 1970s. Additionally, Overpeck et al. (1997) concluded based on tree rings and varves (annual layers of sediment), which are primarily indicators of summer conditions, that Arctic temperatures in the 20th century are the highest in the past 400 years.

The hunters and elders of the study are not alone in their observation of irregular weather patterns; irregular weather patterns, increasing the difficulty of predictions, have been observed by indigenous peoples across the Arctic (Fox 2002). Precipitation trends and increased variability in weather have also received considerable attention in the scientific literature. According to the ACIA (2005), it is likely that precipitation has increased 1 percent per decade over the past. Additionally, more precipitation has begun falling as rain as opposed to snow, Førdland and Hanssen-Bauer (2003) found that the amount of precipitation falling as snow decreased at all stations in the Norwegian Arctic from 1975-2001. Based on satellite images, Groisman et al. (1994) showed that mean annual snow cover extent decreased by 10 percent from the years 1972-1992 in the Northern Hemisphere. More recently, McCabe and Wolock (2010), using monthly snow cover data for the years 1966-2007, have confirmed that snow-covered areas in the Northern Hemisphere have been decreasing since 1970.

Ferguson (1995:16) wrote, "There is considerable uncertainty concerning how a warmer climate would affect regional climatic patterns of northern North America." She predicted, however, that "possible impacts include…altered lake, river, and sea-ice conditions, including early spring breakup, summer reduction, later autumn formation, and reduced winter thickness" (Ferguson 1995:16). Observations of the interview participants confirm that Ferguson's predictions have become reality, particularly with regard to reduced river ice thickness. Data from the Yukon Department of Environment and the Arctic Environmental Data Center have been used to show that breakup dates on the Yukon River at Dawson located in the Yukon Territory (YT), Canada and the Tanana River (a tributary of the Yukon) in Alaska have been occurring earlier in the year (Brabets and Walvoord 2009). Dawson, YT is located near the headwaters of the Yukon River where breakup begins; if breakup is occurring earlier in the year in the Upper YRB, then it will occur earlier downstream in the Lower YRB. Further study of breakup dates on the Yukon by Bieniek et al. (2011) report that the date of breakup depends on a combination of river discharge and melting river ice. Melting river ice is clearly a function of air temperature, which the previous discussion, as well as the observations of the people, demonstrates to be on the rise. Additionally, long-term stream flow records (>30 years) of the YRB indicate a general upward trend in groundwater contribution to stream flow predominately caused by permafrost thaw (Walvoord and Striegl 2007). This increase in groundwater contribution to stream flow, which increases overall river discharge, coupled with increasing air temperatures is a clear indicator that the effects of climate change are causing river ice breakup earlier in the year.

Despite the minimal amount of information relayed by the interview participants about vegetation, owing to the gender imbalance of this study (see Limitations above), it was clear that those with knowledge of the vegetation have observed changes. Scientific research has shown that photosynthetic activity of terrestrial vegetation increased from 1981 to 1994, suggesting an increase in plant growth associated with a lengthening of the active growing season (Myneni et al. 1997). Additionally, this increase was observed to be greatest in the regions between 45ºN and 70ºN (Myneni et al. 1997), encompassing this study area, as noted earlier. The Normalized Difference Vegetation Index (NDVI), which utilizes satellite images to analyze plant growth, vegetation cover, and biomass production, has also shown that both the onset and the length of the growing season has increased North of 45º latitude for the period of 1981-1994 (Holben 1986; Shabanov et al. 2002). Further investigation of vegetation changes is needed in the study area; there are clear indications that climate change is affecting vegetation, but more indigenous women must be interviewed to fully understand the changes in the study as men often "do not pay much attention" to the vegetation.

The interview participants spoke of a change in the range of species of mammals (moose and beaver) as well as a decrease in the number of some bird species (ptarmigan). It is difficult to know if the range of an entire species has shifted, because few studies have been conducted at this scale (i.e.,

a continental scale), and only a moderate number have been conducted at a regional scale (Parmesan 2006). However, as Parmesan (2006:646) reports in her review of the literature, "Nearly every Arctic ecosystem shows marked shifts." Both the Intergovernmental Panel on Climate Change (IPCC 2007) and the Arctic Climate Impact Assessment (ACIA 2005) have reported that species of mammals and birds have begun responding to climate change and predict that the range of species is likely to shift as ecosystems undergo changes due to a warming climate. Additionally, as observed by interview participants, the ACIA (2005) reports that the number of salmon has been far below expected levels, the fish were smaller than average, and their traditional migration patterns seemed to have altered.

The inclusion of indigenous knowledge to understand the local and regional effects of climate change is of the utmost importance. As noted above, the documentation of more localized observations results in a more nuanced understanding of climate change and uncovers new areas for quantitative and qualitative study. Additionally, indigenous knowledge encompasses observations, lessons, and stories about the environment that have been handed down since time immemorial. This allows for a temporal expansion of environmental knowledge in places, such as the Subarctic of Alaska, where scientific studies have only begun collecting data on a scale of decades.

Conclusion

The changes in the environment observed by hunters, elders, and the community as a whole in St. Mary's and Pitka's Point, Alaska are having impacts that range from subsistence to safety. Moreover, climate change has become a socioeconomic issue as the people have less success gathering driftwood coming down the Yukon and Andreafsky Rivers, and travel is hindered by dangerous ice conditions.

The scientific evidence supporting a warming climate in the Arctic and Subarctic is indisputable (ACIA 2005; IPCC 2007). Furthermore, it has become clear that the planet is beyond mitigating the effects of climate change and must begin looking towards adapting to a new climate. Indigenous knowledge and scientific research must work in concert to further understand specific climate change impacts in specific locations in order to develop appropriate adaptation strategies. Utilizing multiple knowledge systems by sharing knowledge across disciplines, class structures, social boundaries, and cultures will result in more informed and appropriately implemented adaptation strategies. Thus, by sharing knowledge, achievement of real solutions to the complex challenges posed by climate change may be answered.

Notes

[1]All indented block text represents direct quotes from St. Mary's and Pitka's Point interview participants, transcribed from the recordings of the interviews conducted from May to August, 2009.

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