LOCAL KNOWLEDGE AND SCIENCE:
Observation of Landscape Change in the Nuiqsut Homelands

Elders cutting fish during an education camp for youth in 2014, photo from the Nuiqsut GPS Community Monitoring Project.
ACKNOWLEDGEMENTS

We thank the residents of Nuiqsut for their valuable knowledge, time, insights, and patience. Thank you also to harvesters who participated in the Nuiqsut GPS community monitoring project and provided photos. The Kuukpikmiut Subsistence Oversight Panel (“KSOP”) provided valuable support in designing and administering the project. The National Science Foundation through Alaska EPSCoR and the state of Alaska provided funds for this project (NSF award #OIA-1208927). We also recognize and thank the scientists who undertook research as part of the EPSCoR Northern Test Case Study. Partial funding provided by the “Cumulative Effects of Arctic Oil Development – planning and designing for sustainability” project (NSF award #1263945).

How to cite report:
I. SUMMARY ................................................................................................. 4
II. INTRODUCTION .......................................................................................... 5
Methods ........................................................................................................ 5
III. ABOUT NUIQSUT ..................................................................................... 6
IV. CHANGES .................................................................................................. 7
Temperature ................................................................................................ 7
Snow ............................................................................................................. 9
Timing of Seasons ....................................................................................... 10
Permafrost .................................................................................................. 12
Lakes ........................................................................................................... 14
Breakup, Rivers and Erosion ...................................................................... 16
Plants .......................................................................................................... 18
Animals ...................................................................................................... 20
V. CONCLUSION ............................................................................................ 23
VI. NTC UNIVERSITY OF ALASKA RESEARCHERS .................................... 23
VII. REFERENCES .......................................................................................... 24

Photo from Nuiqсут GPS community monitoring project.
We interviewed residents of the Alaska North Slope village of Nuiqsut about their observations of environmental change and reviewed scientific literature on the same topic. The interviews focused on land and river systems.

Interviewees largely agreed that many environmental changes have taken place during their lifetimes, but in all areas of change we asked about, interviewees disagreed to some extent about the direction of change. And for every area we asked about, roughly 10% to 30% of interviewees said they had not observed any change. The largest number of interviewees agreed that:

- Winter temperatures are getting warmer (60%)
- Spring is coming earlier (60%) and fall later (50%)
- Local willows are getting bigger (68%)
- There are fewer moose around Nuiqsut (65%)
- There is more erosion, especially around rivers (55%)
- There is either less permafrost or more exposed permafrost (61%)
- There are fewer lakes (50%)

Interviewees were more divided about whether:

- Summer temperatures are now warmer (46%) or colder (27%)
- Snow comes later (25%) or earlier (33%)
- There is now less snowfall (46%) or snowfall is unchanged (27%)
- There are less caribou (33%) or the same number of caribou (33%)

We compared the findings of science-based research with what Nuiqsut residents reported in our interviews and found that in many cases local knowledge and science-based studies were similar. In some cases, however, interviewees differed from the science-based research in their observations of the direction of change. There are several possible reasons for these differing views. Interviewees may have made their observations in different areas around Nuiqsut, not all of which have the same biological or physical characteristics. Interviewees may have lived in the region for different amounts of time (maybe due to being older or younger) and thus, have different perceptions about what has changed. Some interviewees may have received information from sources besides their own observations, such as from researchers’ reports at community meetings or from media or the Internet. And some interviewees may hold different perspectives on what constitutes change, given their experience of cycles in animal populations, various levels of snowfall, and other factors. As well, science-based research may have been conducted in ways that generated invalid results.

The findings of this study suggest that we can learn much from similarities and differences in knowledge of change by improving our overall understanding of present and possible future conditions. Differences and agreement on change reported here also raise important questions about the effects of future change on the well-being of the people of Nuiqsut and the environment on which they depend. Among these questions are how climate change may affect the health of people and animals; how changes in the ecosystem could affect access to subsistence hunting and fishing areas; and how oil and gas development might interact with and influence climate change. Moreover, the findings of this report point toward the need for future ecological monitoring and research conducted in close collaboration with Nuiqsut residents.

Alaska EPSCoR studied changes to landscapes in Alaska and their implications to communities in three regions. The regional studies included “test cases” in Southeast, Southcentral, and Northern Alaska. https://www.alaska.edu/epscor/

The Northern Test Case focused on land-, river-, and lake-based subsistence activities of Nuiqsut, a 450-person Iñupiat village located 18 miles from the Arctic Ocean that relies heavily on traditional subsistence resources.

The research objectives of the Northern Test Case were to:

- Understand how hydrological, landscape, and land-use changes are affecting ecosystems and resources used by residents.
- Understand the consequences of changes to a village’s way of life.
- Assess the ability of North Slope households and communities to respond to changes.
II. INTRODUCTION

This report summarizes knowledge about environmental changes on Alaska’s North Slope, specifically focused on the terrestrial (i.e. land, river, lake) subsistence use area of the community of Nuiqsut. The information in this report is based on observations of change as reported by Nuiqsut residents and a review of findings from scientific studies.

The report is part of a six-year study to understand social and ecological changes in Alaska and the ability of communities to adapt to those changes. The project was funded by the National Science Foundation Established Program to Stimulate Competitive Research (NSF EPSCoR) award #OIA-1208927 and by the State of Alaska. See box on page 4 for more details. Partial funding provided by the “Cumulative Effects of Arctic Oil Development – planning and designing for sustainability” project (NSF award #1263945). A listing of the University of Alaska researchers involved in the study and their contact information is found on page 23 report.

University of Alaska researchers worked in partnership with the Kuukpik Subsistence Oversight Panel (KSOP) to complete the study. KSOP was established as a condition of oil development in the area to provide community oversight of oil and gas development activities and protect subsistence resources. Numerous meetings were held with KSOP to gain permission to do the study and to design and implement parts of the project. At the end of the project workshops were held with board members of the Kuukpik Corporation, the Native Village of Nuiqsut Tribal Council, and the City Council of Nuiqsut to report findings and receive additional feedback.

We asked Nuiqsut residents to describe what changes they have observed over the course of their lifetime. Residents were asked about changes in temperature, snow cover, timing of the seasons, availability of harvested animals, and other physical and biological features that have implications to their subsistence way of life. Our focus was on the terrestrial (i.e., land, rivers, lakes) environment. We compared these observations to the findings of scientific studies to consider differences and similarities among the findings of these two knowledge systems.

METHODS

We worked with KSOP to identify a cross-section of residents to interview. We completed semi-structured interviews with 28 residents in 2014, most of which are active subsistence harvesters. The interviewed residents were 21 men and 7 women, ranging in age from 23 to 77. The questionnaire can be found online (http://www.alaska.edu/files/epscor/pdfs/NTC-survey-instrument.pdf). We had hoped to interview more Nuiqsut residents, but found that “research fatigue” levels were high in the community due to the large number of survey-based studies previously conducted. Because KSOP helped to identify interviewees, we believe the answers we received reasonably reflect the diversity of perspectives in the community. Each figure of this report indicates the total number of people (“n”) who answered each question and the percentages of responses it represents.

In a parallel project of the Northern Test Case, 12 active subsistence harvesters were given Global Positioning System (GPS) units equipped with cameras and asked to photograph what they viewed as important environmental changes. When submitting photos, harvesters filled out a form reporting details about each photo, including its significance to the harvester. Selected photos from this project are included in this report.

We also identified relevant scientific findings about ecological change in the region. We reviewed nearly 60 scientific studies and noted results that pertain to ecological change on the North Slope. These studies are cited in the text and listed in the bibliography at the end of the report.
Nuiqsut is 136 miles southeast of Utqiagvik (formerly Barrow), along the Nechelik Channel of the Colville River. Nuiqsut is an incorporated city of the North Slope Borough, with about 450 residents, 87% of them Iñupiat. The Colville River delta is a traditional hunting and fishing area for the Iñupiat, and until the 1940s, there was a settlement of Iñupiat at Nuiqsut’s current location. In the early 1970s, families resettled the area, and in 1975, it incorporated as a city.

People primarily access Nuiqsut by air, but during the winter, community residents can access the Dalton Highway and the road system via ice and gravel roads that cross North Slope oil fields. The Prudhoe oilfield complex and the terminus of the highway at Deadhorse are about 50 miles from Nuiqsut, with the closest oil field, Alpine, located 8 miles north of the community.

The North Slope Borough provides electricity, water, and sewer services in Nuiqsut. Besides the regional North Slope Borough government, the community has two local government entities: the city government and the federally recognized Native Village of Nuiqsut. The North Slope Borough and the Kuukpik Corporation are the major employers in Nuiqsut.

Under the Alaska Native Claims Settlement Act (ANCSA), Alaska Native regional corporations own sub-surface rights and the the Alaska Native village corporation own the surface rights. The Alpine oil field is partially located on land owned by Nuiqsut’s Alaska Native village corporation, Kuukpik. Kuukpik has a surface-use agreement with ConocoPhilips, the Alpine field operator. Kuukpik’s website reports that it receives some production royalties, and that some Nuiqsut residents receive dividends from the oil and gas companies in exchange for the land use. The Arctic Slope Regional Corporation, the North Slope’s Alaska Native regional corporation, holds the subsurface rights and is a part owner of the Alpine oil field.

Nuiqsut’s economy has traditionally been subsistence-based, and subsistence remains critical to the community’s culture and economy today. According to the North Slope Borough’s 2015 Economic Profile and Census Report [2], two-thirds of Nuiqsut’s Iñupiat households say subsistence foods make up at least half of their diets. The main harvested resources are bowhead and beluga whales, other marine mammals, caribou, moose, whitefish, waterfowl, and berries. The sharing of harvested wild foods is an important aspect of Iñupiat culture, and is actively practiced. Most households also participate in the cash economy.
TEMPERATURES

Key finding: Interviewed residents and weather station data suggest that winter temperatures have increased and that there are fewer extremely cold days.

Temperature affects the landscape and animals in many ways. Unlike some other conditions we discuss in this report, temperature is easily measured, and weather stations give us a long-term record of changing temperatures in areas of the North Slope.

LOCAL OBSERVATIONS

The Nuiqsut residents interviewed strongly agreed (73%) that summer temperatures are changing, but they disagreed about the direction of change: 46% said summers are warmer and 27% said they are colder.

Summer temperatures vary from year to year and overall trends can be hard to assess, which is one possible reason why interviewees were split about the direction of the change (Figure 2). Local observers who reported summers have gotten warmer indicated those warmer temperatures have harmed caribou, leading to fewer and leaner animals. This is partly due to insects: at warmer temperatures, there are more mosquitoes and flies, which harass caribou. This leads caribou to interrupt their feeding and move around to try to escape the insects. Less feeding and more movement can result in skinnier caribou.

There was more agreement among those interviewed about changing winter temperatures: 60% reported winters are getting warmer, and only 8% said colder.

Many described winters in general as milder, with fewer cold snaps. “It used to be -50 for one week,” noted one interviewee. Residents also reported that winter does not last as long and ends earlier. Many interviewees also observed an increase in winter rain freezing on plants, making it hard for animals to get to food. Overall, many interviewees reported that year-round temperatures have warmed up noticeably over the last 10 years.

SCIENTIFIC STUDIES

Data from weather stations show that temperatures around Alaska have increased since the 1950s, with the largest increases in the northern part of the state.

In areas of the North Slope with weather stations, Utqiaġvik recorded the largest increases in temperatures during all four seasons between 1977 and 2015 [3]. Utqiaġvik is one of the few communities in Alaska where temperatures have increased during every season since the 1960s.

There was no weather station in Nuiqsut until the 1990s, but scientists at the University of Alaska Fairbanks used historical data to estimate temperatures prior to 1990s for the traditional territory of Nuiqsut [4]. Around Nuiqsut, which is inland, winter is the only season where temperatures have increased every decade since 1950 (Figure 3). The fall season was cooler than the 1950s, until the 2000s when all seasons were warmer than the 1950s.

<table>
<thead>
<tr>
<th>Season</th>
<th>No change</th>
<th>Other</th>
<th>Colder</th>
<th>Warmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer (n = 26)</td>
<td>15%</td>
<td>12%</td>
<td>27%</td>
<td>46%</td>
</tr>
<tr>
<td>Winter (n = 28)</td>
<td>24%</td>
<td>8%</td>
<td>8%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Figure 2. Results from interviews with Nuiqsut residents about how temperatures during summer and winter have changed over their lifetimes.
Figure 4 (bottom) shows the number of days in past years when temperatures were at least 40 degrees below zero in Utqiagvik and Nuiqsut. The changing number of severely cold days is an important measure because extreme cold has many effects. For example, it can limit plant growth and slow the spread of invasive species [5, 6]. The left graph shows that over more than a century of measurements, the number of days each year when the temperature in Utqiagvik was at least 40°F below zero dropped sharply. The right graph compares the number of days temperatures were below -40°F in Utqiagvik and Nuiqsut. Since the 1990s, the number of very cold days per year varied more in Nuiqsut than in Utqiagvik, but it is likely that if longer-term data were available for Nuiqsut, the downward trend would be similar in the two communities.

Observations from residents of Nuiqsut are consistent with this historical weather station data. Residents’ statements and the weather data both indicate that winter temperatures are increasing more than summer temperatures [7], and that the number of extremely cold days is decreasing.

Some residents reported that these warmer winter temperatures and the effects of warmer temperatures on snow cover have caused them to change the equipment they use for subsistence harvesting. For example, one respondent described switching from a liquid-cooled to a fan-cooled snowmachine because “the liquid-cooled machine can overheat if not enough snow kicks up on the heat exchanger.”

Figure 3. This figure shows temperature changes by decades, compared with temperatures in the 1950s. Data are from the Scenarios Network for Alaska and Arctic Planning (SNAP) at the University of Alaska Fairbanks. https://www.snap.uaf.edu/

Figure 4. Percentage of the days when the temperature was -40 or colder in Utqisgvik (A) and in both Utqiaqvik and Nuiqsut (B). Year is from July to June. Data source: National Oceanic and Atmospheric Administration (NOAA).
**SNOW**

*Key Finding: Local observations and scientific studies both suggest snow is melting earlier in the spring.*

Snow cover is more difficult to measure than temperature. Snow can blow around or evaporate and requires sensitive monitoring equipment. In general, changes in snow cover in the Arctic are not well-understood. Also, scientists have found that freeze-thaw events do not relate well to climate data and are difficult to link with impacts [8, 9], making local observations of freezing and thawing especially important [10].

**LOCAL OBSERVATIONS**

Most interviewees agreed that the amount of annual snowfall has changed: close to half (46%) reported that snowfall is decreasing, and 18% said it is increasing.

Local opinions were also divided about whether the timing of snowfall has changed: 25% said snow falls later, 33% earlier, and 21% saw no change (Figure 5).

It’s not surprising that local perceptions about trends in the amount and timing of snow are split; the timing and extent of snowfall events varies greatly from year to year, so it is difficult to assess long-term trends. One resident noted that the amount of snow varies across even small areas of the North Slope. Nuiqsut can have a lot of snow while nearby Utqiaġvik has low snow. Both low and high snow levels can influence subsistence. Low snow levels tend to increase the likelihood snowmachines will break, while larger snowfalls mean people need to work harder to break trails.

There was larger agreement among interviewees that the snow itself is changing, with more winter rain and ice freezing on snow, and other changes in how snow is drifting in town. As one respondent described it, “We start having a late snowfall, and big snows start with a couple days of rain. Now we got less snow, with ice. Ice covered snow.” Many interviewees said snow also melts sooner at the end of winter, which agrees with the data shown in Figure 6, page 10.

**SCIENTIFIC STUDIES**

The snowmelt in Utqiaġvik has dramatically declined within a single lifetime (~40 years). Snow melt occurred ten days earlier in 2009 than in 1941 and most of the change has happened since 1976 (Figure 6).

This trend of earlier snowmelt is similar across the Arctic, but the rate of change varies within different regions of the Arctic [11]. For example, studies show that the North Slope of Alaska has changed less than some other regions, with snowmelt in Alaska 7.5 days earlier in 2012 than 1979, which differs from areas of the Russian Arctic where snowmelt has occurred 11-15 days earlier [11].

Air temperatures in Utqiaġvik increased between 1967 and 2008. There was also 5% less snow in May, and 24% less snow in June [12] over that time. Scientific data also show that the timing of snowmelt and onset of plant growth in spring is earlier [13-15]. There are large changes in fall snow cover. For example, the fall of 2014 had 30 to 40 more days of snow than the average of 1998 to 2010 [16]. Snow depth is also difficult to measure, as stations to measure snow depth have not been around as long as other weather stations. As well, snowfall is not directly related to snow depth [17, 18].
TIMING OF SEASONS

Key Finding: Scientific findings and most of the interviewed residents indicated that spring is arriving earlier most years, and fall is later.

Subsistence activities are tied to the seasons, as changes in the weather bring changes in types and abundance of animals and plants. Historically, fall was defined in climate studies as September through November, and spring as March through May. But as temperatures and precipitation change, so does the timing of the seasons.

LOCAL OBSERVATIONS

More than half (60%) of Nuiqsut residents we interviewed said that spring now arrives earlier, and fall comes later (50%; see Figure 7.)

Most (60%) also agreed that breakup along rivers happens earlier, with snow melting and rivers breaking up in April rather than May. “Spring seems to be arriving a month earlier than when they were growing up,” noted one resident. Interviewees reported that shifts in seasons can make accessing harvest areas difficult, resulting in missed harvesting opportunities. For example, if ice forms late, it may be harder to find caribou because, as one resident told us, “Caribou do not cross ice that is too thin.” Early arrival of spring also affects ice roads. One resident noted that “The road melt(ed) a few years ago in the middle of April, leaving guys working on the oilfield with no more ice road.”

Of course, early melt and loss of ice roads also influence the ability of local residents to bring in goods to the community by vehicle.

SCIENTIFIC STUDIES

Studies show that the area of ice cover greatly influences the timing of seasons in the Arctic.

A late fall in northern Alaska has been associated with late formation of ice on the Chukchi and Beaufort seas (Figure 8). Studies have found that freeze-up in the Chukchi and Beaufort seas has taken place 7 days later each decade, between 1979 and 2007 [20]. This shift is the greatest change in freeze-up timing of any major water bodies.
Earlier springs and later falls expand the open-water season, which has resulted in more storms and coastal erosion [21]. In the Colville and Kuparuk River deltas, earlier springs coincided with migrating waterfowl arriving three to 10 days earlier in 2013 than in 1968 [22]. Birds that time egg laying with snowmelt have also shifted their laying date forward (Figure 9) [19]. Shifts in seasons make the arrival of fish and animals less predictable and can negatively affect subsistence activities [23].

Nuiqsut interviewees agreed that spring is coming earlier, and fall is arriving later, with some telling how local harvesters are adapting to thinner ice conditions. One respondent described shifts in timing of harvesting by telling how people now “have to wait until the middle of October to travel by snowmachine.”

![Figure 8. Number of open-water days along a 47-mile stretch of the Beaufort Sea coast near Drew Point, close to Teshekpuk Lake in northern Alaska. The blue line shows the departure of ice in the spring and red the arrival of ice in the fall. Shapes of points represent different study locations [21].](https://www.esrl.noaa.gov/gmd/grad/snowmeltdate.html)

![Figure 9. Response of black guillemots to snow melt data on Cooper Island, near Utqiagvik, from 1975-2011. Red dashed line is the day of the year when the first black guillemot egg is observed. Red solid line is the day of the year when the first black guillemot egg is observed overlaid on the trend when the snow melted in spring (black line) [19].](https://www.esrl.noaa.gov/gmd/grad/snowmeltdate.html)
PERMAFROST

Key Finding: Both Nuiqsut residents and scientists have documented areas where thawing permafrost is eroding riverbanks and creating thermokarsts on the tundra—areas where the ground drops and becomes wetter.

Permafrost is ground that is permanently frozen. Depending on its location, permafrost can be continuous or discontinuous—that is to say, it can be everywhere in a given region, or only present in scattered areas. Permafrost can lie at various depths below the surface and can be from a few feet to thousands of feet thick. Changes in permafrost are driven largely by higher or lower temperatures, but precipitation (rain and snow), erosion, and vegetation also influence how permafrost forms or thaws. Changes in permafrost are important because permafrost affects buildings and other infrastructure, regulates shrub growth [24], topography [25, 26], erosion [27, 28], and lake formation [29, 30].

LOCAL OBSERVATIONS

Nearly 80% of Nuiqsut interviewees said the permafrost is changing. Nearly 40% said there is less permafrost now than there used to be, and another 23% said there is more exposed permafrost (Figure 10).

Discussions around permafrost can be challenging because when residents report seeing more permafrost this could be associated with less permafrost because it is now exposed and likely to thaw. Some of those who reported that permafrost is thawing told us they have seen this trend over their entire lifetime. Figure 11 is a Nuiqsut hunter’s photo of an area of tundra where thawing permafrost has caused the ground to drop. “The permafrost is melting fast. Every year wintertime … my house is not level … I see a crack … It wasn’t like that in the 70s, 80s, and 90s.” Interviewees told us they are seeing more permafrost wedges (i.e. frozen ground) exposed by breakup and erosion along rivers, especially along the Colville River after breakup. They reported that exposed permafrost along riverbanks can make rivers wider by melting the bank away, but also ice during breakup can make the river wider too. However, it does not generally cause problems for people unless it blocks the river.

One respondent observed that on the Itkillik River, “Mainly on the south side that’s where all the erosion is changing … You can even see permafrost.” They added about the Colville River, “We didn’t usually see any permafrost, you know, but right now you can see a lot of permafrost on the Colville River, after the breakup it starts eroding.”

Interviewees said problems do arise when thawing permafrost affects ice cellars and shifts ground beneath cabins and other structures. “We put all our whale and whatever meat we had [in an ice cellar] when I was growing up, every family had an ice cellar and now it’s impossible to maintain one,” said one interviewee. Those we interviewed have noticed that thawing permafrost can create caves high in the riverbanks, holes in the ground, and mushy ground, with the latter caused when ice-rich permafrost thaws. An interviewee told us, for example, that an area outside Utqiagvik “used to be an ice pocket before, but then it was exposed to that warmth and it melted that permafrost. That ice bubble that used to be under the ground is [now] gone and it forms a small pond.”

SCIENTIFIC STUDIES

Studies show that reduced snow cover and warmer winter temperatures are contributing to thawing permafrost.
In 2012, record high temperatures occurred at most permafrost stations along the Dalton Highway on the North Slope [25]. The effects of recent higher temperatures on permafrost are evident in several ways. For example, ice on lakes is becoming thinner and sometimes does not freeze all the way to the bottom, which enables permafrost under the lake to thaw faster in the summer months [31]. Both interviewees and scientists have observed that some lakes are getting bigger and others smaller as permafrost thaws [29, 31, 32]. Scientists say that lakes can grow when permafrost begins thawing around them [33] but might also later drain as ice wedges around them thaw [30].

Studies show that thawing permafrost also affects rivers, as Nuiqsut interviewees told us. Figure 12 shows how thawing since 1948 has contributed to erosion, with pieces of the Itkillik’s bank falling off into the river and widening its channel [34].

Houses are not the only structures affected by melting permafrost. Oil and gas pads, roads, and other structures are also negatively impacted [35, 36]. However, it is sometimes difficult to know whether changes in permafrost are due to climate or to the oil and gas activities themselves. Residents and scientists have noticed that human activities like spills and ice roads can influence the landscape (Figure 13; [35]).
CHANGES - LAKES

LAKES

Key Finding: Interviews with residents and findings from scientific research indicate that winter ice on lakes is now thinned because of warming temperatures. Both indicate that some lakes are draining or getting smaller, and both link this, in part, to changes in permafrost.

Hundreds of lakes and ponds dot the tundra around Nuiqsut. Changes in lakes, like changes in vegetation, are a result of many factors, including changes in temperature and precipitation as well as lake depth, characteristics of the underlying ground, the presence of permafrost, and connectivity to other lakes [32, 37, 38].

LOCAL OBSERVATIONS

Half of the Nuiqsut residents interviewed reported that there are fewer lakes in the area, or that lakes have gotten smaller (Figure 14).

The other interviewed residents’ opinions were divided. Some saw no change (21%) and others thought lakes had grown (17%). Residents believe that some changes in lakes are part of a natural process, while others are due to oil and gas development and to changes in climate.

Many of those interviewed stated that lakes go through cycles and change in size. One example of a continuing cycle is when rivers meander and cut into lakes causing them to drain, a process hydrologists call “lake tapping” [36]. However, the creation of lakes was not mentioned as often, and was attributed to floods or melting permafrost. When asked about erosion, one resident mentioned that a lake they visited during moose season is “way down now” because it became connected to the river and drained out. Others reported seeing animals on riverbanks, but were unable to pursue them with boats due to low water levels and erosion (Figure 15).

Warm, dry summers are also causing some shallow lakes to dry up faster in the summer. “All the shallow lakes are now drying up when there is hardly any rain during the summer, when it heats up in July... most of the shallow lakes is now drying up faster,” reported one resident. Meanwhile, some lakes have increased in size by connecting to small ponds around them. One resident commented that people typically stick to river travel in the summer, so residents have limited knowledge about the state of lakes in the summer that are distant from rivers.

Overall, interviewees reported that lake changes are having little effect on subsistence hunting, although they did report four wheelers/ATVs and snowmachines getting stuck in drained lakes, as there are “sink holes in the winter and quicksand-like grass in the summer on lakes that are drying up.” Draining lakes can also leave peat bogs or pits where vegetation covers water and slow-moving vehicles can get stuck.

Some interviewees were concerned about oil companies’ use of water to create ice roads for nearby oil field operations.

Local Perspectives: How have lakes changed?

<table>
<thead>
<tr>
<th>Lakes (n = 24)</th>
<th>21%</th>
<th>13%</th>
<th>50%</th>
<th>16%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent of people</td>
<td>0%</td>
<td>20%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>No Changes</td>
<td>Other</td>
<td>Fewer/Smaller</td>
<td>More/Bigger</td>
</tr>
</tbody>
</table>

Figure 14. Results from interviews with Nuiqsut residents about how lakes have changed over their lifetimes.
One interviewee told us, “The lakes were full [before Alpine oil field in 2000], but today they are less because every year during the ice road season they are pumping more and more water from the lakes, and that is dramatically changing, you know.”

Others said that warmer winters have resulted in thinner ice on ponds. Another reported a somewhat different observation about lake changes: “All the shallow lakes are now drying up when there is hardly any rain during the summer.”

**SCIENTIFIC STUDIES**

*Research shows both losses and gains in lake area in northern Alaska over time [29, 31-33].*

Researchers studying a region that includes Nuiqsut observed an overall slight loss of lake area (less than 1%) during the period 1999 to 2014 [33].

Even though the size of the lakes may not be changing, lakes are changing in other ways. Researchers agree with Nuiqsut residents that ice on lakes has gotten thinner, and they believe the decline in sea ice, linked to warming temperatures, has contributed to thinning ice on lakes in northern Alaska. One study shows that there were 16% fewer lakes around Nuiqsut that froze through to the bottom in 2011 than there were in 1980 [38]. Scientists have documented that when lakes collapse and drain because of melting permafrost, shrubs often grow in the lakebeds (Figure 16, [24, 33]).
CHANGES - BREAKUP, RIVERS, & EROSION

BREAKUP, RIVERS, AND EROSION

Key Finding: Most Nuiqsut residents interviewed said there is more erosion than there used to be, and that increased erosion contributes to changes in river channels and gravel bars. This observation is also supported by scientific studies.

People’s ability to travel on rivers and reach subsistence harvesting areas affects when river gravel bars change in size and when river channels shift. The speed of spring river breakup can change the pattern of rivers and can influence erosion as well. Residents and scientists agree that rivers are dynamic and constantly changing, and that breakup, on average, now occurs both earlier and faster than in the past.

LOCAL OBSERVATIONS

About 43% of interviewees reported that breakup is happening earlier than it used to, but close to 30% said there had been no change. More interviewees agreed about changes in erosion, with 55% saying there is more erosion now (Figure 17).

Interviewees who believe breakup is earlier say that it now takes place in May rather than June, but some also said that breakup has become more variable from year to year. One

Figure 17. Results from interviews with Nuiqsut residents about how breakup and erosion have changed over their lifetimes.

Figure 18. Erosion near Nigilik on the Colville River in 1982 (A) and 2015 (B). Photo A from Walker et al 1987 [39]; Photo B courtesy of Nuiqsut GPS community monitoring project.
respondent summarized the long-term change he has seen: “In the past before climate change, back in the 70s, early 80s, the weather ... was a little cooler, and it took a little bit longer for the ice to break up ... as we noticed the change in climate, the warmer weather, the river has broken up at least a week earlier than it used to back then.”

The pace of breakup influences the amount of erosion, deposit of sediment, and location of channels in rivers. Interviewees who were concerned about more and faster erosion around Nuiqsut said that erosion and changing river channels are linked: erosion brings more sediment into the river, which changes the river channels as it is deposited.

Interviewees said residents now need to find new river routes, as longtime routes have grown unreliable. Almost all interviewees (95%) noted changes in gravel bars, with half reporting that gravel bars have gotten larger. Many said these changes have had minimal effects on subsistence harvesting, because local people adapt and find new routes to harvesting areas. But they also noted that these have led to higher costs due to damage to propellers and bottom units on boat motors, and higher gas costs if using a jet propeller system. Rivers can also erode banks where hunting cabins are located, making it difficult to spend time on the land in traditional family use areas (Figure 18). Low water levels can also decrease access: “My cousin built a cabin on that river. It has now dried up and we can’t get to that cabin anymore. We can see the cabin, but we can’t get to it on the river because it’s blocked off.”

**SCIENTIFIC STUDIES**

*Data collected since the 1970s show that river breakup has been taking place earlier [40], coinciding with earlier springs [41].*

Studies on the Meade River on the North Slope have shown that breakups in the 1970s, when temperatures at night were much colder than in the day, resulted in large ice jams that tore at the banks of the river. More recent breakups on the Meade River, when temperatures are warmer, have been more gradual and produced fewer ice jams [42].

A study of breakup on the Kuparuk River on the North Slope from 2001 through 2010 showed significant range in dates, with breakups taking place between the last week in May and the second week in June and some years having multiple flood events and others none [41].

Similar to what our interviewees told us, satellite images show that rivers are very dynamic and channels can shift greatly from year to year (Figure 19). The Itkillik River had a major shift in 1995, and between then and 2010, sections eroded that were anywhere from 590 to 918 feet wide, with the fastest erosion clocked at 59 feet in a single year [34]. Scientists don’t fully understand how changes in breakup influence the rate of erosion and changes in gravel bars.
CHANGES – PLANTS

PLANTS

Key Finding: Both resident interviews and scientific data indicate different kinds of changes in vegetation in various areas around Nuiqsut, but there is no consensus about a clear trend in the growth and spread of vegetation.

Shrubs and willows grow in the Nuiqsut region, as do berries and wildflowers. Many factors influence the growth and spread of this vegetation. Changes in plants can affect the wildlife that feed on plants, as well as subsistence harvests.

LOCAL OBSERVATIONS

When asked whether they had seen changes in the amount of shrub growth around Nuiqsut, about 55% of interviewees agreed there had been changes. However, they disagreed about whether there was less or more shrub growth, with 45% saying there had been no change and 68% saying that willows around Nuiqsut have gotten bigger (Figure 20). A number of those we interviewed said larger willows have made some trails hard to use, prevented access to some areas, and made glassing for moose difficult. One harvester reported, “We used to go in some of those heavy willowed areas and now we can’t go through those areas because you can’t maneuver to go through the open area.” Oil and gas activity are also influencing plants. One interviewee reported that a 2012 gas blow-out and resulting spill of drilling mud at an exploratory well about 18 miles northeast of Nuiqsut affected the vegetation. “In the first couple of years it stayed brown during the summer, but it has just slowly started to turn green.”

SCIENTIFIC STUDIES

Satellite images and vegetation plots show both increases and decreases in shrubs on Alaska’s North Slope [44-46].

Changes vary greatly from place to place, and remotely sensed data, such as satellite images, cannot yet reliably distinguish between different species of shrubs. Willows have increased in some vegetation plots [47], while others have exhibited few changes in vegetation [48]. Researchers differ, just as Nuiqsut residents do, about whether there is a clear trend of change in vegetation.

Temperature, rain, snow depth, land use, topography, ground ice [48], animal browsing [40, 49], and erosion [50] can all influence the growth, amount, and types of plants in an area. Recent studies have found shrubs are now more

<table>
<thead>
<tr>
<th>Local Perspectives: How are the amount the shrubs changing?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount (n = 22)</td>
</tr>
<tr>
<td>45% No change</td>
</tr>
<tr>
<td>23% Other</td>
</tr>
<tr>
<td>14% Less</td>
</tr>
<tr>
<td>18% More</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Local Perspectives: How are the size of willows changing?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (n = 22)</td>
</tr>
<tr>
<td>23% No change</td>
</tr>
<tr>
<td>5% Other</td>
</tr>
<tr>
<td>5% Smaller</td>
</tr>
<tr>
<td>68% Bigger</td>
</tr>
</tbody>
</table>

Figure 20. Results from interviews with Nuiqsut residents about how shrubs and willows have changed over their lifetimes.
noticeable in areas of the North Slope where shrub extent has previously been documented [47]. For example, the photos in Figure 21 show an increase in shrubs along the Chandler River between 1948 and 2001. Northern Test Case researchers have also found that hares browsing, and to a lesser extent moose browsing, can influence shrub growth along the Colville River (Figure 21 & 22 [44, 51]).

Both residents and scientists travel large distances in the Nuiqsut area, so it is not surprising that both have reported seeing many changes, which sometimes differ depending on the location. Nuiqsut residents told us that as long as 45 years ago, Inupiat people of the North Slope noticed changes in the growth and location of shrubs. As one recalled, “According to my father, back in 1972 that first summer he saw some changes out here ... he said there never used to be willows out here along the river, but now they are 10 to 12 feet high.” Several interviewees also told us that shrubs now are taller on the Itkillik and Chandalar rivers, as well as at the Nuiqsut-area locations Sentinel Hill and Fresh Water Lake Road.

![Figure 21. Photos of the Chandler River in 1948 and 2001 show an increase in shrubs, especially alder. The black boxes and numbers are provided to match locations in the photos [44].](image)

![Figure 22. Evidence of snowshoe hare browsing on feltleaf willow. (A) Shortened stems that were evenly cut by hares, leaving a few unbrowsed tall standing stems. (B) A diagonal cut by hares. Photos taken from Zhou et al. 2017 [52](image)
Key Finding: Local observations and research findings both indicated that the number of moose around Nuiqsut has dropped, as has the number of caribou in the Central Arctic Herd. There is less agreement about reasons for changes, but scientists and residents agreed that animals may be affected by insect harassment, predators, hunting, and winter rain freezing on vegetation.

As plants change, so does animal habitat. Caribou and moose are the two most important subsistence resources Nuiqsut residents harvest [53]. People in Nuiqsut harvest and eat more caribou than moose. In winter, caribou eat mainly lichen [54], while moose eat willows [55]. Declines in lichen combined with increases in shrubs could mean less preferred habitat for caribou and increased habitat for moose [56].

LOCAL OBSERVATIONS

Most interviewees (65%) reported there are fewer moose around Nuiqsut now than in past years.

Those interviewed were more divided about changes in caribou numbers than moose numbers, with 33% reporting there are fewer caribou and another 33% saying there has been no change. Nearly half of residents said the number of snowshoe hares around Nuiqsut has stayed about the same (Figure 23, below).

Hunters and others who track caribou generally agree that their movements are unpredictable, but interviewees reported some general changes. Some residents have noticed thinner caribou, which they believe might be linked to hotter summers, when there are more mosquitoes and flies to harass the caribou. Some interviewees also reported a shift in caribou calving areas. One told us, “I’ve noticed … the meltwater road has changed the calving areas of the caribou. They calve further south from Nuiqsut.”

Interviewees also noted changes in the size of caribou groups moving near Nuiqsut. According to one respondent, “The caribou around this area have gotten leaner as compared to 15-20 years ago because the herds that used to come back then were big herds. We had 5,000 to 10,000-plus herds come through here. Nowadays we just see 300 to 500.” Many residents commented that oil and gas activities have negatively affected caribou in many ways: Disrupted habitat, roads influenced migration, planes flew low and disturbed caribou, and garbage has been left behind (Figure 24).

Unlike caribou, which migrate across the tundra of the North Slope, moose tend to utilize areas with shrubs and trees found around river corridors. Vegetation changes on the Colville River near Nuiqsut may affect moose numbers and distribution in that area. Of those who thought moose numbers have declined, some attributed the decline to an increase in wolf predation (on moose calves in particular) when caribou are not available. They also reported that more hunting by nonlocals and the disturbances caused by nearby oil and gas activities were affecting moose numbers. Some reported that movements and distribution patterns of both moose and caribou were different in the early 1990s, before there was extensive oil and gas activity in the area. Interviewees also stated that their harvests of caribou and moose were impacted by low-flying planes and helicopters driving animals away.
Other interviewees reported that it is harder to see moose because shrubs have gotten taller. Some cited changing weather conditions as another factor. One person told us, “A couple of winters ago we had rain right in the middle of winter, and the temperature went way up and then it would rain over everything and then it would freeze, so everything’s got ice and it was harder for [moose] to get food ... It was like that two years in a row.”

**SCIENTIFIC STUDIES**

*Animal counts show that the Teshekpuk, Western Arctic, and Central Arctic caribou herds have declined in recent years, and attribute the decline to a number of reasons.*

The Teshekpuk herd began to decline in 2011, with poor nutrition and increased predation cited as possible causes [57]. From 2000 to 2008, the Central Arctic herd increased. The herd and peaked at 70,000 animals, from 2008 to 2010. The herd has since decreased to around 22,000 animals [58,59]. The Western Arctic herd has also declined significantly in the past ten years [60].

The distribution and movements of caribou may also be changing.
Research has shown that in the past the Central Arctic herd moved its calving grounds away from roads and oil field facilities, but did use those areas after calving [61]. Other studies have cited additional factors that may affect caribou and other animals, such as predation, insect harassment, and icing events [62, 63], all of which were also noted by Nuiqsut Residents (for examples see Figure 25). High female mortality rate is one explanation for the decline of the Central Arctic herd, but there is a lot of uncertainty on why. Biologists with the Alaska Department of Fish and Game (ADF&G) have not found any trends in the weight of caribou they capture, and say they need to learn more about how insects influence caribou [64]. Recent research shows that the highest aircraft activity is mostly located near human activity like Nuiqsut and a nearby industrial complex, with local harvesters reporting that aircraft is negatively affecting caribou and caribou hunting [64]. Harvest studies show that Nuiqsut residents harvest caribou from three herds: the Teshekpuk, accounting for about 86% of the harvest; the Central Arctic, making up about 13%; and the Western Arctic, 1% [53].

**Scientific surveys and local observations both indicate that moose populations in the Colville and Itkillik river drainages, the sites of most Nuiqsut resident moose harvests [65], have been decreasing since the mid-2000s (Figure 26, [49, 65]).**

Between 2008 and 2011, ADF&G found a 50% decline in moose numbers on the western side of Game Management Unit 26B, which is east of Nuiqsut [65]. Studies show that across the Arctic shrubs are expanding [46, 51], but around Nuiqsut the main change is the increased growth and height of shrubs, which agrees with residents’ observations (Figure 9). The increased growth of shrubs can provide food for moose if they do not grow out of the reach of moose (9 ft.). Taller shrubs provide moose some protection from predators. Around Nuiqsut, moose are on the northern edge of suitable habitat, and even in good years, have a very short summer to feed on leafy plants [66]. Harsh winters may be influencing moose numbers around Nuiqsut [49]. A long winter can make it very hard for moose to get enough food and increases the vulnerability of moose – especially young moose – to predators.
The observations of Nuiqsut residents and findings of science-based research indicate that the climate, land, water, and animals around the community of Nuiqsut are changing, and that unpredictability is increasing. The best-documented changes are rising temperatures across the Arctic, and those rising temperatures are at the heart of many of the changes residents and scientists have observed.

While residents and scientists agree on many of the how, why, and what is changing, there are also differences in some areas. Understanding the basis for each perspective provides insights and potentially offers a more complete picture of change. As residents pointed out, compared to many local harvesters, researchers only spend a fraction of their time on the land and in direct contact with what they are studying. On the other hand, researchers use methods that give a view of change not available to local residents. At workshops with community leaders and researchers, many more topics were discussed. Among them were the implications of climate change to human health and the need for Nuiqsut to have a greater role in future studies.

Our research suggests that similarities and differences in knowledge of change can inform what areas need more communication between researchers and local residents, which can ultimately improve our overall understanding of present and possible future conditions. The findings about change reported here also raise important questions about the future effects of changes on the health and well-being of the people of Nuiqsut and the environment on which they depend. Among those questions are how climate change may affect the health of people and animals; how changes in the ecosystem will affect access to subsistence hunting and fishing areas; and how oil and gas development may interact with and influence climate change?

This report only focused on the observations of change as held by those Nuiqsut residents interviewed. It did not document in detail the rich traditional knowledge of Nuiqsut residents. The findings of this report do support the critical need for future monitoring and research that is conducted in close collaboration between local residents and researchers, and the need to co-produce knowledge in ways that informs decision-making and people’s ability to respond and adapt.

VI. NORTHERN TEST CASE RESEARCHERS

Gary Kofinas, UAF, Principal Research Scientist / Professor Emeritus, and Northern Test Case project leader (social-ecological systems), gary.kofinas@alaska.edu

Todd Brinkman, UAF, Assistant Professor of Wildlife Biology, and Northern Test Case co-leader (human dimensions of wildlife management), tjbrinkman@alaska.edu

Jennifer Schmidt, UAA, Assistant Professor of Natural Resource Management and Policy (integration and synthesis), jjschmidt@alaska.edu

Christopher Arp, UAF, Research Assistant Professor (hydro-ecology), cdarp@alaska.edu

Berill Blair, The Polar Connection (risk analysis), b.blair@polarconnection.org

Eugenie Euskirchen, UAF, Research Associate Professor (terrestrial ecology), seeuskirchen@alaska.edu

Jason Leppi, The Wilderness Society, (watershed ecology), jason_leppi@tws.org

Naomi O’Neal, UAF, former Research Technician, noneal687@gmail.com

Anna Liljedahl, UAF, Research Associate Professor (hydrology), akliljedahl@alaska.edu

Ken Tape, UAF, Research Associate Professor (ecology), kdtape@alaska.edu

Sarah Trainor, UAF, Assistant Professor (social-ecological systems and sustainability), sarah.trainor@alaska.edu

Mark Wipfli, UAF, Professor of Freshwater Ecology (fisheries), mwipfli@alaska.edu

Jiake Zhou, UAF, PhD student (wildlife ecology), jzhou2@alaska.edu
VII. REFERENCES


