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Vulnerability of Subsistence Systems Due to Social and Environmental Change: A Case Study in the Yukon-Kuskokwim Delta, Alaska

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ABSTRACT: Arctic Indigenous communities have been classified as highly vulnerable to climate change impacts. The remoteness of Arctic communities, their dependence upon local species and habitats, and the historical marginalization of Indigenous peoples enhances this characterization of vulnerability. However, vulnerability is a result of diverse historical, social, economic, political, cultural, institutional, natural resource, and environmental conditions and processes and is not easily reduced to a single metric. Furthermore, despite the widespread characterization of vulnerability, Arctic Indigenous communities are extremely resilient as evidenced by subsistence institutions that have been developed over thousands of years. We explored the vulnerability of subsistence systems in the Cup'ik village of Chevak and Yup'ik village of Kotlik through the lens of the strong seasonal dimensions of resource availability. In the context of subsistence harvesting in Alaska Native villages, vulnerability may be determined by analyzing the exposure of subsistence resources to climate change impacts, the sensitivity of a community to those impacts, and the capacity of subsistence institutions to absorb these impacts. Subsistence resources, their seasonality, and perceived impacts to these resources were investigated via semi-structured interviews and participatory mapping-calendar workshops. Results suggest that while these communities are experiencing disproportionate impacts of climate change, Indigenous ingenuity and adaptability provide an avenue for culturally appropriate adaptation strategies. However, despite this capacity for resiliency, rapid socio-cultural changes have the potential to be a barrier to community adaptation and the recent, ongoing shifts in seasonal weather patterns may make seasonally specific subsistence adaptations to landscape particularly vulnerable.

Key words: Yukon-Kuskokwim Delta; Alaska; Alaska Native villages; vulnerability; resilience; subsistence; Yup'ik; Cup'ik

RÉSUMÉ. Les collectivités autochtones de l'Arctique sont classées comme étant fortement vulnérables aux incidences du changement climatique. L'éloignement des collectivités de l'Arctique, leur dépendance des espèces et des habitats locaux de même que la marginalisation historique des peuples autochtones intensifient cette vulnérabilité. Toutefois, la vulnérabilité est le résultat de conditions et de processus divers sur le plan historique, social, économique, politique, culturel, institutionnel, environnemental et des ressources naturelles. Il est difficile d'attribuer la vulnérabilité à un seul aspect. Malgré cette vaste caractérisation de la vulnérabilité, les collectivités autochtones de l'Arctique sont extrêmement résilientes, comme en attestent les modes de subsistance qui se sont développés au fil de milliers d'années. Nous avons exploré la vulnérabilité des systèmes de subsistance du village cup'ik de Chevak et du village yup'ik de Kotlik du point de vue des dimensions saisonnières fortes de la disponibilité des ressources. Dans le contexte des récoltes de subsistance des villages autochtones de l'Alaska, la vulnérabilité peut être déterminée au moyen de l'exposition des ressources de subsistance aux incidences du changement climatique, de la sensibilité d'une collectivité à ces incidences et de la capacité des institutions de subsistance à absorber ces incidences. Les ressources de subsistance, leur saisonnalité et les incidences perçues de ces ressources ont été étudiées au moyen d'entrevues semi-structurées et d'ateliers participatifs d'établissement de calendrier. Selon les résultats, bien que ces collectivités soient aux prises avec des incidences disproportionnées de changement climatique, l'ingéniosité et l'adaptabilité des Autochtones pavent le chemin à des stratégies d'adaptation convenant à leur culture. Cependant, malgré cette capacité de résilience, les changements socioculturels accélérés ont la possibilité de faire obstacle à l'adaptation collective, sans compter que la variation continue des tendances climatiques saisonnières peut rendre les adaptations de subsistance saisonnières au paysage particulièrement vulnérables.

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Mots clés : delta Yukon-Kuskokwim; Alaska; villages autochtones de l'Alaska; vulnérabilité; résilience; subsistance; Yup'ik; Cup'ik

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INTRODUCTION

The Yukon-Kuskokwim Delta (YKD) is a vast, flat, marshy lowland plain supporting a diverse and abundant wildlife population and some of the largest centers of Indigenous populations in Alaska. This region has been home to the Yup'ik and Cup'ik people for thousands of years. Archaeological evidence suggests habitation in this area dates to between 2500 and 3500 BP (Shaw, 1998). The Cup'ik village of Chevak and Yup'ik village of Kotlik—the communities represented in this study—are both located in the YKD. The rich and varied resource base of the Bering Sea coast has allowed for the development of complex cultural traditions (Fienup-Riordan, 2000). As many as 15 000 people may have lived in the YKD at the time of Euro-American contact (Fienup-Riordan, 2000). Despite dramatic declines in population, resulting from disease epidemics in the nineteenth and twentieth centuries, today the YKD is home to 25 000 people, 85% of whom are Yup'ik or Cup'ik Natives (U.S. Fish and Wildlife Service, 2014).

Alaska has warmed twice as fast as the rest of the United States over the past 60 years with mean annual temperatures rising six degrees Fahrenheit in winter months and projected to rise two to four additional degrees by 2050 (Chapin et al., 2014). The YKD is vulnerable to the degradation of permafrost, seasonal flooding, and sea-level rise (Burkett and Kulser, 2000). Due to the reduction in autumn sea ice that historically provided a buffer against storms, severe storms coming across the Bering Sea are impacting coastal communities (U.S. General Accounting Office, 2003). The combined effects of inundation, salinization, and sedimentation may cause storm-driven tides, which often reach far inland, to have dramatic impacts on plant communities, freshwater resources, permafrost stability, and landscapes used by wildlife (Terenzi et al., 2014).

Subsisting off the land is a source of pride and a central component of Yup'ik and Cup'ik cultural identity and values (Ballew et al., 2006; Johnson et al., 2009). Subsistence harvesting in the YKD is based on a seasonal round of available resources. Wolfe (1981:36) described the demographic pattern of the region as, "…dynamic movement within seasonal configurations." While movement across the landscape to exploit the locations where particular resources are most plentiful still exists, long duration seasonal subsistence camps are, for most, a thing of the past (Loring and Gerlach, 2010; Fienup-Riordan et al., 2013; Herman-Mercer et al., 2016; Penn et al., 2016). Instead, groups of hunters or families travel to collect specific resources in day or multi-day trips. Subsistence harvesting in the YKD, as in other Alaska Native villages (ANV), is supplemented by the cash economy and must be balanced against the time commitments of wage labor (Burnsilver et al., 2016). Employment in YKD villages is primarily in the public sector with educational, health, and social services being the largest industries. According to U.S. Census Bureau (2013 – 17) estimates in 2017, 60% of the population of Chevak 16 years or older participated in the labor force, with 50% of labor participants working in government. In Kotlik, U.S. Census Bureau (2013 – 17) estimates show that 46% of those 16 years or older participated in the labor force in 2017 and 76% of those in the workforce were employed in government. Cultural shifts regarding subsistence practices are driven by changing technologies (transportation), household schedules (work and school), and a changing climate (Herman-Mercer et al., 2016).

Subsistence harvesting in Alaska is regulated by a complex system of state and federal institutions (Caulfield, 1992; Huntington, 1992) that began with the passage of the Alaska Native Claims Settlement Act by the United States Congress, in 1971. This act extinguished both Indigenous land claims and hunting and fishing rights. In recognition of the importance of subsistence traditions and lack of legal protection for those traditions, both the state of Alaska and the federal government passed laws intended to protect subsistence use of fish and game resources by giving subsistence use priority over other interests (i.e., commercial and sport). Subsistence use is a codified legal term in the state of Alaska (ADFG, 2016a), defined by the Alaska National Interest Lands Conservation Act. The Alaska Board of Fisheries (BOF) and the Alaska Board of Game manage subsistence on state and private lands, whereas the Federal Subsistence Board manages subsistence on federal public lands—roughly 60% of the state (ADNR, 2000). Adding to this complexity, salmon harvesting on the Yukon River, which crosses the Canadian border, is further regulated by international treaty obligations. In 1985, the Pacific Salmon Treaty was ratified by the United States and Canada mandating "escapement"—the upstream passage of a certain number of salmon into Canadian waters each year.

In major scientific assessments (Chapin et al., 2014; Gray et al., 2018) and regional studies (ACIA, 2004), Arctic Indigenous communities are classified as highly vulnerable to climate change impacts (Ford et al., 2015). The remoteness of Alaskan and other Arctic villages, their dependence upon local species and habitats, and the historical marginalization of Indigenous peoples enhance this characterization of vulnerability. Lavell et al. (2012:32) describe vulnerability as, "…a result of diverse historical, social, economic, political, cultural, institutional, natural resource, and environmental conditions and processes."

Despite being categorized as vulnerable, Arctic Indigenous communities are extremely resilient (Wildcat, 2009; Norton-Smith et al., 2016). Resilience is defined as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure" (IPCC, 2007:880). A hallmark of Arctic Indigenous resilience are the subsistence institutions that have been developed and fine-tuned over thousands of years (Ford et al., 2015).

Subsistence institutions are the broad informal rules, habituated behaviors, values, norms, and customs that govern society and manage common pool resources (Adger, 2000; West and Ross, 2012). Arctic Indigenous subsistence institutions are built upon the utilization of a portfolio of resources (Robards and Alessa, 2004; Brinkman et al., 2007; Hansen et al., 2013), food sharing practices (West and Ross, 2012; BurnSilver et al., 2016; Kofinas et al., 2016), and community resource pooling (West and Ross, 2012; Brinkman et al., 2016). These characteristics have allowed Indigenous communities to be resilient, thrive in the sometimes harsh and variable Arctic environment (West and Ross, 2012; Ford et al., 2015), and protect against the impacts of year-to-year variation in resource availability (Wolfe, 1981). In the context of subsistence harvesting in ANV, vulnerability may be determined by analyzing exposure of subsistence resources to climate change impacts, the sensitivity of a community to those impacts, and the capacity of subsistence institutions to absorb these impacts. Thus, the vulnerability of subsistence systems in ANV depends upon interactions between government regulations, cultural identity, social norms, and values, as well as climate change. Seasonality is embedded in subsistence strategies because seasons regulate natural resources (e.g., harvesting of plants, migration of fish and animals) and the use of these resources is regulated by state and federal seasonal restrictions. Our objective was to examine how climate change impacts may contribute to the vulnerability of two ANV located in the YKD—Chevak and Kotlik—in the context of current subsistence practices and historical subsistence institutions, through the lens of the strong seasonal dimensions of resource availability.

METHODS

Study Area

This research took place in the ANV of Chevak and Kotlik in the YKD (Fig. 1). Chevak is a Cup'ik community with a population of 1060 and Kotlik is a Yup'ik community with a population of 629, as estimated by the U.S. Census Bureau, Population Division (2017). The authors have been working in these communities for several years with Tribal Council staff and community members on community-based water-quality projects, permafrost monitoring projects (Schuster and Maracle, 2010; Schuster et al., 2011), and participatory research projects. The work presented here is part of a larger project, Strategic Needs of Water on the Yukon (SNOWY) (Herman-Mercer and Schuster, 2014), resulting from discussions that began at the Yukon River Inter-Tribal Watershed Council's biennial summit meeting in 2009, and subsequent meetings and workshops between researchers, community, and Tribal Council representatives. SNOWY was reviewed by the University of Alaska, Anchorage Institutional Review Board and approved by the participating communities and Tribal Councils. The data and results of SNOWY have been shared with the participating villages in a variety of formats, including in-person presentations in the communities, as well as online and paper reports that serve to both store and share data and information with the communities.

The villages of the YKD are remote, located far from Alaska's road system, with travel in and out of the region accomplished via small planes. Within the villages there are gravel roads and wooden boardwalk systems. These roads and boardwalks end outside city limits, which are typically between 4 and 12 km^2. The marshy conditions make walking long distances difficult and impact movement using all-terrain vehicles (ATV) during the snow-free months. Long distance travel is only possible by boat, traversing the many rivers and sloughs that dominate the landscape during the open water season (roughly June to October) or by snowmobile when the water is frozen and the tundra covered by snow.

Field Methods

Semi-structured interviews and participatory mapping-calendar workshops were held in Chevak and Kotlik to investigate subsistence resources, their seasonality, and perceived impacts to these resources. Participants were recruited for this research with the help of our local partners in the Tribal Councils in each village. Additionally, a community dinner was held in each village where a brief presentation about the project was given, the researchers were introduced to the broader community, and community members were encouraged to participate in the project. An honorarium was provided to participants to compensate them for their time and thank them for sharing their knowledge.

Some community members participated in both interviews and the participatory mapping-calendar workshop while others only participated in one activity. Table 1 shows the number of participants and the gender of those community members who participated in an interview, a participatory mapping-calendar workshop, or both from each village. The semi-structured interviews (Schensul et al., 1999) utilized a question guide structured thematically to include broad questions about seasonality in weather patterns and subsistence resources (see Herman-Mercer et al., 2016 for question guide). The interviews were open-ended with the flexibility to be guided by the participant's interest and knowledge of the subject (Huntington, 1998).

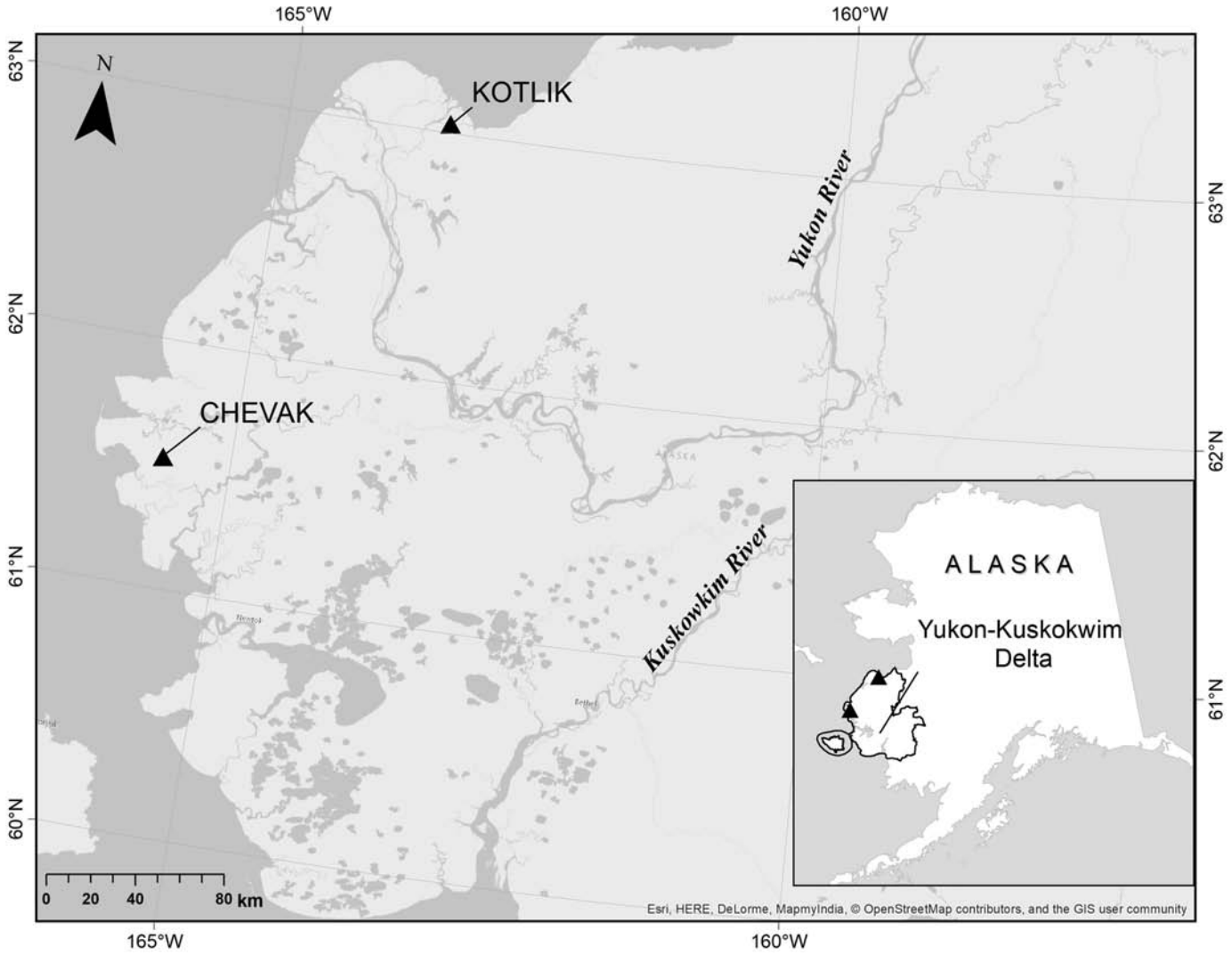

FIG. 1. Study location with inset of the state of Alaska. Basemap credit: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

During the participatory mapping-calendar workshops, participants were divided into small groups and asked to create a calendar of subsistence resources categorized by the season that resource is harvested. For this project a four-season calendar was used—we asked participants to describe resources for winter, spring, summer, and fall. The onset of each season was not dictated; however, seasonal timing was explored in the interviews. Next, each group was assigned a season and asked to create a map of subsistence resource areas for that season. Participants hand-drew the map and the larger group was asked to agree on a set of key landmarks that would be placed on each map for comparability. Asking participants to hand-draw the maps, as opposed to giving them a satellite-derived base map to draw on, was deemed the best way to ensure that the maps were not bounded or biased in any way by the investigators. Instead, participants drew maps with spatial extents matching the subsistence resources for a season and indeed, in some cases groups taped multiple sheets of paper together to increase the extent of their drawing. Following the workshop, Global Positioning System (GPS) points of the key landmarks were collected to assist in geo-referencing the maps. Seasonal calendars created by each group during the participatory mapping-calendar workshops were later combined to create a poster for each village, which was taken back to the communities for validation. Participants discussed the resources displayed on the calendars and made corrections and additions where necessary.

Analysis

Interview data were reduced and organized by applying codes to the transcripts. An a priori codebook was developed based on the themes present in the interview question guide. These themes included the onset of seasons and seasonality of weather patterns, subsistence resources, and any changes in either of these patterns as noted by the respondents. The result of this coding was text grouped by season, subsistence resources, and change as associated

TABLE 1. Number of community members (by gender) who participated in interviews, mapping workshops, or both.

Village	Gender	Interview participants	Participatory mapping-calendar workshop participants	Participated in both interviews and workshops	Participants total
Kotlik	Male	11	10	5	
	Female	10	6	3	
					29
Chevak	Male	7	5	3	
	Female	7	8	3	
					21

with seasonal weather patterns, any change in a subsistence resource, or changes in community harvesting patterns. Using the a priori-developed codes allowed for a grounding in the data (Corbin and Strauss, 1990) and the creation of a posteriori codes: recent impact, location, and other. The a posteriori codes were applied to the clusters of text that resulted from the initial coding. Recent impact included any impact on the resource described by participants (e.g., flooding, erosion, access). The location code was used for text describing a resource's proximity to the village. Finally, "other" was used to code text describing any other salient information about that resource (e.g., gender divisions or harvesting strategies).

In addition to applying codes to the transcripts to determine which subsistence resources were most prominently discussed by our participants, we also created a list of subsistence resources identified in the hand-drawn maps and community-validated subsistence calendars. Interview transcripts were queried for specific subsistence resources in this list using the Find tool in Microsoft Word. Resources mentioned in at least half of the interviews were considered the most prominent.

Hand-drawn maps were manually digitized using the GPS locations of known landmarks chosen by participants during the workshop, as well as by matching environmental features displayed on hand-drawn maps (rivers, sloughs, volcanoes, and mountain ranges) with their counterparts on a satellite image (U.S. Geological Survey, 2016). Once the digital image had been orientated by landmarks and environmental features, point locations of subsistence resources were added. While the precision in the placement of points representing subsistence resources may be low, this method proved valuable in understanding the differing spatial extents and density of subsistence harvesting locations in each season, which is most important in the results presented here. Straight-line distances were calculated from point locations of subsistence activities to the communities' schools, which are generally centrally located in each village.

RESULTS

Prominent Subsistence Resources

The activities of bird hunting, egg gathering, and seal hunting were the most prominent spring subsistence activities in both Chevak and Kotlik. In Chevak, coastal fishing for herring, collecting herring eggs, and gathering wild greens are prominent springtime activities that the participants from Kotlik did not indicate they pursue. Subsistence salmon fishing and berry picking are the most prominent summer subsistence activities as indicated by participants of both communities.

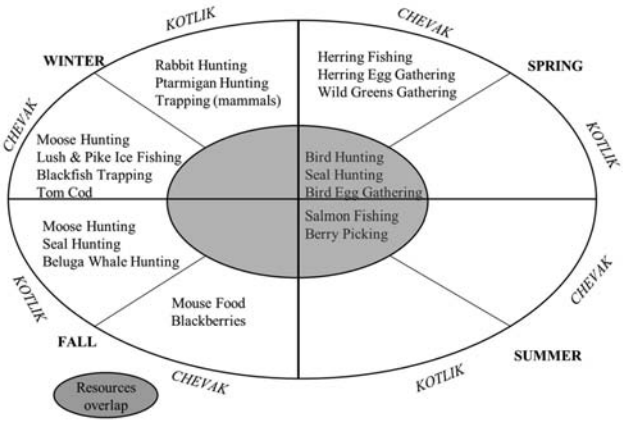

FIG. 2. Prominent subsistence species by village and season as identified in interviews, seasonal calendars, and subsistence maps. Areas of overlap between villages are shown in the center gray oval.

Figure 2 displays prominent subsistence resources for the villages of Chevak and Kotlik, revealed by text query analysis of the interview transcripts and their associated season of harvest, as indicated on the seasonal calendars. The outer oval represents seasonal subsistence harvesting, with each season partitioned to represent each village. The inner oval, which is not partitioned by village, highlights the resources that were identified as prominent in both villages during the same season. The most prominent species in each village show some overlap in spring and summer, but differ in winter and fall.

All the prominent winter and fall resources displayed in Figure 2 were identified during interviews in both communities. This result indicates that both communities are utilizing these resources, but the relative importance and timing of activity differs. Mouse food (roots and stems of sedges and cotton grass gathered by tundra lemmings) is a prominent fall resource in Chevak. However, mouse food is only mentioned by older generations in Kotlik and is not a prominent resource. When asked specifically about how many people gather mouse food, Theresa Prince of Kotlik said, "Not the young ones…." In Kotlik, participants

described the trapping of mammals, for both sustenance and fur, as a prominent activity that elders pursued in the past and young adults actively engage in today. However, all discussion of trapping in Chevak focused on historical trapping, with interview participants explicitly stating that trapping is not something practiced presently. Andrew Boyscout, of Chevak, reported: "The last two trappers that I know of was, could be 20 years ago, 15, 20 years ago."

Moose is one of the most prominent subsistence resources in both communities, but at different seasons. In Chevak, moose are harvested in winter, whereas in Kotlik moose harvesting is primarily a fall activity. U.S. Fish and Wildlife Service data show the expansion of moose into the YKD beginning in 1950, though the habitat surrounding Kotlik and Chevak was designated as moderate and the moose population considered low density (U.S. Fish and Wildlife Service, 1988). According to our interview participants, moose have only been available in the YKD since roughly the 1980s. During the 1985–86 harvest season, 52 moose were reported harvested in Game Management Unit (GMU) 18, which represents 29 villages, including Kotlik and Chevak (U.S. Fish and Wildlife Service, 1988). In 2008, 132 male moose were reported harvested in a single village (Emmonak) in the same GMU (ADFG, 2016b). This increase in animals harvested highlights the large number of moose that have moved into this region in recent decades. Prior to the 1980s, moose were only harvested by those who could afford the long distances required to find them: "Usually only the rich guys were able to afford it all the way up [into the lower Yukon River area]" (Robert Okitikun, Kotlik).

Location

The location of subsistence resources is important for understanding mobility and distance, which were identified by participants as limiting seasonal factors. Figure 3 presents boxplots of the distances traveled in pursuit of subsistence resources for each village and season, calculated from seasonal subsistence maps. The boxplots represent all subsistence resources placed on each map (shown as "n" after the season's name in Fig. 3), as opposed to only the most prominent resources shown in Figure 2. The hand-drawn nature of the maps resulted in some maps representing many more subsistence activities than others. It is therefore important to keep in mind when looking at the boxplots that participants from Chevak only placed two subsistence resources on the map they created for spring. Participants in Kotlik did not place any subsistence resources on their winter map, instead they drew an extent map that highlighted the distances traveled for subsistence purposes; this did not include the specific locations. Despite these limitations, the boxplots (Fig. 3) and the digitized maps (Figs. 4 and 5) show that subsistence harvesting is at its greatest spatial extent in the snow-covered months of winter for both villages and is more circumscribed during the fall for Chevak and the spring for Kotlik.

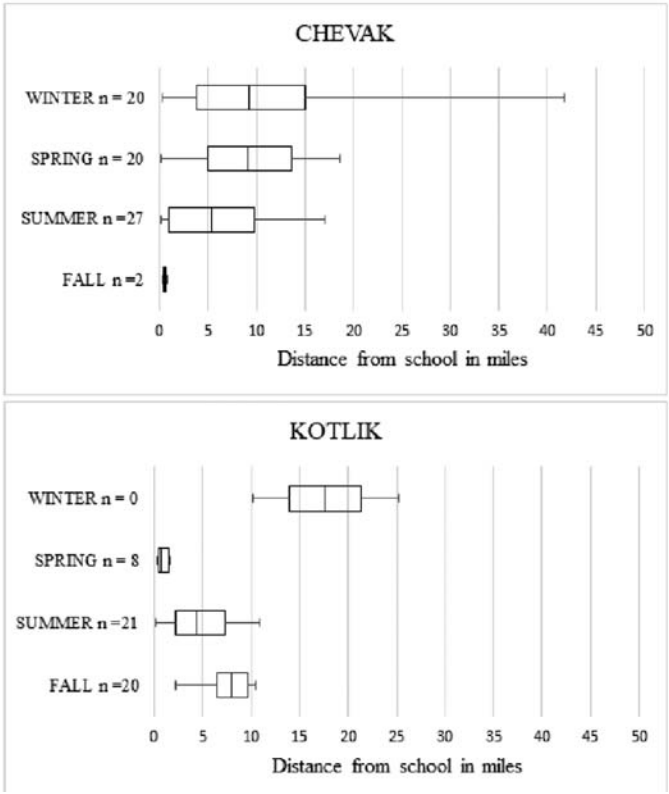

FIG. 3. Box plots showing seasonal distances traveled in pursuit of subsistence resources for each season. The number of resources drawn on each map and used to create the box plot are shown as "n" next to each season.

Subsistence harvesters' hand-drawn maps reinforce the difference in seasonality and distance to moose populations for Chevak (a winter subsistence species) and Kotlik (a fall subsistence species). When asked if moose hunting took place nearby, one interview participant from Chevak stated, "No, we usually travel 40 miles northeast or close to 70 miles north depending on where we feel like going" (Sam Ulroan). Participants in Kotlik however stated that moose hunting took place close to the village: "Not far. Moose would come to our area here in Kotlik. And we travel up maybe five, ten miles out" (Benedict Aparezuk).

Recent Impacts

A comprehensive list of impacts to prominent subsistence resources identified by participants is presented in Tables 2 and 3. Recent impacts included a late thaw in the spring of 2014, which affected the ability to fish for herring in Chevak, as the fish migrated past the village while sea ice was still present. This late thaw impacted bird hunting in Kotlik, as hunters were unable to use boats to access bird hunting locations. Other impacts discussed by interview participants were ice conditions affecting seal hunting, floods affecting mouse food gathering in Chevak and trapping fur-bearers in Kotlik, as well as low tide in the fall, impacting boat access to moose hunting locations in Kotlik.

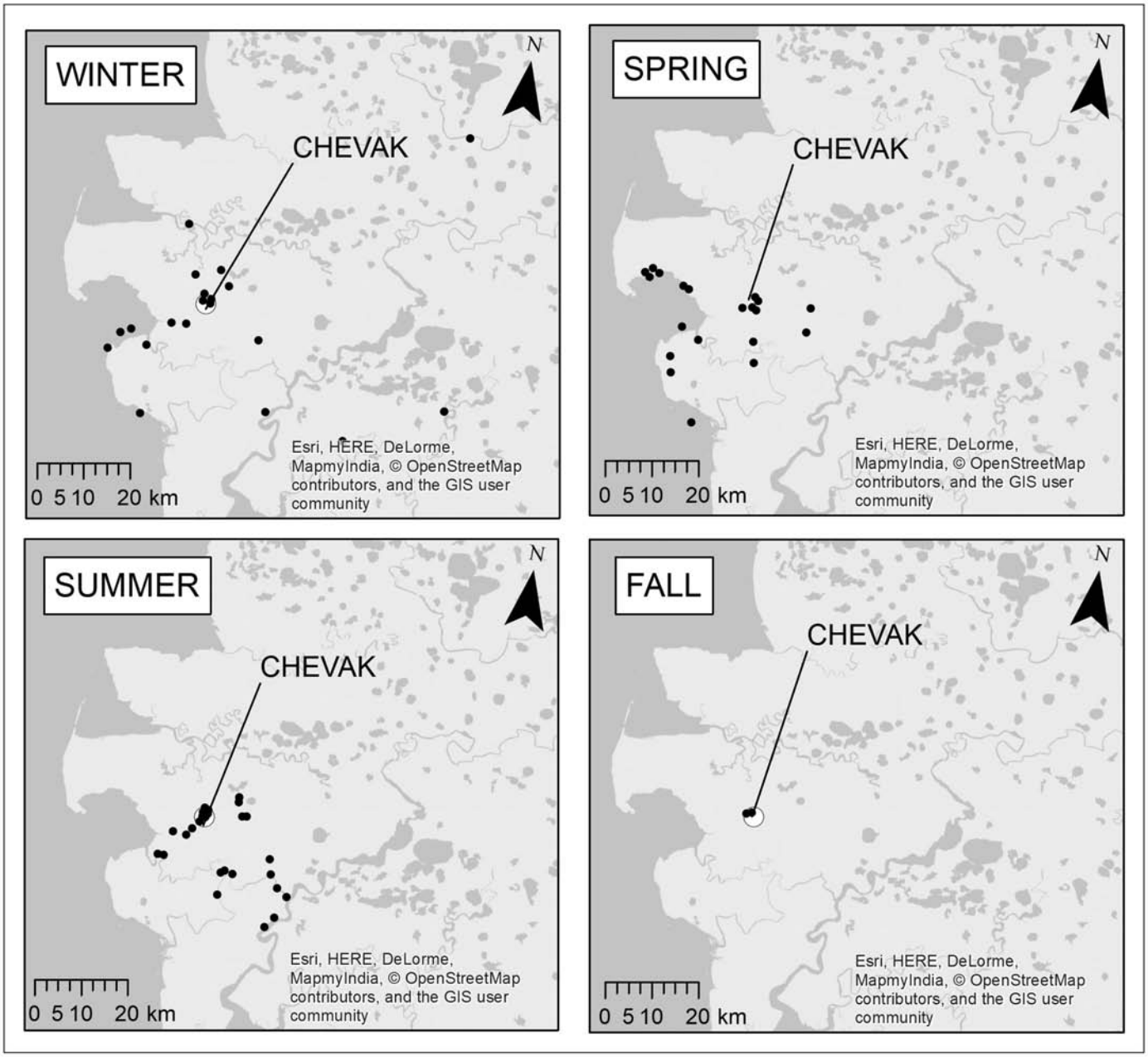

FIG. 4.Maps of seasonal subsistence harvesting locations identified by workshop participants in Chevak appear as black circles. Basemap credit: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

In Chevak, the long distances traveled in the winter for moose hunting, to set and check blackfish traps, and to fish under the ice for pike and lush were all described as activities impacted by a lack of snow in recent years. Sam Ulroan of Chevak stated, "We haven't been able to go out due to the lack of snow. Our freezer's empty." He went on to describe how the extended winter warm spell in 2013–14 impacted the ability to set and check blackfish traps, which are typically set under the ice:

> Well if it freeze[s] over you go out there and setup blackfish traps early in the season and if it melts off, it's kind of hard to cross the river again…and the blackfish traps sit out there for extra 2–3 weeks before you can check them. You don't go as far as you want to go. The amount of snow and the amount of freeze [impact setting and checking blackfish traps].

The warm spell in the winter of 2013–14 was also described as changing the migration patterns of blackfish:

> This year the blackfish are very confused, like when we had that rain and high temperatures all the way up … to the end of January, the blackfish, usually we'll be able to eat them and get them all the way up to February … They started their migration … so men have been going

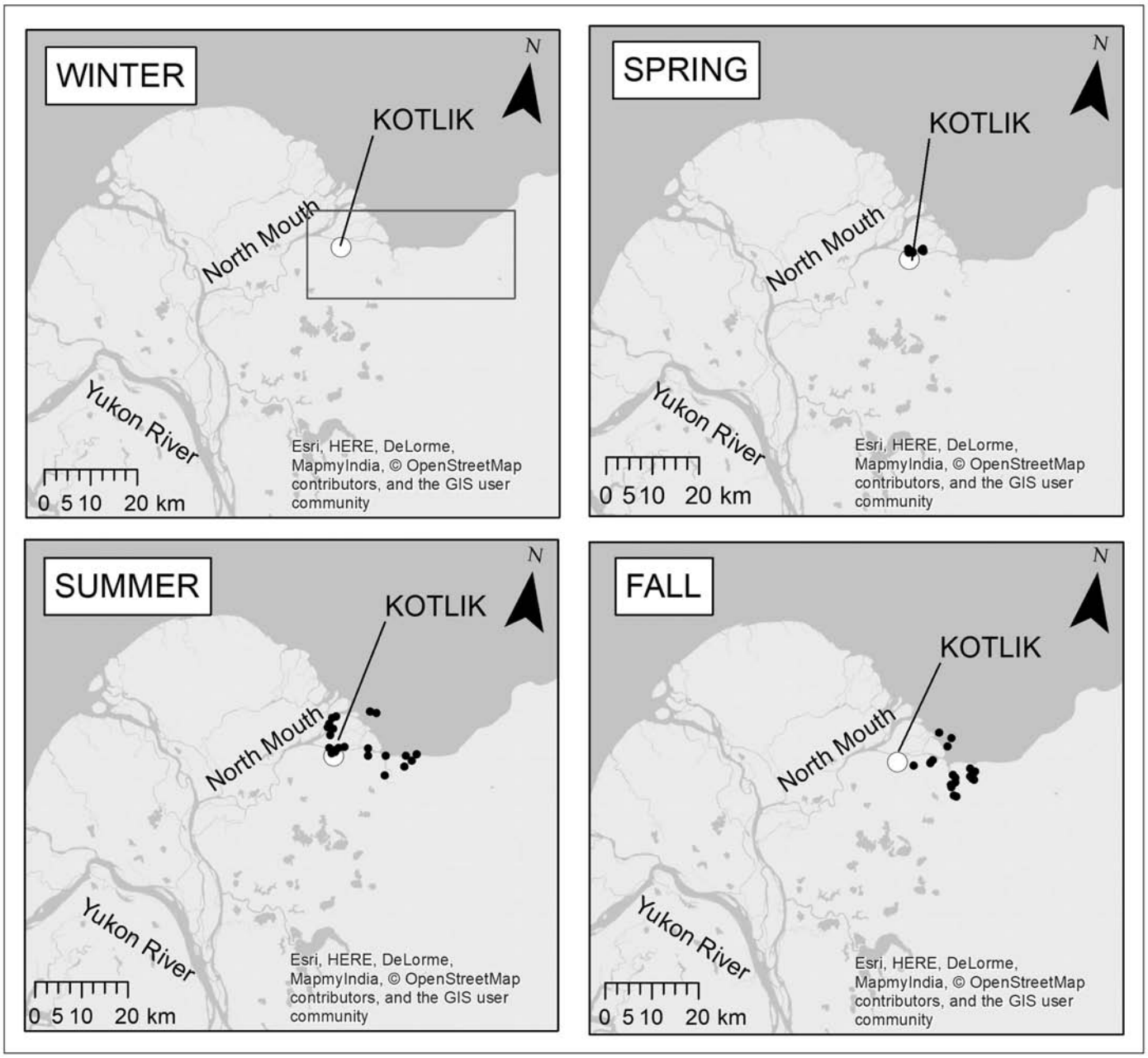

FIG. 5. Maps of seasonal subsistence harvesting locations identified by workshop participants in Kotlik appear as black circles.The winter map shows the extent of the participant-created maps. Basemap credit: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

> all over the tundra looking for them and so far they are gone, that's something very strange.
>
> (Anonymous, Chevak)

People travel 50 miles or more in the winter to ice fish for lush and pike, this was also impacted by a lack of snow.

> So because people want to go ice fishing as part of their diet, they go a long ways to get lush and pike. Fifty something miles out to the lake way over there, they haven't been going out because there was hardly any snow on the trail and the people who try to go out either break their snow-gos or you know they go through hardship.
>
> (Anonymous, Chevak)

Although the lack of snow during the winter of 2013–14 was discussed by interview participants in Kotlik, it was not identified as impacting subsistence harvesting. Lack of snow was discussed in both Kotlik and Chevak as a concern for the summer berry harvest, as the amount of snow is tied to the abundance of berries. In contrast to the focus on winter subsistence species in Chevak, Kotlik participants most often discussed the regulations imposed on

TABLE 2. Recent impacts on prominent subsistence resources as reported by participants in Kotlik.

Season	Prominent resource	Impact
Winter	Rabbit hunting	2013 Flood
	Trapping mammals	2013 Flood
	Ptarmigan hunting	No impact reported
Spring	Bird hunting	Late thaw
	Seal hunting	No impact reported
	Egg gathering	No impact reported
Summer	Berry picking	Lack of snow
	Subsistence salmon	Regulations
Fall	Moose hunting	Low tide

TABLE 3. Recent impacts on prominent subsistence resources as reported by participants in Chevak.

Season	Prominent resource	Impact
Winter	Moose hunting	Lack of snow
	Lush and pike ice-fishing	Lack of snow
	Blackfish trapping	Lack of snow
Spring	Herring fishing	Late thaw
	Herring egg gathering	Late thaw
	Seal hunting	Poor ice conditions
	Egg gathering	Late thaw
Summer	Berry picking	Lack of snow
	Subsistence salmon	No impact reported
Fall	Mouse food	Flooding

subsistence harvesting of Chinook salmon ("king" salmon) during the summer of 2013. Kotlik is located roughly five miles from the north mouth distributary of the Yukon River into the Bering Sea (Fig. 5). The north mouth is one of the locations where Chinook salmon begin their migration up the Yukon River. Informants lamented the regulations as impacting their ability to harvest fish. "The fish is getting hard to come by because there are too many regulations and rules you know" (Clement Mathais, Kotlik). "Fish and game has been watching it really hard there…not to fish for king salmon" (Isidore Hunt, Kotlik). Notably, Chevak is less connected to the Yukon River and is located in a different regulatory fishing district. When speaking of subsistence salmon fishing in Chevak, participants explicitly mentioned that they do not get very many Chinook salmon: "But we don't get as many kings as the two main rivers, north and south of us—the Yukon and the Kuskokwim" (James Ayuluk, Chevak). "A few kings, just a little bit, but our main summer is the chums" (Angela Boyscout, Chevak).

Change

Change was most often discussed in terms of a change or decline in the population of a species. In Kotlik and Chevak, chum and Chinook salmon were described by interview participants as declining in abundance over the past three to four years. John Stone, of Chevak, said: "Yeah, there used to be abundant more salmon in the season." Seal populations were reported by interview participants as less abundant. Investigators were told that although people continue to harvest seals because of the importance of seal oil, more and more people were turning to moose as an alternative big game source of subsistence. However, based on our interviews, it is not clear if the population dynamics of either moose or seal are related to this substitution.

In addition to population changes, interview participants also discussed cultural changes in subsistence activities. They said needlefish, for example, were no longer harvested because people no longer rely on dog teams for winter transportation. Needlefish, though consumed by humans, were primarily harvested for dog food in Chevak. Without dog teams to feed, interviewers were told that needlefish are now only harvested by one or two people in Chevak. While family preference plays a large role in the length of time spent at fish camp in the summer, some of our interview participants stated that they spend less time at fish camp today than in their youth. When asked about fish camp, Angela Boyscout of Chevak stated, "…now that we have everything going fast, we have stronger motors, we are able to get to farther distance and go right home. When we were young we would spend about a month, maybe a month and a couple weeks, in fish camp. But today it is different. Some people still go out and they will go out for a couple weeks."

DISCUSSION

The results of this case study identified prominent subsistence resources and highlighted the localized nature of subsistence resource utilization. This localization occurs across ANV and depends not only on the available resource base, but also on the cultural traditions and preferences of the community (Wolfe, 2004; Loring and Gerlach, 2015). However, our results also found prominent subsistence resources identified in both villages, with overlapping seasonality (birds, seals, bird eggs, salmon, and berries). These are resources that are both nutritionally and culturally important in this region of Alaska (Johnson et al., 2009).

Writing about the subsistence economy of the YKD in 1966, Klein (1966:323) stated, "By far the most important single item in the subsistence economy is salmon." Salmon and seal oil consumption both contribute to the health of Alaska Native populations because of their high content of omega-3 fatty acids, which may contribute to protection against coronary heart disease (Johnson et al., 2009). The historical and current importance of seals is illustrated by the ritual return of seal bladders to the sea, known as the Bladder Festival. The Bladder Festival encourages seals to return to the hunters each season and was traditionally held at the time of the winter solstice by the Yup'ik and Cup'ik in this region (Fienup-Riordan, 1983). In the Cup'ik language, the month of April is called *Tengmiirvik*—"the time the geese arrive," which signifies the importance of waterfowl as one of the first available subsistence resources in the spring after a winter of relying on stored food. Wild berries are also a key component of Yup'ik, Cup'ik, and indeed, Alaskan Native cultural identity and are a rich source

of antioxidants (Leiner et al., 2006). In western Alaska, there are at least 29 plant species that produce berries and families often pick more than 75 L of berries annually (Hupp et al., 2013, 2015). Wild berries are the essential ingredient in *akutaq*, or "Eskimo ice cream," which is traditionally made in this region with seal oil and whitefish, though local, regional, and modern varieties exist.

The cultural and spiritual value of the prominent subsistence resources identified by our participants stems from the nutritional importance these resources have played in Yup'ik and Cup'ik society for thousands of years. The value of subsistence resources, both culturally and nutritionally, supports the physical, spiritual, and emotional health of Alaska Natives (Redwood et al., 2008). The remainder of the discussion places our results regarding recent impacts, change, and the location of subsistence resources in the context of the concept of vulnerability, by exploring the exposure of these prominent subsistence resources to climate change impacts, the sensitivity of the communities of Chevak and Kotlik to those impacts, and the capacity of current subsistence institutions to absorb or adapt to impacts—the hallmark of resiliency (IPCC, 2007).

Exposure

Exposure refers to the nature and degree to which a system experiences environmental or socio-political stress (Adger, 2006). Participants in Chevak described exposure to the environmental stress of lower snowpack conditions in terms of their ability to reach more distantly located winter subsistence resources via snowmobiles. While it is difficult to link any isolated weather event or abnormal season specifically to climate change, there has been a recent trend towards warmer winters with less snow in Alaska (Di Liberto, 2016). When considering a community's exposure to a stressor, it is important to also understand the characteristics of that stressor—the magnitude, frequency, duration, and areal extent of the hazard (Burton et al., 1993). There is evidence based on Arctic Climate Impact Assessment models and others that warming in the Arctic is most pronounced in the autumn and winter seasons (Serreze and Francis, 2006). Air temperature is a key driver in whether precipitation falls as rain or snow, and warmer temperatures increase the probability of rain-on-snow events, which interrupt or reduce snow coverage (Bieniek et al., 2018), and thus impact access to winter subsistence resources.

Climate data indicate that the duration of less precipitation falling as snow is long-term and the areal extent is widespread. In terms of the exposure's magnitude, interview participants in Chevak described four of five prominent winter subsistence species as being impacted by the lack of snow. Participants described how a lack of snow during the winter of 2013 – 14 hindered their ability to access winter subsistence locations via snowmobile; likewise, the warm spell impacted the availability of blackfish, potentially by influencing their migration patterns.

Climate change's physical impacts on resources are amplified through human regulation of increasingly scarce resources, causing environmental stressors to be linked to, or be the cause of, socio-political stressors. In Interior Alaska, this has been notably apparent in the regulation of moose hunting seasons, which many Native hunters describe as not keeping pace with climate change-caused seasonality shifts in both the conditions on the landscape for reaching hunting grounds and the life cycle of moose (i.e., timing of the rut) (Loring et al., 2011; McNeeley and Shulski, 2011; McNeeley, 2012). In this case study, participants in Kotlik described exposure to stress brought about by socio-political measures in the form of Chinook salmon restrictions. Many communities that rely on the Yukon salmon fishery have expressed concern regarding the way the fishery is managed to ensure that international conservation goals are met (Loring and Gerlach, 2010; Loring et al., 2011). Beginning in the late 1990s, Yukon Chinook salmon numbers began to fall below historical averages. In 2000, the salmon run failed to produce expected returns and was declared a "stock of yield concern" by the Alaska BOF (Ikuta et al., 2014). Since this failure in 2000, the number of Chinook salmon traveling the Yukon River has only been at or above average once, in 2003 (ADFG, 2015). Since 2008, because of the continuing decline, commercial fishing of Yukon Chinook salmon has not been allowed by the Alaska Department of Fish and Game (ADFG). The Chinook subsistence fishery experienced restrictions in 2008 and 2009 as well as 2011 – 15, including a complete closure in 2014 and 2015.

Kotlik participants stated that the regulations put in place as a result of reduced availability of Chinook salmon in the Yukon River watershed hindered access to subsistence resources. In 2013, the year our participants describe, subsistence fishery restrictions included restrictions on the size of nets used for salmon fishing, as well as when fishing was allowed. In Yukon Fishing District One, where Kotlik is located, Chinook salmon subsistence fishing was only open for two 36-hour periods each week throughout the Chinook salmon season. In unrestricted years, subsistence fishing was open 24 hours a day, seven days a week. Pervasive changes in the environment influence resource-management protocols, including those established for fisheries, and directly affect the people living in Arctic communities (Loring and Gerlach, 2010; Richter-Menge et al., 2017). While subsistence fishers have little control over regulations imposed by BOF, the ADFG is aware of the frustration of Yukon River subsistence fishers and in 2017 several new outreach and communication strategies were implemented. Just as it is difficult to directly implicate climate change in specific short-term weather events, the complexity of the life cycle of salmon and the ecology of the Yukon River coupled with state, federal, and international regulatory systems make it difficult to identify the direct cause of Chinook salmon declines. The Yukon Chinook salmon population rebounded slightly in 2016 and 2017 (United States and Canada Yukon River Joint Technical

Committee, 2017, 2018), though restrictions similar to those in place in 2013 were implemented. This level of restriction may be the new normal, which raises the possibility that this will be a long-term socio-political stressor for ANV dependent on the Yukon River fishery.

Sensitivity and Capacity

Sensitivity, as a metric for vulnerability, describes the degree to which a system is modified or affected by stressors (Adger, 2006). The capacity of a system to adapt is in its ability to evolve to accommodate environmental hazards or policy change to expand the range of variability with which it can cope (Adger, 2006). The relationship between seasonality and subsistence practice reveals the sensitivity of these communities to climate change as seasons regulate the availability of subsistence resources. Subsistence practices and institutions are closely interlinked with adaptation strategies, both historical and current. This is evident in the subsistence maps, which highlight the seasonal nature of movement across the landscape. Mapping subsistence areas can provide insights into the ways in which environmental changes can affect use patterns and the sensitivity of those patterns (Huntington et al., 2013). Historical adaptation to the landscape is reflected in the overall distances traveled in the shoulder seasons of fall and spring when the landscape is in a state of flux and travel can be more difficult. As shown in the results section, winter, followed by summer, are the seasons when people in both villages travel the greatest distances for subsistence purposes. Seasonal mobility may become a sensitivity as seasonality shifts and summer and winter weather become less predictable.

The different seasonal timing of moose hunting displayed in Chevak and Kotlik highlight historical adaptations that promote resiliency to a variable landscape embedded in subsistence institutions. Participants in Kotlik stated that hunters only travel 5 – 10 miles for moose hunting, whereas in Chevak, hunters must travel roughly 50 miles. Access to a nearby population of moose in Kotlik allows for successful hunting via boat travel in the fall, whereas in Chevak, hunters utilize environmental conditions in the winter when snowmobiles may be used for longer-distance travel. Additionally, moose harvesting in the YKD exemplifies the flexibility of subsistence institutions utilizing a portfolio of resources, as moose are a relatively new resource that the villages readily accepted and began exploiting when it became available to them.

Nearly four decades ago, Wolfe (1981:58) commented on the subsistence economy of the YKD: "Because of the region's high current dependency on local fish and game resources, disruptions to the fish and game resources or fishing and hunting practices entailing reduced access or availability of the region's resources, would be expected to have direct and potentially negative effects on the economy of the Yukon delta population." While it is difficult to analyze the sensitivity of these communities to impacts on subsistence resources and harvesting without an in-depth examination of household reliance on subsistence resources as a food source, it is important to recognize the nutritional and cultural value of subsistence species when examining the vulnerability of local subsistence systems. Household sensitivity regarding impacts on subsistence resources is necessarily related to household food security. Research has shown that not every household in a community participates in subsistence harvesting (Wolfe, 2004; Kofinas et al., 2016), and that food security in ANV is not always tied to participation in subsistence harvesting or household income (Kofinas et al., 2016). Wolfe (2004) identified a common ratio ("the 30:70 rule") in which 30% of the harvesters, termed "super-households" (Wolfe et al., 2009) typically account for 70% of the total community harvest. These super-households help maintain the cultural and physical well-being of a people adapted to wild foods. However, household access to flows of subsistence resources from super-households is not equal within a community and can depend on a household's social capital (Kofinas et al., 2016). Thus, a community's sensitivity to climate change impacts on subsistence resources is complicated and likely spread unevenly from household to household, dependent upon social capital, participation in harvesting, and household income. That said, a profound change in diet, in which culturally valuable species are displaced, can result in serious repercussions for peoples' health and well-being, particularly when environmental pressures are at play (Turner and Turner, 2008). When determining the vulnerability of subsistence harvesting to changes in climate or society one must consider not just whether residents can put food on the table, but also the type of food, and how that food was procured.

Embedded in our participants' statements and stories is a clear connection to place (e.g., navigating or "wayfinding" by snowmobile) and an understanding of dynamic change (e.g., moose populations). Participants also describe social changes in subsistence systems such as less reliance on extended seasonal subsistence camps, increased reliance on faster modes of transportation such as ATVs, snowmobiles, and boats with larger motors, as well as a schedule dominated by school and work commitments. Social and economic changes can circumscribe responses to climate impacts and adaptation approaches with the potential to increase a community's sensitivity to change. In addition to climate change-related challenges, Indigenous Arctic communities are also experiencing social change exerted by external and internal pressures that make previously flexible and resilient subsistence practices less so (Ford et al., 2015). For example, subsistence systems built on diversity and flexibility are currently constrained by societal changes (e.g., changing technology and schedules), regulatory systems (e.g., Chinook salmon restrictions), and competing land uses (e.g., extractive industries). Further, local knowledge systems are being affected by socio-cultural change and changing demographics, which can result in a loss of location-specific knowledge

on environmental conditions and hamper the perception of change (Alessa et al., 2008; Ford et al., 2015; Herman-Mercer et al., 2016).

The residents of Kotlik and other communities reliant on Yukon River Chinook salmon may have the ability to increase the harvest of one species of salmon to compensate for the loss of availability of Chinook. There is evidence that this type of resource substitution may already be in practice as harvests of summer and fall chum salmon substantially increased in 2012 as compared to 2010 and 2011 harvest numbers (Fall et al., 2013). In Chevak however, it is unclear how households will cope with impeded access to subsistence locations due to less snowpack over time. The diverse resource base utilized by communities in the YKD and the flexibility built into the subsistence system that allows for species substitution may be what makes these systems most adaptable (BurnSilver et al., 2016). However, restricted access to multiple species due to an inability to travel in the winter, particularly if super-households that contribute subsistence resources to much of the community are impacted, may have long-term implications on community health and well-being.

CONCLUSION

Combining contextual information from interviews with the results of the comprehensive seasonal calendars and spatial information provided by the hand-drawn maps allows us to make connections between local observations and knowledge of impacts on resources, cultural information about the processes and preferences of subsistence harvesting, and the role that location plays in both. The multiple modes of data collection are a source of strength in this research project. Local knowledge and observations provide insights into potential points of vulnerability and resiliency that highlight both historical and current adaptation strategies. A weakness of this research lies in the lack of data concerning household sensitivity. Next steps should include research to better understand the differential nature of sensitivity experienced by households, how households are adapting to climate change impacts on subsistence resources and harvesting, and what qualities (social capital, household income, etc.) support household resilience.

The results of this research indicate that the subsistence systems in Kotlik and Chevak are exposed to climate change impacts. The villages are exposed to different environmental and socio-political stressors corresponding to specific seasons and harvesting strategies. Historical seasonally specific subsistence practices, such as traveling farther to collect resources in the summer and winter, may be particularly vulnerable as seasonal weather patterns shift. The adaptive capacity of these communities lies in the subsistence institutions that have been developed and utilized over thousands of years in this region. These institutions have resiliency and flexibility at their core. However, rapid socio-cultural change, coupled with rapid environmental change has the potential to stress subsistence institutions beyond their traditional resiliency. Future research should examine the vulnerability of subsistence practices in the context of historical community resiliency and adaptability, the current socio-cultural and environmental context, and the cultural and nutritional importance of specific resources.

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