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Alaskan wild food harvester information needs and climate adaptation strategies

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ABSTRACT. Changing biophysical conditions due to amplified climate change in northern latitudes has significant implications for species' habitat and populations and can dramatically alter interactions between harvesters and local resources. Tribal, regional, and state governments, federal agencies, and other local planning entities have begun documenting observations of changing harvest conditions and the information necessary for communities to adapt to shifting resource availability. We identify and evaluate what stakeholders are saying about wild foods in the context of climate change information needs in Alaska through a review of published grey literature (n = 87). Documents consistently expressed that climate change was impacting habitat conditions, resource distribution, and the abundance of wild foods. They solicited more information on biophysical processes (e.g., sea ice conditions) and population-level responses (e.g., shift in migration patterns). They also recommended that future projects focus on information that will improve food security, travel access, and community well-being. Documents suggested that communities have successfully sustained harvest practices, but most current adaptations are localized decisions being made by harvesters to manage the risks of current climate change. Strategies include finding new areas to hunt, substituting harvest species with other wild foods, or using new modes of travel. Documents also identified several adaptation strategies that still need to be implemented, and are dependent on actions by actors at larger scales; these strategies include legal, policy, and management actions to help reduce climate change impacts to wild food harvest. This review of the grey literature complements the climate-change literature by describing information needs of Alaskan wild food harvesters as well as providing tangible suggestions about how to improve adaptation and management strategies for harvesters grappling with changing resource conditions in the Arctic.

Key Words: *adaptive capacity; Alaska; Arctic; cultural services; needs assessment; subsistence; wild foods*

INTRODUCTION

Wild food harvest, e.g., hunting, fishing, and gathering, supports the livelihoods of numerous rural northern communities around the world. For many residents in Arctic communities, harvesting and consuming wild foods are cultural necessities and essential for health and well-being (Van Daele et al. 2001, Stafford Smith et al. 2011, Loring and Gerlach 2015). However, the practice of harvesting wild foods is increasingly under threat from shifts in weather extremes and long-term climate change (Lynn et al. 2014). Alaska has warmed at approximately twice the global rate affecting a host of processes including redistributions of plant species (Pearson et al. 2013), degrading permafrost (Jorgenson et al. 2010, Liljedahl et al. 2016), earlier snowmelt and later freeze-up (Euskirchen et al. 2010), changing seasonality and extent of river and sea ice (Brown et al. 2018), wetland drying (Chen et al. 2018), and increasing wildfire frequency and severity (Kasischke et al. 2010). Implications from changing biophysical conditions are striking for wildlife habitat and populations, and can dramatically alter interactions between harvesters and local resources (Huntington et al. 2016). Changes to distribution and abundance of resources can impact availability, access, and procurement of wild foods (Brinkman et al. 2013, Loring and Gerlach 2015). Because wild foods are commonly shared throughout indigenous communities, these resources concurrently influence many individuals at once, and declining availability could result in a much broader cumulative impact on food security and culture (Ford 2009).

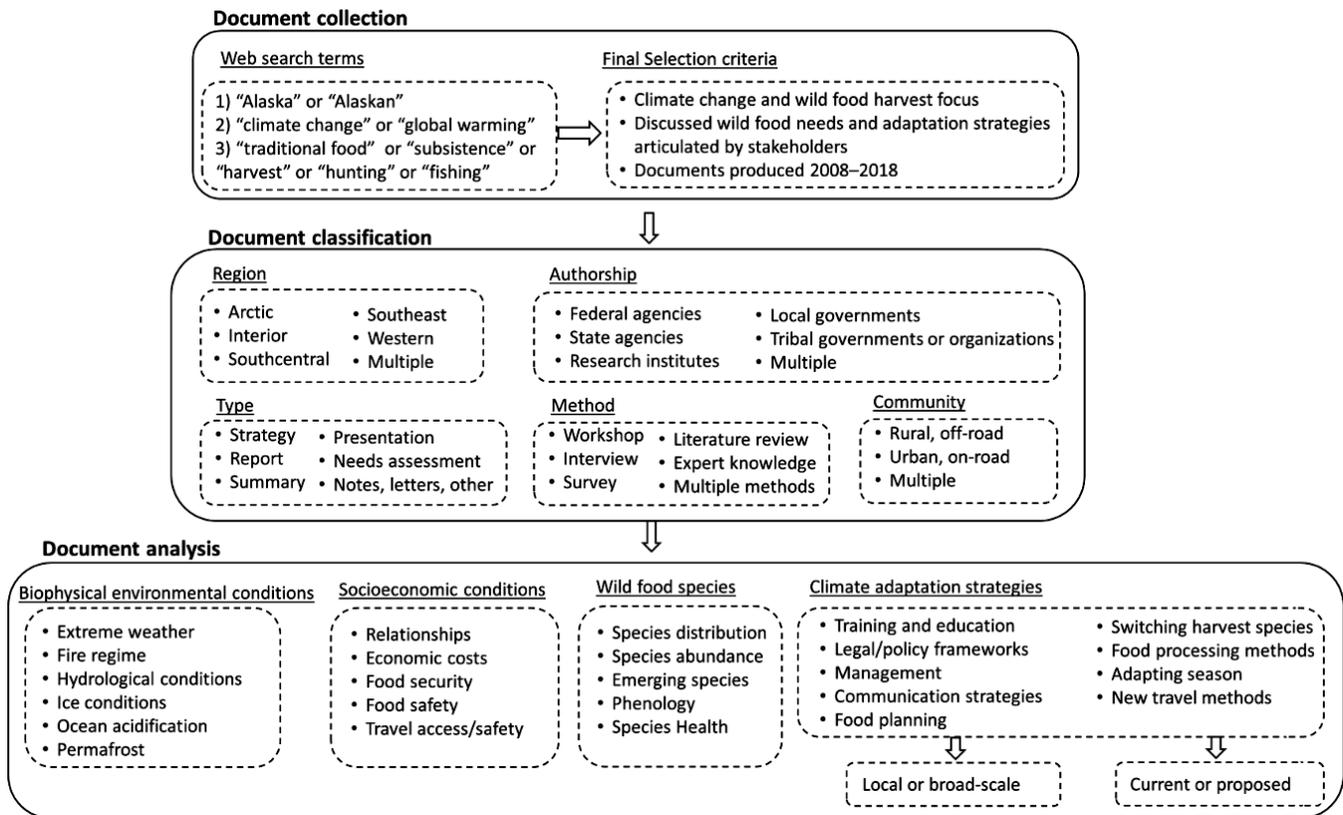
Alaska and the Arctic northern latitudes are widely regarded as a sentinel of global climate change (Hinzman et al. 2005), resulting in a rapid proliferation of research. The explosion of new information has made it challenging for rural residents and

decision makers to track existing projects, understand their cumulative insights, and gauge remaining information needs (Ford and Pearce 2012). The scientific emphasis on generating more and better information also shifts the focus away from partnering with user groups to generate research that meets their needs, which often involves utilizing knowledge to better adapt to changing conditions (Tribbia and Moser 2008, Knapp and Trainor 2013). It has become increasingly important to incorporate user needs into research design and community-based research frameworks for communities seeking to adapt to potential climate risks (Miller and Wyborn 2020). Tribal, regional, and state governments, federal agencies, and other local planning entities have suggested how scientific practices should change to make research more applicable for Alaskans including a process that is transparent, builds networks for knowledge sharing, and creates place-based long-term partnerships with communities (Knapp and Trainor 2013, 2015). Consequently, any process to identify climate change research needs would benefit from drawing from local information needs in their research design.

As residents in northern communities are identifying what they need to know to help them adapt harvest practices to climate change, they are also formalizing strategies to prepare for the physical and socioeconomic impacts (Ford and Pearce 2012, Wotkyns and González-Maddux 2014, Kettle et al. 2017). These preparatory measures include more training, requests for technical assistance, applications for funding to support mitigation and adaptation efforts, and formalized climate adaptation plans (Meeker and Kettle 2017). Rural and indigenous communities have relied on mobility, flexible hunting and harvesting seasons, detailed local and traditional knowledge, and

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Fig. 1. Graphical representation of the document coding and analysis approach.



social networks to share resource conditions. At the same time, several rapid climate-related changes have made these adaptive responses less reliable, e.g., shifting distribution of sea ice to harvest marine mammals (Huntington et al. 2016) and others more difficult, e.g., time constraints from employment (Pearce et al. 2015). Wild food gathering requires flexibility to harvest resources that are accessible, and the ability to make modifications to take advantage of resource availability given localized conditions (Ford et al. 2009, Brinkman et al. 2016). Thus, adaptation strategies are often opportunistic and depend on the ability of individuals or local groups to make changes to harvest strategies such as substitutions when resources are unavailable (Nuttall et al. 2005, Ford et al. 2006). However, with changing environmental conditions, adaptations in harvest timing and location also require broader institutional support in policy and regulatory reform at the state or federal level (Kofinas et al. 2010, McNeeley 2012, Huntington et al. 2017).

Given the importance of wild foods in rural communities in Alaska, there is demand to better understand how Alaskan harvesters are adapting to changing climate and what knowledge gaps can be filled by credible information. First, it is critical to understand overarching information needs as they relate to food harvest so that they can be prioritized and addressed by decision makers. Second, although there is an extensive literature that documents the multiple climate adaptation strategies for subsistence and food security in the Arctic (Ford and Pearce 2010, Pearce et al. 2012, Pearce et al. 2015, Berner et al. 2016) there

remains a limited understanding of local adaptive capacity as it relates to information needs. Our objectives with this paper are to (1) describe what observations are being made within the grey literature about wild foods in the context of climate change; (2) express what information needs are identified in relation to climate change impacts on wild food harvest; and (3) characterize what climate change-related harvest adaptation strategies are proposed and already being implemented, and how these efforts may be enhanced by resource management and policy actions.

METHODS

Document collection

To gather and retain documents, we used a combination of web and document word searches (Fig. 1, Appendix 1). Web searches were designed to collect documents that focused on three themes: (1) Alaska; (2) global climate warming; and (3) wild food harvest. We chose a set of search terms that were indicative of the three preliminary themes (Fig. 1, Box 1). To ensure that we were collecting all possible documents, we tried a series of permutations with combinations of search terms. We evaluated the combination of terms by the volume of content produced and if content was related to the three preliminary themes. Additionally, we bounded our search by assessing documents that were produced from 2008 to 2018. Following our web search, documents were imported into NVIVO and reviewed using word searches that included the original search terms. Each document was then individually reviewed to ensure that content addressed

wild foods needs and adaptation strategies (Fig. 1, Box 1). Here, wild food harvest refers to hunting, fishing, and gathering activities that supports the livelihoods of Alaskan residents including customary and traditional uses of Alaska's fish and wildlife resources, e.g., subsistence hunting and fishing. Documents were typically created by organizations such as local, state, regional governments, and tribal councils (Appendix 1). Several of these documents were produced by more than one organization or in collaboration with multiple groups. Given the diversity of contributors, we broadly characterized all groups as "stakeholders," or non-academic entities that are likely to be impacted by climate effects on wild foods. Stakeholders included wild food harvesters, tribal community members, tribal organizations, state and federal agencies and non-profits. Documents created by research institutions were only included if they assessed the needs of a stakeholder group in order to inform local management and decision making. Peer reviewed journal articles were not included in the document review. Prior to document analysis, we confirmed our document sample through conversations with local experts in different sectors.

Document classification

To classify documents, we recorded the name(s) and type of organization, e.g., state agency, that created or wrote the document, where we found the document, e.g., website URL, type of document, methodology, as well as the year it was published (Appendix 1). Finally, to provide information regarding the geographic scope of the documents, we recorded the region and whether the community was on or off the road system. If a document focused broadly on wild foods across the state or focused on > two regions, we assigned it a "Multiple" regions classification. We summarized these classifications by providing the percentage of total documents that were coded in each group.

Document analysis

We used qualitative content analysis methods to assess (1) stakeholder observations related to climate effects on wild food harvest; (2) information needs directly associated with climate effects on wild food harvest; and (3) what adaptations were being proposed and implemented to meet stakeholder needs (Fig. 1). Content analysis is a methodology that groups sections of text related to similar themes, to identify thematic patterns across documents (Bernard and Ryan 2010). Our design included both deductive (concepts related to our analytical framework) and inductive (emergent themes related to research questions) elements. This "hybrid" approach to coding is appropriate for exploratory studies because it allows for document concepts to shape on-going analysis (Bryman 2016). We began with a coding list based on prior research of Alaskan climate change needs (Knapp and Trainor 2013, 2015) and then expanded on this list to include wild food harvest themes and concepts. Once the preliminary rounds of coding were conducted, we used the word search feature to confirm that we had labeled all themes within each document. Documents were coded twice by a single coder to make sure all stated themes were captured. We did not track how stakeholders' needs and adaptation strategies changed overtime. Additionally, if documents were produced by more than one stakeholder group, we did not separate the various observations made by groups because it was difficult to distinguish the various viewpoints. Hierarchical coding reports were used to summarize how often a theme was coded and how many documents included a specific theme.

To summarize the information, we coded documents into three major climate-related themes: wild food species, biophysical environmental conditions that affect wild food harvest, and socioeconomic conditions that result from unpredictable wild food harvest. Impacts to wild food species included needs statements or observations related to changes in species-level populations, geographic distribution, or health. Biophysical environmental conditions included statements related to environmental or climatic changes to species habitat or the biophysical environmental conditions associated with wild food harvest. Changing socioeconomic conditions include statements related to economic, cultural, and health costs associated with unpredictable wild food harvest. Coded statements were then placed into subthemes within each category (Fig. 1, Appendix 2). We presented the percentage of total documents that included statements related to stakeholder observations of the various subthemes. These statements were associated with direct observations or experiences individuals or communities encountered while harvesting wild foods. We also quantified the total number of coded statements mentioning a research or information need related to the same major sub-themes. The information needs statements were assertions for more information, data, or strategies related to wild food harvest in the context of climate change.

Finally, we coded statements related to adaptation strategies associated with climate-related changes to wild foods. Adaptation strategies were any actions that stakeholders employed to offset the negative consequences associated with climate change impacts on wild food resources (Appendix 2). We differentiated between current strategies being implemented at the time of writing from those that were proposed and still in need of implementation. Additionally, we recorded if adaptation strategies were being implemented at the local scale, i.e., adaptations from within communities, or at broader scale outside the jurisdiction of stakeholder groups. Local-scale adaptations include strategies adopted by individual harvesters, tribal councils, or local governments. Broad-scale adaptations were strategies proposed at the regional or state level, or were strategies proposed within a community, but could not be implemented without the support of regional, state, or national institutions.

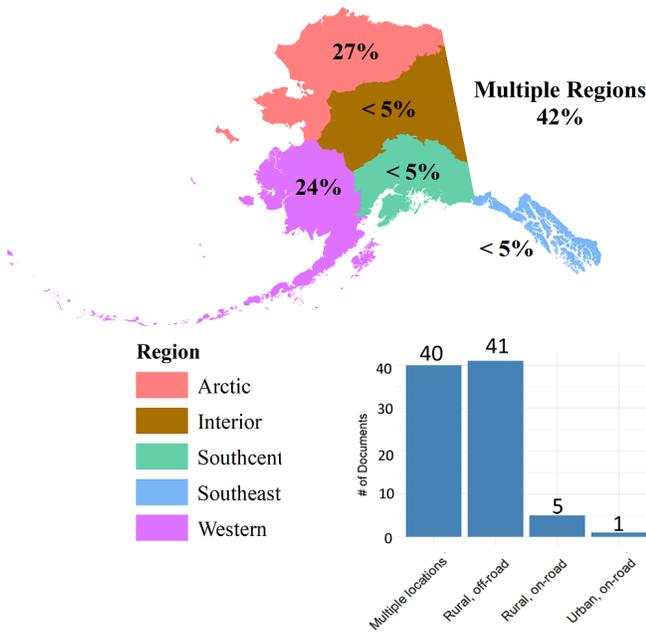
RESULTS

Document information

We collected and analyzed 87 documents through web searches related to climate change in the context of wild food harvest in Alaska. Organizations that created documents included state agencies (20%) and federal agencies (22%), tribal governments or organizations (25%), research institutions (8%), multiple agencies (21%), and local governments (4%; see Appendix 1, Column 5). Documents in the review were created using expert knowledge (32%), workshops (22%), surveys/interviews (16%), and literature reviews (10%). Several documents (20%) utilized more than one method to assess climate change needs. The majority of documents covered multiple regions (42%) in Alaska (Fig. 2), followed by Arctic (27%) and Western (24%) Alaskan communities. Far fewer documents focused directly on Interior (3%), Southeast (2%), and Southcentral (2%) communities. Of these communities, 47% of documents were classified as off-road communities (i.e., communities off the Alaskan road system), < 5% classified as urban, on-road communities (i.e., city centers

connected to the highway system), < 5% rural, on-road communities (i.e., connected to the highway system, but in remote parts of the state). The rest of our documents (46%) represented both on and off-road communities across Alaska (Fig. 2).

Fig. 2. Map of five major Alaskan regions, proportion of documents reporting needs for each region, and community-type.



Observed changes to wild food resources

Nearly half (48%) of the documents described observations that wild food species are changing as a result of climate change. Almost half of all documents (47%) stated that the geographic distributions of traditionally harvested wildlife, fish and plant species have shifted on the landscape. Stakeholders also noted that wild food species have changed in abundance (36%). Over a third of documents (35%) observed emerging or new species that may impact or interact with harvest species. Several documents (28%) also identified that the timing (phenology) of when species can be found across their range has shifted.

Stakeholder documents (40%) described that the biophysical environmental conditions that support habitat and access to wild foods have also changed. Over a third of the documents (35%) referenced observed changes in river ice and sea ice conditions including changes to ice coverage, thickness, and timing of formation. Some documents (29%) stated that hydrological conditions are changing and could have important implications on Alaskan riparian and aquatic harvested species. Stakeholders also stated that changes to the wildfire regime, such as increased fire severity, extent, and frequency, have affected habitat conditions for harvested species. Other important biophysical transformations included permafrost degradation (11%) and ocean acidification (10%).

The majority of stakeholder documents (60%) describe some socioeconomic impacts related to climate change and wild food species. Half the documents (50%) stated changes to interpersonal

connections or relationships, which included statements on community connections, and self-worth or self-identity. As one document stated,

Food is the cornerstone of our culture and self- and shared identity. Harvesting of traditional foods is how cultural values, skills, and spirituality are learned - this is how all learn to be within their environments and to be part of the ecosystem. (Appendix 1, #16)

Over a third of documents (41%) identified safety and travel concerns related to traditional harvest users accessing resources. Stakeholder documents also stated the impacts on community food security (44%) and safety (37%). Other important socioeconomic impacts included economic costs associated with loss of harvest resources (32%) and increased development in areas used for traditional harvest (13%).

Stakeholder information needs

Species distribution (n = 121) was the most frequently discussed information need related to climate effects on wild food species (Fig. 3). Species abundance (n = 78), novel or emerging species (n = 73), phenological changes (n = 64), and species health (n = 47) were also regularly mentioned climate change information needs (Fig. 3). Ice conditions (n = 114) were referenced most as an information need related to changing biophysical environmental conditions impacting wild food harvest. Other biophysical information needs included extreme weather (n = 65), hydrological conditions (n = 62), fire regimes (n = 32), permafrost degradation (n = 30), and ocean acidification (n = 18; Fig. 4). Finally, relationships (n = 141) were the most commonly stated information need related to impacts on the socioeconomic conditions related to changing wild food harvest. Travel access and safety (n = 136), food security (n = 100), food safety (n = 94), and economic costs (n = 56) were also frequently discussed information needs (Fig. 5).

Fig. 3. Stakeholder information needs related to wild food species (2008–2018).

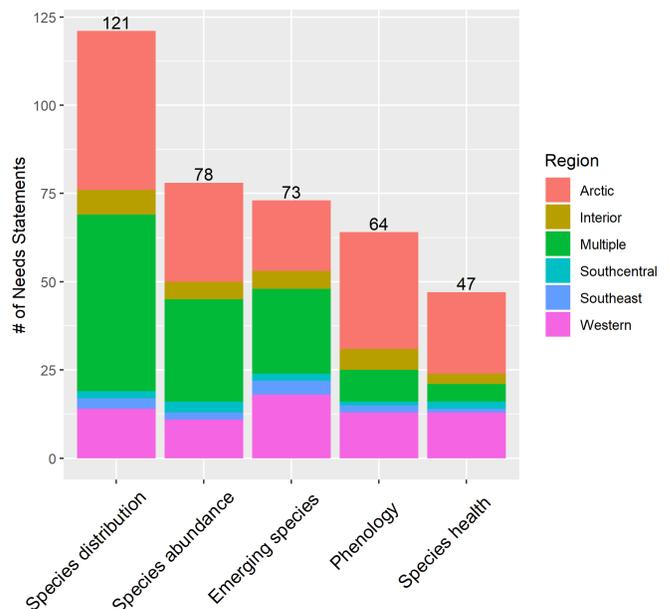


Fig. 4. Stakeholder information needs related to biophysical environmental conditions that affect wild food harvest (2008–2018).

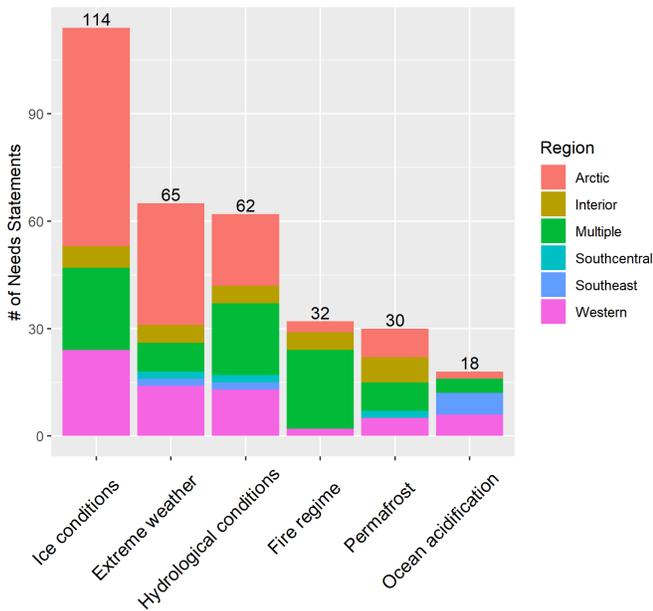
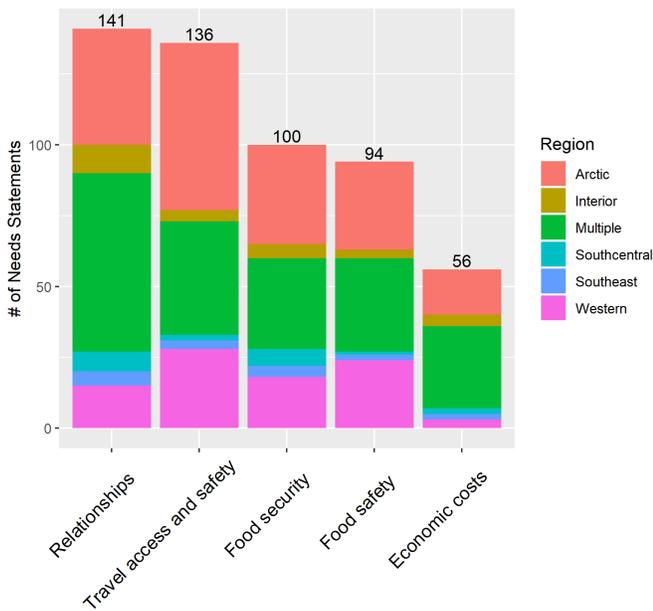


Fig. 5. Stakeholder information needs related to socioeconomic conditions that result from unpredictable harvest (2008–2018).



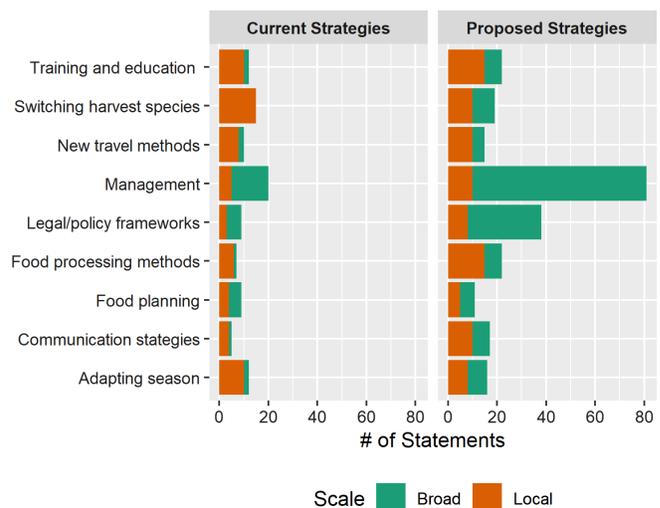
Adaptation strategies

Forty-two percent of documents described various adaptation strategies that help communities cope with changes to traditional harvest practices. Most of the proposed adaptation strategies stated the need for adaptable management (30%) and legal and

policy frameworks (12%). Management refers to actionable, applied decision-making strategies for natural resource managers, whereas adaptable legal and policy frameworks refer to the processes and procedures that guide management of natural resources (Appendix 2). Switching harvest species (9%), training opportunities (10%), new communication strategies (7%), as well as improved techniques to process and store foods (8%) were other common strategies that still needed to be implemented by stakeholders. The vast majority of those strategies were proposed (n = 136 statements) or have not yet been implemented compared to strategies that have already been adopted (n = 55 statements) by local residents or organizations (Fig. 6). Most of the current adaptation strategies that have been adopted are localized and employed by groups of individuals within communities (n = 55 statements), versus at broader-scales (n = 32 statements). For example, switching harvest species, adapting harvest season, and community food planning are a few strategies that have been incorporated into local practice. However, most of the adaptation strategies (n = 150 statements) that still need to be implemented are being proposed at a broader-level scale (e.g., state government), than at the local level (n = 91 statements). One document stated,

The challenge for environmental and resource management agencies will be to manage for healthy, productive ecosystems in a future made less certain due to a changing climate. This will necessitate possible changes to their institutional, legal and policy frameworks to respond quickly enough to sustain the natural resources they manage for the public trust. (Appendix 1, #8)

Fig. 6. Number of harvester statements that addressed both current and proposed climate-related adaptation strategies to wild food harvest. Adaptation strategies were recorded at the local scale (i.e., adaptations from within communities or user groups, orange bars), and at the broad scale (i.e., outside the jurisdiction of user groups, green bars).



DISCUSSION

Observations of biophysical system reverberate to social system

An increased understanding of what local people are seeing and how it relates to their needs could improve the dialog regarding the relevance of climate change research (Knapp and Trainor 2013). Almost half of the documents described alterations to biophysical environmental conditions that can impact harvesters directly by changing access, affecting food storage, and shifting modes of transportation. Changing sea ice and hydrological conditions were the most common observations reported in our search. Sea ice is an essential component for indigenous hunters that harvest marine mammals and is changing rapidly. These changes affect hunters by transforming access and altering the safety and effectiveness of ice as a substrate for hunting (Huntington et al. 2016, 2017). Thinner ice can create dangerous conditions leading to injuries and equipment damage (Mahoney et al. 2009). During the summer, people navigate large waterbodies by boat to harvest fish species or to access remote hunting areas. Our findings are consistent with other recent studies that document community concerns related to variable breakup and freeze-up conditions (McNeeley and Shulski 2011, Jones et al. 2015), which have led to reduced access to harvest areas (Brinkman et al. 2016). Documents also spoke broadly about changes in extreme weather events affecting both safety and access to wild food resources. For example, more frequent storms have led to fewer safe boating days, which can reduce hunting opportunities for marine species. Several documents described how changes in permafrost degradation could alter the hydrology of lakes and rivers that have traditionally been used to access wild foods. Additionally, harvesters observed how permafrost degradation affects the utility of traditional ice cellars, which has implications for food safety and security.

Documents suggested that species are shifting their distributions in space, e.g., home ranges, and time, e.g., seasonal migration, which has implications for the availability of these resources for local hunters. Shifting spatial distributions of wild food resources might require hunters to travel further or acquire new modes of transportation, all of which have added economic costs (Brinkman et al. 2014). Increases in temperature over the last century have clearly been linked to shifts in the geographic range of fauna, with the largest changes occurring across tundra ecoregions (Lawler et al. 2009). Given the magnitude of projected temperature changes in Alaska, it can be expected that species will continue to disperse into new suitable areas (USGCRP 2018). Changing patterns of species distribution and abundance are very likely linked to observations of shifting biophysical habitat conditions (Marcot et al. 2015). Examples include declines in lacustrine environments affecting migratory birds or shifting sea ice influencing spatial use patterns of marine mammals. Additionally, shifting environmental conditions during controlled hunting seasons may impact the harvest of wildlife resources (Hasbrouck et al. 2020). Documents also described novel interactions between new species and current species. The arrival of invasive species presents a whole new set of conservation and management concerns, whereas the appearance of game species could present new harvest opportunities.

In some cases, new subsistence resources are becoming available. In other cases, nuisance animals or predators

that compete with people have hampered the success of subsistence activities. (Appendix 1, #31)

The majority of documents expressed that climate change-driven effects to wild food resources were impacting socioeconomic conditions within their communities. Fifty percent of reviewed documents described changes to interpersonal connections and relationships within their communities. This result acknowledges the importance of the wild food system from a social perspective, recognizing the importance of all aspects of harvesting, preparing, consuming, and sharing wild foods. Sharing food is an important cultural practice, and although it minimizes the risk of food insecurity, sharing also connects community members socially (Collings et al. 1998). One document stated,

Food is the cornerstone of our culture and self- and shared identity. Harvesting of traditional foods is how cultural values, skills and spirituality are learned - this is how all learn to be within their environments and to be part of the ecosystem. The relationship between Inuit and all else that makes up the Arctic environment aids in the maintenance of cultural and environmental integrity. (Appendix 1, #16)

Documents also described that climate change has negatively affected the accessibility of wild food resources. Previous work has documented the disproportionately large effects of perceived climate-driven changes on travel to subsistence resources (Porter et al. 2014, Brinkman et al. 2016, Cold et al. 2020). The ability to access wild foods is essential for Arctic food security (Lambden et al. 2007) and changing environmental conditions can not only reduce the ability to procure wild foods, but can also impact the safety and well-being of local harvesters (Brubaker et al. 2011, Clark et al. 2016).

Harvest adaptation strategies

Our review found that most current adaptations are decisions being made locally within communities to manage the risks of current climate change on wild food harvest in Alaska. Most of these strategies include finding new areas to hunt, substituting harvest species, or using new modes of travel. Research has shown that Arctic wild food harvesters have demonstrated significant adaptability in the face of changing resource conditions (Cruikshank 2001, Ford et al. 2006). Adjusting to accommodate changes to wild foods is likely one of the primary adaptations because harvesters can improvise strategies related to travel, such as deciding the mode of access, as opposed to confronting large-scale changes to biophysical habitat conditions. These current strategies suggest that there are adaptations being employed to manage changing conditions and are indicative of localized adaptive capacity to future climate change. Additionally, documents described several current broad-scale adaptation strategies that were being implemented and planned by organizations at the regional or state level. For example, regional food planning activities, such as harvest and storage workshops, were being organized across multiple communities (Appendix 1, #16, 65, 69). Several documents described local observers collecting information about environmental change that was then linked to regional observation networks (Appendix 1, #35, 36, 37, 39).

Our review also identified adaptation strategies that still need to be implemented including several proposed legal, policy, and management actions. For example, documents called for extending hunting seasons, increasing bag limits, and changing resource access regulations because of unusual weather patterns and the inability to meet harvest needs (Appendix #1, #2, 48, 65, 69, 73). Our results are consistent with other studies that have proposed changes to hunting seasons to increase local access to natural resources and allow for more adaptive regional wildlife management (McNeeley 2012). Many of the strategies that were not yet implemented were categorized as “broad-scale,” and needed to be coordinated and adopted at levels outside of local communities.

Barriers to adaptation

An increasing number of studies have identified commonly reported barriers to climate change adaptations (Biesbroek et al. 2013, Eisenack et al. 2014, Piggott-McKellar et al. 2019), including financial and institutional obstacles (Ekstrom and Moser 2014). Our review identified several local adaptation strategies, such as finding new areas to hunt or adopting new techniques to harvest wild foods that hinged on finding financial resources for implementation to happen on the ground. Barriers related to new economic costs were identified by > 30% documents. Increasing costs associated with accessing areas to hunt, such as requiring more expensive equipment and larger amounts of fuel, may prohibit traditional wild food gathering practices. One document asserted,

The increasing cost of participating in subsistence activities and dramatic changes in the social context of Arctic indigenous communities are causing a seeming decline in local fishing and hunting knowledge and level of participation in subsistence practices. (Appendix 1, Document #2)

Several reviewed documents also stated that the management of wild foods was hindered by outdated policies based on historical factors that do not account for climate change. This barrier was usually mentioned in relation to resource management and local access to subsistence resources. One document stated,

Adaptable legal and policy frameworks, many laws, regulations and policies on the federal, state, and local levels were developed for a static environment where climate change was not recognized. The challenge for government leaders and businesses will be to adapt to a future made less certain due to a more rapidly changing climate. This will necessitate an evaluation of existing laws, regulations and policies and possible changes to institutional, legal and policy frameworks in an adaptive manner. (Appendix 1, Document #8)

The failure to recognize localized problems is a common mismatch between scales of management institutions (Schultz et al. 2019). Documents recommended that local harvesters should be involved in the decision-making process. Such efforts can develop capacity for community-driven projects and create supportive relationships with a wider network of actors. One document stated,

It helps to have people working for land management agencies who have lived in the area for a long time, who

know and understand the local way of life. Local people can also provide information about the land and resources that helps researchers and agencies do their work better. Can decision-making move to the community level in some way?” (Appendix 1, #69).

Finally, policy makers and managers must often make difficult decisions regarding natural resource populations based on past conditions with limited and often incomplete baseline data (Nichols et al. 2011). Several documents describe the need for better data on both biophysical habitat and socioeconomic conditions to make more informed decisions. Increased harvest reporting, in particular, was described as a tool needed to assess the variability and extent of adaptive uses of fish and wildlife resources.

Opportunities for future work and management directions

Our review highlights topics, scales of organization, and regions that could benefit from additional information to better understand wild food harvester needs as they relate to changing resource conditions. Opportunities for adaptation exist for resource managers and other local decision makers when management strategies are adaptive and incorporate an understanding of climate variability in conjunction with local observations and resource needs. It will be important for researchers and managers to consider resource availability and accessibility, which accounts for not only the abundance of wild foods, but also for seasonal variations, spatial distributions, and obstacles to access (Brown et al. 2015, Brinkman et al. 2016). The ability to predict altered spatial distributions varies dramatically by species (Sekercioglu et al. 2008), and presents challenges to managers developing and implementing comprehensive strategies that mitigate the effects of climate changes on wild foods. However, developing future distribution models for key wild foods (e.g., Baltensperger and Joly 2019) could help agencies start planning efforts to access new areas to allow hunting. Additionally, it is possible that climate change could produce dramatic changes in the abundance of new subsistence species that would prompt a reconsideration of available management actions. For example, new fishing opportunities are opening in the Arctic (Carothers et al. 2019); however, failure to effectively manage new species could result in conflict with commercial fisheries and lost food security opportunities. It is also conceivable that climate change, including increased precipitation and temperature, will produce widespread habitat changes that may provide new opportunities for harvest, but also new needs for adaptive habitat management.

Documents call for a more responsive system that is flexible and accounts for high resource variability. Harvesters have proposed or already adopted adaptation strategies to meet changing conditions, but their actions will need a regulatory system that is quick to respond to in-season changes to resources (McNeeley 2012). Researchers should consider whether localized, improvised adaptations are effectively meeting the needs of local harvesters, or if they are being hindered by adaptive mismatch across management entities, e.g., state/federal agencies. Future work could identify where mismatch is occurring for important wild foods and whether newly designed policy and management tools could further enhance local adaptations while maintaining the legal and policy obligations of the institution. Boundary work to

support cross-scale arrangements such as improving communication across governance levels and local harvesters would greatly enhance future adaptive capacity (Cash et al. 2006). Additionally, scenario planning could also provide opportunities for communication between resource managers and local communities that will aid decision making under wild food resource uncertainty (Knapp et al. 2017).

Documents strongly voiced the need for new, adaptive decision-making strategies to manage fisheries, wildlife, and other wild foods resources. This result is consistent with the co-management literature that states that both local and indigenous knowledge can complement knowledge generation (Berkes 2009) and the management of wild food resources (Armitage 2005, Armitage et al. 2011). Knowledge partnerships in a management setting can bring together different entities, build trust, resolve conflict, and allow for more efficient joint problem solving (Kofinas 2009). Previous work has recommended that climate change science can be more relevant if it includes integration of different forms of knowledge, user driven science, and regionally grounded stakeholder suggestions (Dilling and Lemos 2011, Ford et al. 2013, Kalafatis et al. 2015, Stone 2020). Significant partnership with local communities can encourage user-driven science including products and deliverables that could be used by harvesters grappling with food insecurity, unsafe travel conditions, and maintaining cultural connections to the land (Chapin et al. 2016).

Limitations of research

In this review, we did not conduct a longitudinal analysis to assess how stakeholder needs and adaptation strategies changed over time. It is conceivable that contemporary needs have shifted in importance over the past decade or that harvester observations have fluctuated as they experience new conditions over time. Additionally, it is feasible that individuals, communities, and institutions have generated new adaptation strategies in the meantime that were not captured in this review. We also bounded our document search over a 10-year period (2008–2018) and only analyzed documents that met our search criteria. This left out meeting notes, e.g., subsistence resource committees, that may have been relevant but did not meet our criteria. Furthermore, stakeholders could have produced documents that were indirectly related to climate change or wild foods, but did not use our search terms and were subsequently missed in our web search. Here, we focused on the needs and adaptation strategies that were described most frequently across documents. We assumed that needs and adaptations that were more frequently expressed corresponded with a greater need, while others that were described less frequently, were not as important. It is also possible that the geographic distribution of the grey literature influenced the number of stated research needs. It was difficult to evaluate the variation in needs among regions because of the high proportion of documents created for multiple regions; however, our analysis does highlight places, e.g., Southcentral, where additional assessment might be needed. Finally, although we recognize that several partnerships have been implemented over the past decade targeting Alaskan climate change needs, it was not our intent to evaluate these, but to focus on what was being said by harvesters in the grey literature. Despite these challenges and assumptions, this review of the grey literature is a useful and available indicator of Alaskan harvester needs.

CONCLUSIONS

Amplified climate change in Alaska has altered the relationship between harvesters and local wild food resources. In wild food harvest systems, climate change directly impacts biophysical habitat conditions that are linked to species dynamics and the socioeconomic well-being of communities. Our review contributes to climate change needs and adaptation literature by examining a body of work, i.e., grey literature, to identify locally grounded observations of changing resource conditions and remaining information needs to inform direct actions. The findings from this study support recent research (McNeeley et al. 2012, Herman-Mercer et al. 2019) that wild food adaptation actions emerged locally, but broader legal, policy, and management frameworks were still needed to adapt to rapid climate change. The results demonstrate that coordination is required at regional and national levels to ensure wild food harvesters can adapt planning and management activities. This assessment has provided insight into the ways in which organizations may adapt to maintain food security, health, and cultural connections as an integral component to their lifestyle changes.

Responses to this article can be read online at:
<https://www.ecologyandsociety.org/issues/responses.php/12509>

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Data Availability:

Document were derived from the following resources available in the public domain: document URLs can be found listed in Appendix 1: column 4.

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Appendix 1. Document information including title (Column 2), date published (Column 3), where we found the document (website; Column 4), the name and type (e.g., state agency; Column 5) of organization that created the document, type of document (e.g., report, Column 6), methodology (Column 7), geographic region (Column 8), and if the region was on or off the road system (Column 8).

#	Title	Date	URL	Organization Name and Type	Type of Document	Method	Region	Community
1	A Summary of the Alaskan Marine Arctic Conservation Action Plan for the Chukchi and Beaufort seas	2010	https://www.adaptationclearinghouse.org/resources/a-summary-of-the-alaskan-marine-arctic-conservation-action-plan.html	The Nature Conservancy (Nonprofit)	Strategy	Workshop	Arctic	Rural, Off-road
2	A Synthesis of Climate Adaptation Planning Needs in Alaska Native Communities	2017	https://accap.uaf.edu/sites/default/files/resources/Meeker%20and%20Kettle%202017_Synthesis%20CAP%20Alaska%20Native%20Communities.pdf	Alaska Center for Climate Assessment and Policy (Research Institute)	Report	Literature Review	Multiple	Rural, Off-road
3	A Ten-Year Prioritization of Infrastructure Needs in the U.S. Arctic	2016	https://www.cmts.gov/downloads/NSAR_1.1.2_10-Year_MTS_Investment_Framework_Final_5_4_16.pdf	U.S. Department of Transportation (Working Group)	Strategy	Expert Knowledge	Arctic	Rural, Off-road
4	Adapting to Climate Change: A Call for Federal Leadership	2010	https://www.c2es.org/site/assets/uploads/2010/04/adapting-to-climate-change-call-for-federal-leadership.pdf	Pew Center on Global Climate Change (Nonprofit)	Strategy	Expert Knowledge	Multiple	Multiple
5	Alaska's Climate Change Strategy	2010	https://www.cakex.org/case-studies/alaska%E2%80%99s-climate-change-strategy	Alaska Adaptation Advisory Group (Working Group)	Strategy	Expert Knowledge	Multiple	Multiple
6	Alaska Climate Change Strategy: Health and Culture Technical Working Group	2008	https://dec.alaska.gov/climate-change/	Alaska Department of Environmental Conservation (State Agency)	Summary	Expert Knowledge	Multiple	Multiple
7	Alaska Climate Impact Assessment: A Commissioners Summary of Findings	2008	http://bonnernetwork.pbworks.com/f/comissioner+report.pdf	Alaska Climate Impact Assessment Commission (State Agency)	Presentation	Expert Knowledge	Multiple	Multiple

8	Alaska Department of Fish and Game Climate Change Strategy	2010	http://www.adfg.alaska.gov/static/lands/ecosystems/pdfs/climatechangestrategy.pdf	Alaska Department of Fish and Game (State Agency)	Strategy	Literature Review	Multiple	Multiple
9	Alaska DOT & PF Adaptation to Climate Change	No Date	http://climatechange.transportation.org/pdf/gregovichadot.pdf	Alaska Department of Transportation (State Agency)	Presentation	Expert Knowledge	Multiple	Multiple
10	Alaska Energy Research Needs	2010	ftp://ftp.aidea.org/2010AlaskaEnergyPlan/2010%20Alaska%20Energy%20Plan/Research%20Needs%20Assessment/Research%20Needs%20Assessment.pdf	The Alaska Center for Energy and Power (Research Institute)	Report	Expert Knowledge	Multiple	Multiple
11	Alaska Region Climate Change Response Strategy 2010-2014	2010	http://www.nps.gov/akso/docs/AKCCRS.pdf	National Park Service (Federal Agency)	Strategy	Expert Knowledge	Multiple	Multiple
12	Alaska State Climate Change Policy	2017	https://dec.alaska.gov/climate-change/	Alaska Department of Environmental Conservation (State Agency)	Summary	Expert Knowledge	Multiple	Multiple
13	Alaska Wildland Fire Coordinating Group Fire Research Needs 2011	2011	http://fire.ak.blm.gov/content/admin/awfcg_committees/Fire%20Research%20Development%20and%20Application/c.%20AWFCG_Fire%20Research%20Needs_2011_Final.pdf	Bureau of Land Management (Federal Agency)	Needs Assessment	Expert Knowledge	Multiple	Multiple
14	Alaska Wildland Fire Coordinating Group Needs	2017	https://fire.ak.blm.gov/content/admin/awfcg_committees/Fire%20Research%20Development%20and%20Application/c.%20AWFCG_research_needs_list_2017.pdf	Bureau of Land Management (Federal Agency)	Summary	Expert Knowledge	Multiple	Multiple
15	Alaska's Climate Change Strategy: Public Infrastructure and Climate Change	2012	<u>Not available</u>	Alaska Department of Transportation (State Agency)	Presentation	Expert Knowledge	Multiple	Multiple

16	Alaskan Inuit Food Security Conceptual Framework	2015	https://iccalaska.org/wp-icc/wp-content/uploads/2016/03/Food-Security-Summary-and-Recommendations-Report.pdf	Inuit Circumpolar Council-Alaska (Tribal government or organization)	Summary	Multiple Methods	Arctic	Multiple
17	Aleutian and Bering Sea Islands Landscape Conservation Cooperative Strategic Science Plan Workshop Report	2013	https://lccnetwork.org/sites/default/files/Resources/ABSI%20LCC%20Strategic%20Science%20Plan%20Workshop%20Report.pdf	Aleutian and Bering Sea Islands Landscape Conservation Cooperative (Federal Agency)	Report	Workshop	Western	Rural, Off-road
18	Aleutian and Bering Sea Islands Landscape Conservation Cooperative Strategic Science Plan	2015	https://lccnetwork.org/sites/default/files/Resources/ABSI%20LCC%20Strategic%20Science%20Plan.pdf	Aleutian and Bering Sea Islands Landscape Conservation Cooperative (Federal Agency)	Strategy	Literature Review	Western	Rural, Off-road
19	American Indian and Alaska Native Climate Change Project	2011	https://www.fs.fed.us/pnw/pubs/pnw_gtr944.pdf	US Department of Agriculture and Oregon State University (Multiple Organizations)	Notes, letters or other	Survey	Multiple	Multiple
20	Arctic Landscape Conservation Cooperative Future Needs Assessment	2013	http://arcticlcc.org/projects/management/future-needs-assessment/	Arctic Landscape Conservation Cooperative (Federal Agency)	Needs Assessment	Interview	Arctic	Rural, Off-road
21	Arctic Landscape Conservation Cooperative Strategic Science Plan	2013	http://arcticlcc.org/assets/about/scienceplan/ALCC_Strategic_Science_Plan_draft_Feb2013.pdf	Arctic Landscape Conservation Cooperative (Federal Agency)	Strategy	Survey	Arctic	Rural, Off-road
22	Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies For Future Research	2008	http://www.arcodiv.org/news/NPRB_report2_final.pdf	Institute Of Marine Sciences (Federal Agency)	Report	Expert Knowledge	Arctic and Western Alaska	Rural, Off-road

23	Assessment of Potential Health Impacts of Climate Change in Alaska	2018	http://www.epi.alaska.gov/bulletins/docs/tr2018_01.pdf	Department of Health and Social Services (State Agency)	Summary	Literature Review	Multiple	Multiple
24	Building Food Security in Alaska	2014	https://www.crcworks.org/akfood.pdf	Department of Health and Social Services and Alaska Food Policy Council (State Agency)	Summary	Interview	Multiple	Multiple
25	Changing Conditions in the Arctic: Strategic Action Plan	2011	http://www.whitehouse.gov/sites/default/files/microsites/ceq/sap_8_arctic_full_content_outline_06-02-11_clean.pdf	Multiple Organizations	Strategy	Expert Knowledge	Arctic	Rural, Off-road
26	Chugach Regional Resources Commission Climate Change Workshop Outcomes	2016	https://tribalclimateguide.uoregon.edu/literature/2016-chugach-regional-resources-commission-climate-change-workshop-outcomes	Chugach Regional Resources Commission (State Agency)	Summary	Workshop	Southcentral	Urban, On-road
27	Chukchi Sea and Norton Sound Observation Network: Harvest and Use of Wild Resources in 9 Communities in Arctic Alaska	2017	https://www.arlis.org/docs/vol11/M/993004497.pdf	Alaska Department of Fish and Game (State Agency)	Report	Interview	Arctic	Rural, Off-road
27	Climate Change and Health Effects in the Bristol Bay Region of Alaska	2014	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_042014_Climate-Change-Bristol-Bay-Region.pdf	Bristol Bay Native Association, Bristol Bay Area Health Corporation, Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Summary	Survey	Western	Rural, Off-road
28	Climate Change and Health Impacts Point Hope, Alaska	2009	https://www.cidrap.umn.edu/sites/default/files/public/php/26952/Climate%20Change%20HIA%20Report%20Point%20Hope_0.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Summary	Literature Review	Western	Rural, Off-road

29	Climate Change and Indigenous Peoples- A Synthesis of Current Impacts and Experiences	2016	https://www.fs.fed.us/pnw/pubs/pnw_gtr944.pdf	US Department of Agriculture (Federal Agency)	Report	Literature Review	Multiple	Multiple
30	Climate Change and Private Forest Landowners in Alaska: A Needs Assessment	2011	http://s3-us-west-2.amazonaws.com/wp2.ca.hnrs.wsu.edu/wp-content/uploads/sites/32/2019/04/P2259.pdf	US Forest Service and Washington State (Multiple Organizations)	Needs Assessment	Expert Knowledge	Multiple	Multiple
31	Climate Change and Subsistence: What it means to Alaskans and how we can adapt	No Date	https://seagrant.uaf.edu/bookestore/download.php?loc=fla%2FM-139%2FM-139PDF.pdf&pub=M-139PDF&title=Clima+te+Change+and+Subsistence%3A+What+It+Means+to&bypass=TRUE	Alaska SeaGrant Marine Advisory Program, National Oceanic and Atmospheric Administration (Multiple Organizations)	Notes, letters or other	Expert Knowledge	Western	Multiple
32	Climate Change and Tribes	2012	No Longer Available	US Forest Service (Federal Agency)	Presentation	Expert Knowledge	Multiple	Multiple
33	Climate change: anticipated effects on ecosystem services and potential actions by the Alaska Region, U.S. Forest Service	2010	http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_038171.pdf	US Forest Service (Federal Agency)	Summary	Literature Review	Multiple	Multiple
34	Climate Change Impact Assessment for Surface Transportation in the Pacific Northwest and Alaska	2012	http://www.wsdot.wa.gov/research/reports/fullreports/772.1.pdf	Washington State Department of Transportation (State Agency)	Needs Assessment	Multiple Methods	Multiple	Multiple
35	Climate Change in Atqasuk, Alaska Strategies for Community Health	2015	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_072014_Climate-Change-in-Atqasuk.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Arctic	Rural, Off-road
36	Climate Change in Kivalina, Alaska Strategies for Community Health	2011	http://www.anthc.org/chs/ces/climate/upload/Climate-Change-in-Kivalina-Alaska-Strategies-for-Community-Health-2.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Strategy	Interview	Arctic	Rural, Off-road

37	Climate Change in Levelock, Alaska Strategies for Community Health	2013	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_042014_Climate-Change-in-Levelock.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Western	Rural, Off-road
38	Climate Change in Nondalton, Alaska Strategies for Community Health	2015	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_112013_Climate-Change-in-Nondalton.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Western	Rural, Off-road
39	Climate Change in Nuiqsut, Alaska Strategies for Community Health	2014	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_072014_Climate-Change-in-Nuiqsut.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Arctic	Rural, Off-road
40	Climate Change in Pilot Point, Alaska Strategies for Community Health	2015	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_092013_Climate-Change-in-PilotPoint.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Western	Rural, Off-road
41	Climate change in Point Hope, Alaska: Strategies for Community Health	2010	https://www.cakex.org/sites/default/files/documents/CCH_AR_082010_Climate-Change-in-Point-Hope.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Western	Rural, Off-road
42	Climate Change in Selawik, Alaska Strategies for Community Health	2016	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_052012_Climate-Change-in-Selawik.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Western	Rural, Off-road
43	Climate change in the Bering Strait Region	2015	https://lccnetwork.org/resource/climate-change-bering-strait-region	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Interview	Western	Rural, Off-road

44	Climate Change in Wainwright Strategies for Community Health	2015	https://anthc.org/wp-content/uploads/2016/01/CCH_AR_062014_Climate-Change-in-Wainwright.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Report	Multiple Methods	Arctic	Rural, Off-road
45	Change Climate Change Scenario Planning for Central Alaska Parks	2014	https://irma.nps.gov/DataStore/DownloadFile/497782	National Park Service (Federal Agency)	Report	Workshop	Interior and Arctic	Rural, On-road
46	Climate Change Water Infrastructure Forum	2008	<u>Not available</u>	Environmental Protection Agency (Federal Agency)	Report	Workshop	Multiple	Multiple
47	Community Observations on Climate Change: Nushagak River Trip Report	2014	http://anthc.org/wp-content/uploads/2016/01/CCH_AR_092014_Climate-Change-and-Upper-Nushagak-River.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Summary	Multiple Methods	Western	Rural, Off-road
48	Community Observations on Climate Change: Arctic Village, Fort Yukon and Venetie, Alaska	2016	https://anthc.org/wp-content/uploads/2016/01/Upper-Yukon-River-Climate-Assessment-Final.pdf	Alaska Native Tribal Health Consortium (Tribal Government or Organization)	Summary	Survey	Interior and Arctic	Rural, Off-road
49	Cultural Resources Climate Change Strategy	2017	https://www.nps.gov/subjects/climatechange/culturalresourcesstrategy.htm	National Park Service (Federal Agency)	Summary	Multiple Methods	Multiple	Multiple
50	Current coastal change projects and priority information needs in Western Alaska	2015	https://accap.uaf.edu/project/current-coastal-change-researchmanagement-projects-and-priority-information-needs-western	Alaska Center for Climate Assessment and Policy and Western Landscape Conservation Cooperative (Multiple Organizations)	Needs Assessment	Literature Review	Western	Rural, Off-road
51	Elim Hazard Impact Statement	2012	http://www.commerce.state.ak.us/dca/planning/acc	City of Elim (Local Agency)	Summary	Multiple Methods	Western	Rural, Off-road

mp/Elim.html

52	Emerging Issue Summary: North Slope Science Initiative	2009	http://catalog.northslopescience.org/catalog/entries/8606-nssi-emerging-issues	North Slope Initiative Oversight Group (Multiple Organizations)	Summary	Multiple Methods	Arctic	Rural, Off-road
53	Experts Workshops to Comparatively Evaluate Coastal Current and Ice Movements in the Northeastern Chukchi Sea	2014	https://www.uaf.edu/cfos/research/projects/experts-workshops-to-comp/	International Arctic Research Center (Research Institute)	Report	Workshop	Arctic	Rural, Off-road
54	Exploring Stakeholder Needs for Coastal Research in a Rapidly Changing Arctic	2018	https://climatechange.umaine.edu/2018/06/18/exploring-stakeholder-needs-coastal-research-rapidly-changing-arctic/	University of Maine, Arctic Landscape Conservation Cooperative, Arctic Borderlands Ecological Knowledge Society (Multiple Organizations)	Summary	Interview	Arctic	Rural, Off-road
55	Exploring the Subsistence Fisheries of Point Lay and Wainwright, Alaska	2016	https://www.arlis.org/docs/vol11/M/965293136.pdf	Alaska Department of Fish and Game (State Agency)	Report	Multiple Methods	Arctic	Rural, Off-road
56	Food Security and Wild Resource Harvests in Alaska	2018	http://www.adfg.alaska.gov/static/home/subsistence/pdfs/food_security_whitepaper.pdf	Alaska Department of Fish and Game (State Agency)	Summary	Expert Knowledge	Multiple	Multiple
57	Hazard Impact Assessment: Kipnuk, AK	2011	https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/ACCIMP/HazardImpactAssessments/KipnukHIA.aspx	Alaska Department of Commerce, Community, and Economic Development, Kipnuk Traditional Council (Multiple Organizations)	Summary	Multiple Methods	Western	Rural, Off-road

58	Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change	2010	http://www.niehs.nih.gov/health/assets/docs_a_e/climate-report2010.pdf	National Institute of Health, National Oceanic and Atmospheric Administration, Center for Disease Control and Prevention (Federal Agencies)	Needs Assessment	Expert Knowledge	Multiple	Multiple
59	Health Problems Heat up	2007	Not available	Trust for American's Health (Non-profit)	Report	Expert Knowledge	Multiple	Multiple
60	Immediate Action Workgroup: Recommendations to the Governor's Subcabinet on Climate Change	2009	https://dec.alaska.gov/media/4558/immediate-action-workgroup-final-report-12-mar-09.pdf	Alaska Governor Subcabinet on Climate Change (State Agency)	Report	Expert Knowledge	Arctic	Multiple
61	Impacts of Climate Change on Tribes in the United States	2009	Not available	National Tribal Air Association (Tribal Government or Organization)	Report	Expert Knowledge	Multiple	Multiple
62	Implications of Climate Change and Research Needs for Coastal Processes in Cold Regions	2009	Not available	Multiple Organizations	Presentation	Expert Knowledge	Multiple	Multiple
63	Kotzebue Meeting Notes: Improving Local participation in research in Northwest Alaska	2013	http://www.arcus.org/files/page/documents/893/lccko_tzebuenotes.pdf	Western Alaska Landscape Conservation Cooperative, Arctic Research Consortium of the U.S., Northwest Arctic Borough, Noorvik Native Community, Native Village of Kotzebue (Multiple Agencies)	Notes, letters or other	Workshop	Arctic	Rural, Off-road
64	Nelson Lagoon Hazard Impact Statement	2011	http://www.aebfish.org/nl/hiaNL102811.pdf	Aleutians East Borough (Local Agency)	Summary	Multiple Methods	Western	Rural, Off-road

65	Nome Tribal Climate Adaptation Plan	2017	https://accap.uaf.edu/sites/default/files/resources/Nome%20Tribal%20Climate%20Adaptation%20Plan%20%28Final-LowRes%29.pdf	Alaska Center for Climate Assessment and Policy (Research Institute)	Unassigned	Interview	Western	Rural, Off-road
66	Optimizing Military Training Land Use into the Future, NH Joint Engineering Society Conference	2011	http://www.nhjes.org/2011_Joint_Conference/presentations/1B%20Shoop%20-%20AK%20training%20lands%20v2[1].pdf	US Army Corps of Engineers (Federal Agency)	Presentation	Expert Knowledge	Multiple	Multiple
67	Prioritized fire research topics for Alaska	2011	http://fire.ak.blm.gov/content/admin/awfcg_committees/Fire%20Research%20Development%20and%20Application/f.%20Fire%20Research%20Topic%20Promotion%20Flyer_Final.pdf	Alaska Wildland Fire Coordinating Group (Multiple Organizations)	Needs Assessment	Workshop	Multiple	Multiple
68	Priority Information Needs: Federal Subsistence Fisheries	2010	https://www.fws.gov/nativeamerican/pdf/tek-fisheries-resource-monitoring-plan.pdf	Fisheries Resource Monitoring Committee (Multiple Organizations)	Report	Multiple Methods	Multiple	Multiple
69	Promoting Resilience Adaptation: A Synthesis from Four Regional Workshops in Alaskan Arctic	2017	https://adapталaska.org/wp-content/uploads/2017/10/ak-adaptation-workshop.pdf	Aleutian Pribilof Islands Association, Western Alaska Landscape Conservation Cooperative, Aleutian and Bering Sea Landscape Conservation Cooperative (Multiple Organizations)	Summary	Workshop	Arctic and Western	Rural, Off-road
70	Research Needs Work Group: Recommendations on Research Needs Necessary to Implement an Alaska Climate Change Strategy	2009	https://digital.library.unt.edu/ark:/67531/metadc226606/m2/1/high_res_d/rn_12jun09_dftrpt.pdf	Alaska Research Needs Work Group (Multiple Organizations)	Report	Expert Knowledge	Multiple	Multiple

71	Resilience Climate Change White Paper	2017	Not available	Environmental Protection Agency (Federal Agency)	Article	Literature Review	Multiple	Multiple
72	Resource for Consideration by National Climate Assessment Teams Addressing the Impacts of Climate Change on Native Communities	2011	http://www.tribesandclimatechange.org/project_docs/submission_to_nca_2011_11_30.pdf	Cooperative Institute for Research in Environmental Science (Research Institute)	Notes, letters or other	Workshop	Multiple	Multiple
73	Southeast Alaska Environmental Conference: Report on the Climate Adaptation Summit	2016	https://nplcc.blob.core.windows.net/media/Default/2016_Documents/UAF/SE%20Climate%20Adaptation%20Summit_Final%20Report-1.pdf	Central Council of Tlingit and Haida Indian Tribes of Alaska, Alaska SeaGrant (Tribal Government or Organization)	Summary	Workshop	Southeast	Multiple
74	Snow, Ice and Permafrost Hazards in Alaska	2011	https://accap.uaf.edu/sites/default/files/resources/AlaskaCryosphereHazardFinal.pdf	Alaska Division of Geological and Geophysical Surveys and Alaska Center for Climate Assessment and Policy (Multiple Organizations)	Needs Assessment	Workshop	Arctic	Rural, Off-road
75	Southern Kenai Peninsula, Alaska Community Health Needs Assessment Executive summary	2014	http://mappofskp.net/wp-content/uploads/2014/12/2nd-CHNA-Exec-Summary.pdf	Southern Kenai Mobilization through Action and Planning Partnerships (Local Agencies)	Summary	Survey	Southcentral	Multiple
76	Stakeholder Based Regional Marine Research Plan for the Aleutian Islands	2016	https://seagrants.noaa.gov/Portals/0/Documents/AlaskaRegionalResearchPlan.pdf	Alaska SeaGrant (Research Institute)	Report	Workshop	Western	Rural, On-road
77	State of Change Climate Change Scenario Planning for Central Alaska Parks	2014	https://www.snap.uaf.edu/sites/default/files/files/State-of-Change_Final_August-2014.pdf	National Park Service, Scenarios Network for Alaska and Arctic Planning, Alaska Center for	Report	Workshop	Interior and Arctic	Rural, Off-road

				Climate Assessment and Policy (Multiple Organizations)				
78	The State of Change: Climate Change Scenario Planning for Northwest Alaska Parks	2014	https://www.snap.uaf.edu/sites/default/files/files/State-of-Change_Final_August-2014.pdf	National Park Service, Scenarios Network for Alaska and Arctic Planning, Alaska Center for Climate Assessment and Policy (Multiple Organizations)	Report	Workshop	Arctic and Western	Rural, On-road
79	The State of Change: Climate Change Scenario Planning for Southwest Alaska Parks	2014	https://www.snap.uaf.edu/sites/default/files/files/State-of-Change_Final_August-2014.pdf	National Park Service, Scenarios Network for Alaska and Arctic Planning, Alaska Center for Climate Assessment and Policy (Multiple Organizations)	Report	Workshop	Southcentral	Rural, Off-road
80	The Arctic Climate Change and Security Policy Conference	2009	https://carnegieendowment.org/2009/06/24/arctic-climate-change-and-security-policy-conference-final-report-and-findings-pub-23314	The Carnegie Endowment for International Peace (Research Institute)	Report	Workshop	Arctic	Rural, On-road
81	The effects of a changing climate on key habitats in Alaska	2010	http://www.adfg.alaska.gov/static/lands/ecosystems/pdfs/sp10_14.pdf	Alaska Department of Fish and Game (State Agency)	Summary	Expert Knowledge	Multiple	Rural, Off-road
82	Tribal Recommendations for the Fiscal Year 2012 Department of the Interior Climate Change Adaptation Initiative	2012	Not available	Affiliated Tribes of Northwest Indians (Tribal Government or Organization)	Notes, letters or other	Expert Knowledge	Multiple	Multiple
83	Tribal Science Priorities for the National EPA	2011	http://www.epa.gov/tp/pdfs/nts-priorities-guide-2011.pdf	Tribal Science Council (Tribal Government or Organization)	Needs Assessment	Expert Knowledge	Multiple	Multiple

84	US Climate Change Science Program Stakeholder Listening Session	2008	Not available	Alaska Department of Environmental Conservation (State Agency)	Report	Workshop	Multiple	Multiple
85	Western Association of Fish and Wildlife Agencies Climate Change Committee Annual Update for Committee Members	2011	http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentVersionID=57780	Western Association for Fish and Wildlife Agencies Climate Adaptation Committee (Multiple Organizations)	Needs Assessment	Survey	Multiple	Multiple
86	Whitefish and Other Nonsalmon Fish Trends in Lake Clark and Iliamna Lake, Alaska, 2012 and 2013	2015	http://www.adfg.alaska.gov/techpap/TP411.pdf	Alaska Department of Fish and Game and Bristol Bay Native Corporation (State Agency)	Report	Survey	Western	Multiple
87	Wildlife Response to Environmental Arctic Change	2008	https://archive.arcus.org/alaskafws/downloads/pdf/WildREACH_Workshop_Report_Final.pdf	US Fish and Wildlife Service (Federal Agency)	Needs Assessment	Workshop	Arctic	Rural, Off-road

Appendix 2. Major sub-theme definitions that were used during the coding process.

OBSERVATIONS and RESEARCH NEEDS

Wild Food Species:

Species distribution: species distribution, dispersion, and migration patterns

Species abundance: population size, number of individuals per species,

Emerging species: novel or invasive species, new species in a certain area

Phenology: the timing of species on the landscape, changes to annual life cycle

Species health: wildlife/fish and plant disease, wildlife/fish body condition,

Biophysical Environmental Conditions:

Extreme weather: changing temperature, precipitation, and wind patterns

Fire regime: changes in wildfire severity, extent, and frequency

Hydrological conditions: lake/river drying, flooding, and morphology

Ice conditions: ocean/lake/river ice thickness, extent, and quality

Ocean acidification: oceanic pH levels

Permafrost: permafrost slumping, loss, and erosion

Socio-economic Conditions:

Relationships: individual and community-wide communication, connections, and relationships

Economic costs: financial costs associated with harvesting and processing wild foods

Food security: reliable access in terms of quantity, quality, and diversity of wild foods

Food safety: bioaccumulation, disease exposure

Travel access/safety: changes in travel conditions that impact harvester safety

ADAPTATION STRATEGIES

Training and education: classes, workshops, and outreach associated with wild food harvest

Legal and policy framework: new legal or decision-making processes and procedures that guide management of natural resources.

Management: Co-management, adaptive management, actionable, applied decision-making strategies for natural resource managers

Communication strategies: new virtual, written, or oral modes of communication to share wild food information

Food planning: household and community-wide wild foods sharing efforts

Switching harvest species: adopting new techniques to harvest non-traditional or new wild foods

Food processing methods: adopting new techniques to process and store wild foods

Adapting season: adjusting the timing of wild food harvest

New travel methods: adopting new modes of transportation to access wild foods
