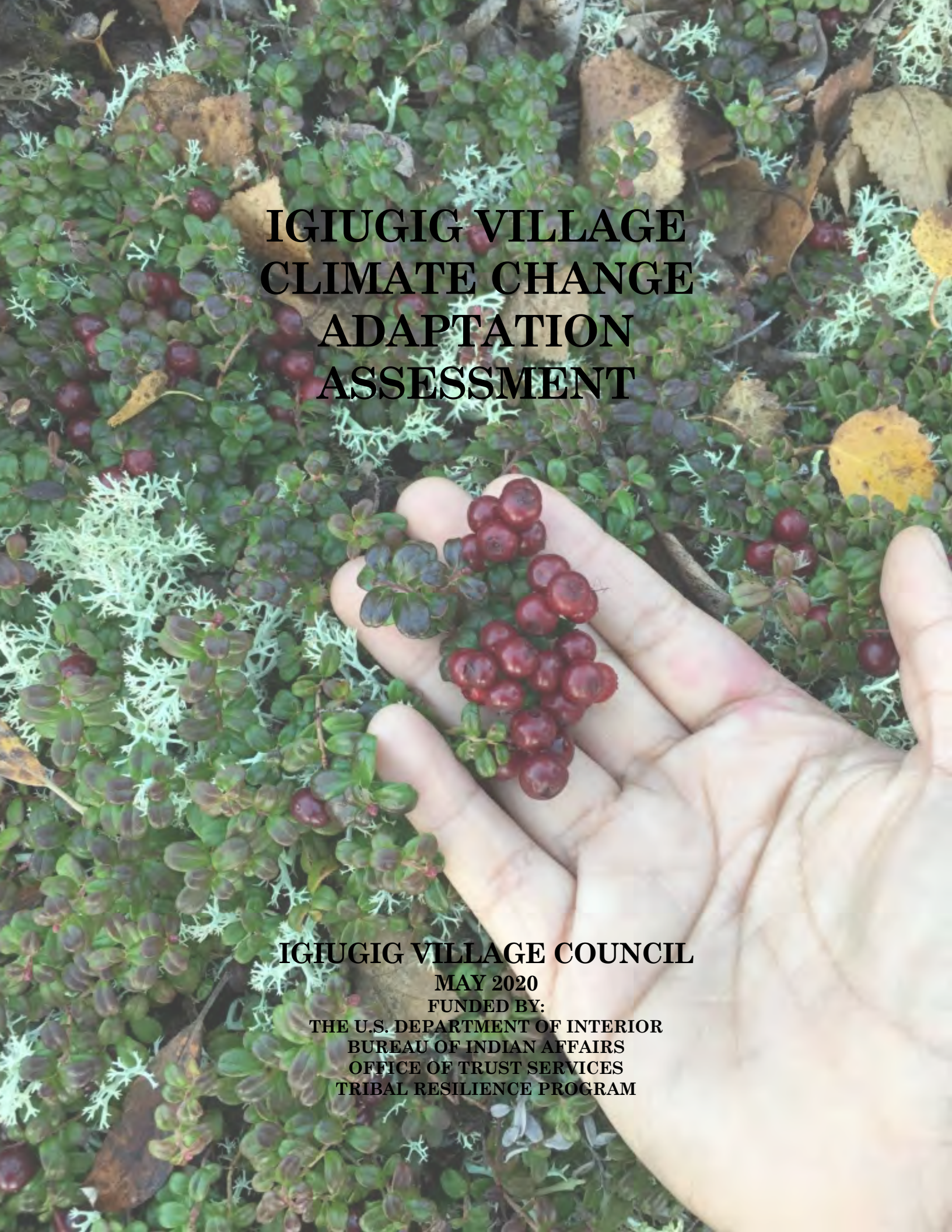


A close-up photograph of a person's hand holding a small cluster of bright red, round berries. The hand is positioned in the lower right quadrant of the frame. The background is a dense forest floor covered with green moss, small green plants, and scattered brown and yellow autumn leaves. The lighting is natural, highlighting the textures of the moss, leaves, and the skin of the hand.

IGIUGIG VILLAGE CLIMATE CHANGE ADAPTATION ASSESSMENT

IGIUGIG VILLAGE COUNCIL

MAY 2020

FUNDED BY:

**THE U.S. DEPARTMENT OF INTERIOR
BUREAU OF INDIAN AFFAIRS
OFFICE OF TRUST SERVICES
TRIBAL RESILIENCE PROGRAM**

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Quyana to our funder who made this Adaptation Assessment possible – The U.S. Department of the Interior, Bureau of Indian Affairs, Office of Trust Services, Tribal Resilience Program.



Image 1: Makuryat Dance group performs at the repatriation site at Old Igiugig, Qinuyang, Alaska 2017

IGIUGIG FROM PAST TO PRESENT

Geography

Igiugig is located in southwest Alaska approximately 250 air miles southwest of Anchorage, at the headwaters of the Kvichak River as it flows from Lake Iliamna (Figure 1). Igiugig is characterized by low-lying topography, tundra interspersed with boreal forests, and wetlands draining towards the Kvichak River. The Iliamna/Kvichak is a major watershed and part of the largest Sockeye Salmon run in world.

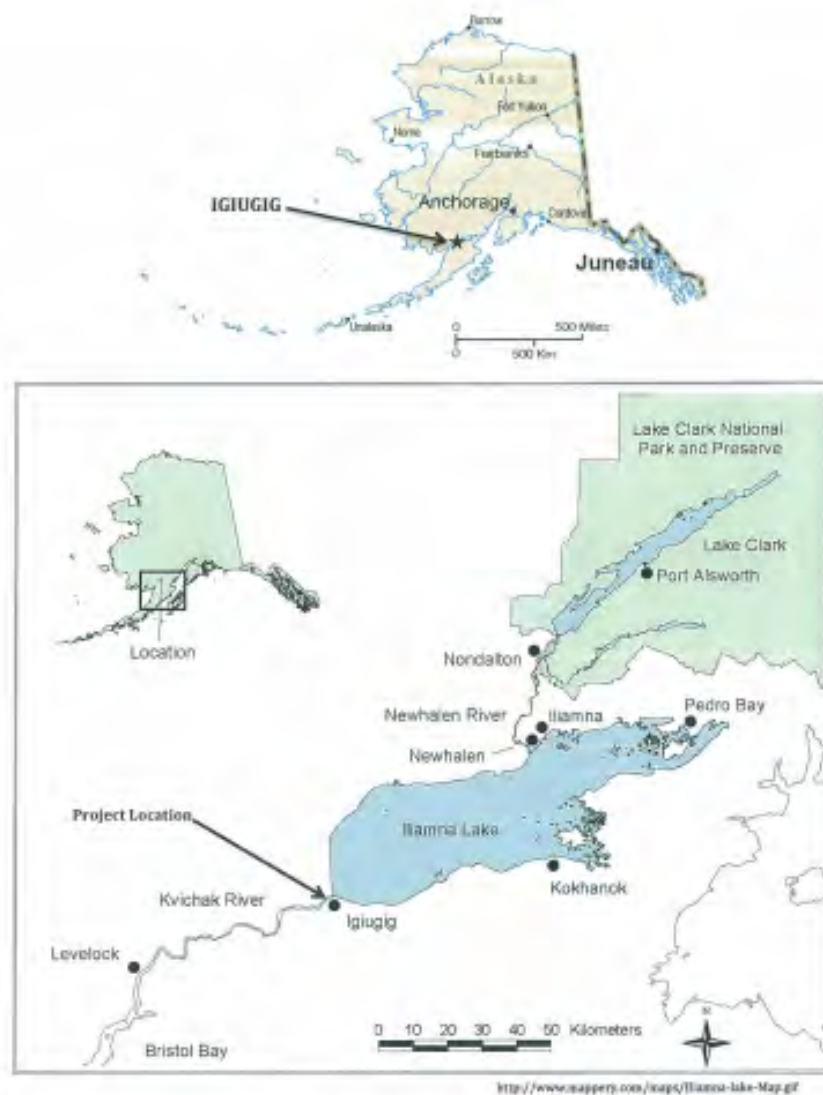


Figure 1: Map of Alaska showing Igiugig Location

History and Culture

The name of Igiugig in Yup'ik is *Igyaraq* (meaning “throat”) to depict the location where the lake drains into the river. This location is at the convergence of three major Alaska Native groups: the Alutiiq, Dena'ina Athabascan, and Yup'ik. Based on

archeological evidence, this area has been continually inhabited for over 8,000 years, since “time immemorial.” The Indigenous lifestyle centers around the ecology of salmon, caribou, waterfowl, and a host of wild berries and plants of the tundra and taiga. Rural tribes moved seasonally following the pulse of biological activity. With colonization and westernization, tribes eventually moved to permanent settlements while maintaining fish camps and trapping lines. The subsistence way of life remains vital to the identity and narrative of the region’s people, not just in provisions but also in spiritual manifestations and the continuation and dissemination of Indigenous knowledge systems.

Government

The Igiugig Village Council (IVC) is the federally recognized tribal government of the Native Village of Igiugig. IVC is the only local government and oversees the ongoing business affairs and wellbeing of Igiugig, a self-sufficient village with strong cultural and environmental values. The IVC is directed by a comprehensive strategic plan, which is informed by ongoing community-based participatory processes.

Igiugig Village Council’s mission is to provide resources, programs, and infrastructure to enhance our quality of life. As a community, we strive for a prosperous future by fulfilling our goals: sustainable social and economic development that is compatible with our subsistence way of life; invest in life-long education; provide a safe, welcoming community that provides affordable living and a strong, diversified local economy; maintain good working relationships with other communities, lodges, and state/federal/local agencies.



Community Planning Efforts for Resilience

Igiugig is a resilient community, characterized by strong community values that support community coherence while allowing for diversity and individual expression. The high degree of resilience means that the community is well equipped to navigate uncertainty and environmental and socioeconomic fluctuations. Communities arise from a collective sense of purpose. They share a common history as well as a vision for survival and well-being. Engaging in planning processes helps to determine the pathway to achieving that vision, and Igiugig uses such processes actively to move the community towards greater self-sufficiency (Mannell, 2013).

In Igiugig, a planning process was formalized when IVC began development of an in-depth Community Comprehensive Plan using a consulting firm and local planners, funded by the Administration for Native Americans (2000). This plan was written as a proactive approach to meet community challenges and develop projects that will assist Igiugig in its capacity to become self-sufficient in areas of energy, education, and economics, all the while focusing on projects that will be culturally appropriate and sustainable. All community members took part in the planning process, from infants to elders, driven by the logic of coming together to ensure the prosperity of the community as a whole now and into the future. The comprehensive plan has served as a guiding document for tribal operations and the process for prioritizing projects, programs, and future plans. It has also helped to inform strategic collaborations to carry out community efforts for resilience.

Many partnerships, plans, and participation in regional studies have grown from the strategic plan. The list below shows a few selected efforts that are relevant to the Adaptation Assessment:

- *2002 Water Resources Management Plan, Igiugig Village Council*: ensuring continuous sustainable management of water resources, including access to clean drinking water and a healthy watershed for plants, animals and humans to thrive.
- *2010 Bristol Bay Regional Visioning Plan, Bristol Bay Native Corporation*ⁱ: informing regional visioning and development through community values and strategic planning.
- *2011 Community Partnership for Self-Reliance (CPS) project, Alaska Native Science Commission and University of Alaska Fairbanks*: an effort aimed at maintaining and strengthening cultural integrity and self-sufficiency in the face of ongoing change. This effort was initiated in response to Native leader Larry Mergulieff's challenge to universities to do research based on the real priorities of Alaska Native communities. CPS aims at coupling institutional technical skill and method with local needs and knowledge (Chapin et al. 2016). As part of the CPS, Igiugig conducted an analysis of renewable energy options and forged a partnership with UAF's Alaska Center for Energy and Power (ACEP).

- *2011 Iliamna Lake Seals Local and Scientific Understanding, North Pacific Research Board, Bristol Bay Native Association, and ADF&G Division of Subsistence*ⁱⁱ: providing broad local knowledge on the use, behavior, and physiology of Lake Iliamna seals to enhance scientific understanding and protect habitat (Burns et al. 2012).
- *2016-2018 Mulchatna Caribou Herd study, Alaska Department of Fish and Game Division of Subsistence*ⁱⁱⁱ: providing local knowledge of the historical and present day relations to the Mulchatna Caribou Herd.
- *2019 MicroFEWS collaboration, University of Alaska Fairbanks*^{iv}: collaborating on research on and implementation of renewable energy infrastructure.
- *2019 Igyararmiuni Ciunerkaput, “Our Sustainable Futures”, Igiugig Village Council*: community strategy developed for the purpose of re-establishing tribal authority over traditional territory, stewarding our resources in keeping with our Native values, and ensuring a prosperous future for our community
- *2019 “Igiugig Conservation Planning Atlas and Report,” by Marcus Geist, Geographer, Artesian Knowledge LLC and Tim Troll, Executive Director of Bristol Bay Heritage Land Trust, for Igiugig Native Corporation*: planning process to ensure continuous sustainable management and relations with environmental and cultural heritage on Igiugig Native Corporation lands.
- *2020 Igiugig Community Cultural Center Planning and Implementation Guide, Igiugig Village Council*: a guiding plan for the creation of a community cultural center as a gathering space to conduct activities such as traditional dancing, business and community meetings, a classroom to facilitate language learning, and a commercial kitchen to create value-added products from foods grown and harvested locally.
- *2020 NREL energy vision, National Renewable Energy Laboratory*: planning for a renewable energy future.

These efforts demonstrate that Igiugig is actively working towards reaching the vision of a thriving and self-sufficient community. However, the lifestyle and Indigenous knowledge of Igiugig is being challenged by the speed of climatic change. The adaptive integrity of the Indigenous population of Igiugig is built upon thousands of years of a direct relationship to the landscape and the ability to read changes and patterns within the geography. The speed of modern change is threatening the tribes’ ability to adapt as well as putting constraints on cultural dissemination, communication, and education of young tribal members.

The community is already witnessing the impacts of climate change. For instance, the bulk fuel farm, which sits above the river storing 114,000 gallons of petroleum products, began eroding into the Kvichak River and required a major sheet pile stabilization construction project (2012). The erosion occurred due to late freezing, super saturated soils, hurricane winds and high river levels. Other observations of

climate change impacts include several years of poor berry crops, the lake not freezing, as well as the absence of the caribou herd that historically has used Igiugig lands as part of their migration. These and other changes have made the community alarmed and helped identify the need for this present report.

In 2018, IVC applied to the Bureau of Indian Affairs Tribal Resilience Program to complete an adaptation assessment. After receiving funding, the process of creating this report began with initial identification of environmental changes believed to be related to climate change. One of the goals of this adaptation assessment is to combine the lens of Indigenous knowledge with the lens of modern science, creating new ways of thinking, learning, and adapting. This bridging is not only beneficial for Igiugig as an Alaska Native community, but is essential for moving towards more integrated ways of solving the complex problems of the 21st Century (Johnson et al. 2016). As plans are implemented, and experience builds, so too does local capacity: “[Planning] involves thinking about where a community wants to be down the road and taking calculated actions to achieve this future. In this way a plan creates hope” (Mannell, 2013).

SCOPE AND AIM OF ADAPTATION ASSESSMENT



Image 2: Aerial view of Igiugig, AK

This Adaptation Assessment is the first step in developing a climate adaptation plan for the Igiugig Village Council (IVC). The ultimate objective of this assessment is to create a baseline foundation of information, research, and partnerships that are locally driven and dynamic in nature.

The assessment springs from the recognition of the unsettling changes to the climate and subsequent changes to the local landscape with impacts on resources, infrastructure, public safety and the *Igyararmiut* way of life. The velocity of the climatic changes experienced and expected to come coupled with the geography of the area is undermining the village's capacity to adapt and thrive. This Adaptation Assessment begins the process of learning and researching climate change projections in order to determine the best practices moving forward.

The assessment draws from the latest scientific data available, with a special focus on the Indigenous knowledge systems that have been in place for thousands of years. Local interviews with village elders and community members provide a deeper knowledge concerning community systems, including ecological, energy, and educational systems.

With help from the Igiugig community, as well as regional, state, and national partners, this Assessment outlines vulnerable resources that are impacted and threatened by climate change. Further, the Assessment aims to build connections between existing Indigenous knowledge networks with other experts, technicians, and researchers. Ultimately, the report aims to lay the groundwork for further research and development that will aid the Igiugig Village Council in developing and implementing Igiugig's Resiliency Action Plan.

This is a working document, meant to evolve with the changing fabric of the landscape, that will serve as a guide for future planning in resiliency and ensure that the people of Igiugig will continue to thrive into the future.



Image 3: Iliamna Lake at Igiugig, Alaska 2017

METHODOLOGY AND PROCESS

Indigenous Knowledge and Indigenous Planning

In planning for and gathering data to support this Adaptation Assessment, the Igiugig Village Council (IVC) has been guided by the cultural values of Igiugig and a Yup'ik worldview, including an understanding of social and environmental systems as highly connected and an emphasis on respectful relations and reciprocity, including between the human, the non-human and the more-than-human. The Yup'ik way of life involves many values including cooperation, sharing, and respect for Nature and land. “The unpredictability of starvation, the length of the winter season when food was scarcer, and surviving in the harsh Northern climate required a cooperative effort. Over time, the Yup'ik culture developed complex traditions and relationships to ensure that the people would always share, cooperate, and respect each other. It is easy to describe “subsistence” as merely the seasonal harvesting of resources, but to do so would be to neglect a Yup'ik relationship to their land and resources that transforms subsistence socially and spiritually into a way of life” (Salmon 2008). For over 8,000 years, we have adapted ourselves and our economies in the context of where we live. Rapid climate change will require us, now more than ever, to utilize the traditional values and native ways of knowing to guide evidence-based decision making for adaptation.

A central principle for this assessment has been the integration of scientific knowledge with Indigenous knowledge about changes and impacts. Integration of knowledges and worldviews allows for a comprehensive understanding of the many

ways in which climate change impacts the community and the wide range of approaches that can help reduce vulnerabilities and enhance resilience (Johnson et al. 2016; Kimmerer 2012). Where climate change effects are extreme, data is often limited. Few weather stations offer long-term reliable histories. However, traditional knowledge offers a rich source of information. Partnerships between communities and scientific researchers can, ideally, be valuable to all concerned. Linking local reports and experiences to data and models can help with long-term climate change planning and adaptation. Igiugig community members hold a large amount of knowledge about the natural environment and have maintained a close connection to the local terrestrial and aquatic ecosystems through time spent on the land and through oral traditions. This knowledge forms the starting point for the assessment of current and future climate change impacts in Igiugig.

All community projects in Igiugig are founded on the concepts of Indigenous Planning, and this assessment is no exception. The characteristics of Indigenous planning are that the planning processes: 1) have always existed, 2) require a commitment to political, social, economic, and environmental change, and 3) are community and place-based (Matunga 2013, 5). Community projects are similarly informed by the concept of Indigeneity, which features outcome-oriented thinking and focuses on creating solution-oriented, and value-driven solidarity wherein “each person can contribute effectively to the whole from their place of belonging so that we can all move forward into the future together” (Harris and Wasilewski 2004, 495).

Scenarios Network for Alaska and Arctic Planning (SNAP)

In seeking to combine Indigenous knowledge and scientific research data, IVC has made use of the services provided by the Scenarios Network for Alaska and Arctic Planning (SNAP). Since 2007, SNAP, which is part of UAF’s International Arctic Research Center, has used climate data to develop credible projections that advise policy and management across Alaska and the Arctic. Computer models that simulate relationships between climate, vegetation, fire, and other key variables are important tools for understanding and projecting environmental change (Rupp et al. 2007). SNAP helps partners choose the best ways to visually communicate climate research messages by creating maps, websites, interactive tools, maps, diagrams, and print publications. Outputs and products allow for clear understanding and continuing dialogue between climate modelers and user communities in order to foster efficient decision-making and sound collaborative research.

Tribal Climate Change Adaptation Planning Toolkit

At the practical level, planning and data-gathering for the Assessment has been informed by The Tribal Climate Change Adaptation Planning Toolkit (TCCAPT)^v. TCCAPT is a methodology developed by the institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University for Native American and Alaska Native communities to identify important sources of vulnerability, explore adaptation needs and enhance community resilience in the context of climate change.

The toolkit is based on the guiding principles from The Interagency Climate Change Adaptation Task Force. Adapted to a tribal context, these principles include:

- Adopt integrated approaches: Integrate climate change preparation and response into core policies, planning, practices, and programs whenever possible.
- Prioritize the most vulnerable: Prioritize helping people, places, natural systems, and infrastructure that are most vulnerable to climate impacts; Design and implement with meaningful involvement from all parts of society; Address issues of inequality and environmental justice associated with climate change impacts and adaptation.
- Use best-available science: Ground adaptation in best-available scientific understanding of climate change risks, impacts, and vulnerabilities, accepting high levels of uncertainty; Adjust plans and actions as our understanding of climate impacts increases and as changing circumstances dictate.
- Build strong partnerships: Coordinate adaptation efforts across multiple sectors, geographical scales, and levels of government and build on the existing efforts and knowledge of a wide range of stakeholders; Ground adaptation efforts in local or regional risks and needs.
- Apply appropriate risk-management methods and tools: Adopt or develop a risk management approach to assess and respond to climate change and aid in understanding the potential consequences of inaction as well as options for risk reduction.
- Apply ecosystem-based approaches: Integrate the protection of biodiversity and ecosystem services into adaptation strategies in order to increase resilience of human and natural systems to climate and non-climate risks, providing benefits to society and the environment.
- Maximize mutual benefits: Where possible, use strategies that complement or directly support other related climate or environmental initiatives, such as efforts to improve disaster preparedness, promote sustainable resource management, and reduce greenhouse gas emissions including the development of cost-effective technologies.
- Continuously evaluate performance: Include measurable goals and performance metrics, both qualitative and quantitative, to continuously assess whether adaptive actions are achieving desired outcomes; Maintain flexibility in order to build a robust and resilient process that can accommodate uncertainty and change.

Based on the principles outlined above, the toolkit suggests seven steps for creating a climate change adaptation assessment and plan. The present Assessment accounts

for the first four steps, including initiation, assessment of impacts and vulnerabilities, assessment of risk and prioritization for planning, and development of adaptation strategies. All seven steps suggested by TCCAPT are outlined below.

1. **Initiate climate change planning efforts:** This first step includes building and maintaining support with community leadership and members, building a planning team and establishing internal and external partnerships and securing funding. It also includes gathering data on climate change impacts of the region and scoping these to the sectors and resources of high importance for the community.
2. **Assess climate change impacts and vulnerabilities:** The second step involves developing climate change scenarios based on available information, identifying/characterizing current and projected impacts on sectors and planning areas of interest, and assessing the vulnerabilities of the sectors and planning areas to those impacts.
3. **Assess risks and prioritize areas for planning:** The third step involves assessing risks posed by climate change impacts and prioritizing sectors and planning areas for development of adaptation strategies.
4. **Develop adaptation strategies:** The fourth step involves developing adaptation goals—major results the tribe wants to accomplish—and developing and prioritizing adaptation actions.
5. **Write and integrate adaptation plan:** The fifth step involves writing the adaptation plan and getting it reviewed and approved by the community. It also involves integrating the plan into other management and planning activities/documents.
6. **Implement the adaptation plan:** The sixth step involves identifying feasible first steps for implementation as well as building leadership, partnership and community support for implementing adaptation actions. It also includes locating funding and ensuring you have the right implementation tools.
7. **Measure progress and update plan:** The seventh and final step involves tracking progress in implementing actions and attaining goals as well as evaluating effectiveness of adaptation actions. It also involves continuously monitoring changes in climate and associated impacts, reviewing basic assumptions as well as updating the plan regularly to respond to changing circumstances and/or data as new information becomes available.

Adaptation Assessment Process

The principles and steps outlined in the TCCAPT have guided the Igiugig adaptation assessment process. A series of eight community-planning meetings were conducted over the course of the assessment period. The initial meeting informed the community about the toolkit and methodology for the assessment. The following meetings were held around focused themes, with the first theme exploring local hazards. It was

discussed that while previously erosion was a serious issue (the bulk fuel farm, for example), the community has mitigated for those imminent threats. Thus, the threat of wildfire to subsistence resources, infrastructure, and community health was determined to be the main hazard. The assets the community selected to protect were prioritized as 1. Subsistence lifestyle and food security, 2. Water quality, and 3. Infrastructure. The main climate change hazards were identified and are shown below in order of priority:

1. Wildfire risk
2. The shifting seasonal harvest calendar
3. Water quality issues due to increased water temperatures
4. Melting permafrost
5. Erosion
6. Invasive species
7. Increase in vegetation, such as rapid succession of alders
8. Glacial melt
9. Loss of snow pack
10. Flooding

As a community, Igiugig determined that climate change impacts to the subsistence way of life was the over-arching concern. The community needed to first understand the climate change projections specific to the Lake Iliamna and Kvichak River watershed, to predict impacts on primary subsistence resources, and to develop plans to reduce risk to wildfire. These meetings were followed up with interviews of Elders and other community members concerning observed changes that might be related to climate change as well as insights on how this affects subsistence and quality of life. This information was supplemented through technical assistance received from SNAP to complete climate change modeling and projections for the community.

During assessment meetings, community members and tribal leaders identified four indicator species of concern, which together represent water, land, and air. These species are: Sockeye Salmon/*sayak* (*Oncorhynchus nerka*), Moose/*Tuntuwak* (*Alces alces*), Ptarmigan/*Qangqiiq* (*Lagopus species*), and Cloudberries/*Atsalugpiat* (*Rubus chamaemorus*). A vulnerability assessment was done for each of these, using a vulnerability matrix provided within the TCCAPT. The community was concerned with all subsistence resources, but determined that assessing for four indicator species was more valuable and more time-efficient than attempting to assess all in the timeframe of this project. Furthermore, it is the intent that monitoring the critical four species will indirectly encompass other species as well.

In the sections that follow, we first provide an overview of the main climatic changes occurring across Alaska. We then share our understanding of changes specific to Igiugig in an effort to determine the impacts of such changes to the subsistence way of life that is foreseen by the *Igyararmiut*.

A CHANGING CLIMATE

As global concentrations of greenhouse gases have increased since the beginning of the industrial revolution, scientists have concluded that climate change, and in particular the warming of land, air, and water temperatures, is a major threat to the systems that support our civilizations (IPCC 2014). The change is global, but research and traditional observation have shown that the polar regions of the planet are being affected at a greater rate than anywhere else (Richter-Menge et al. 2019).

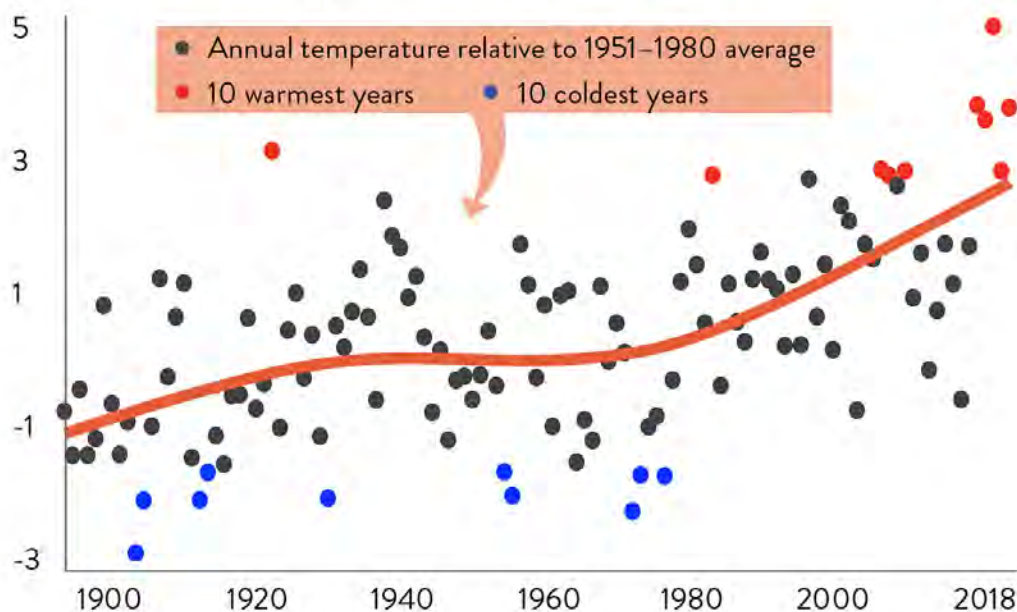
As the speed of change and disruption are increasing in the modern age, the ability to adapt and transition has become more of a challenge, evermore so for rural Alaskan communities who depend on subsistence activities (Loring et al. 2016). Alaska and other northern Arctic communities are experiencing extreme climate events at a faster pace than any other place in the world. Extreme events such as wildfires, floods, and erosion threaten lives and infrastructure. Changes in the duration of the seasons with warmer air and water temperatures are disrupting natural cycles including soil geochemistry, melting permafrost, and vegetative change such as rapid succession. All these events cause social, mental, physical, and economic problems to the community, which is dependent on the subsistence resources (Herman-Mercer et al 2019).

The vulnerability of Alaska Native communities to climate change impacts is not only dependent on geography and a subsistence-dependent way of life, but is tied to colonial political and socio-economic structures and processes that for centuries have undermined the capacity of Alaska Native communities to govern themselves and strengthen their cultural integrity (Cameron 2012). As a result of industrialization and the continuous unsustainable use of fossil fuels and exploitation of humans and non-humans (Wildcat 2009), climate change is part of a larger socio-ecological-technological system, and vulnerability to climate change can thus be seen as an intensification of colonialism (Whyte 2017). While the purpose of this assessment is to identify and assess Igiugig's need for and ability to adapt to current and expected future climatic change, it is important not to lose sight of the bigger challenge to address the root causes of climate change.

Overview of Climate Change in Alaska

In Alaska, climate change is not a distant or abstract concern. Alaska's high-latitude setting places it at the front lines of environmental change. Rising temperatures, altered seasonality, accelerating permafrost thaw, changing wetland and vegetation dynamics, shifts in precipitation, and increasing wildfire frequency and severity are among the factors rapidly altering the landscape, and thus affecting human uses of that landscape. In the Arctic and sub-Arctic, climate change is accelerated and its effects are profound.

Annual temperatures for Alaska, 1900–2018



Credit: Rick Thoman, Alaska Center for Climate Assessment and Policy.

Data source: NASA GISS & UAF/Brian Brettschneider



Figure 2: Statewide Temperature Change (from Thoman and Walsh 2019)

The observed climatic changes are projected to continue throughout this century (Markon et al. 2018). Key changes projected statewide include continued impacts to Alaska residents and communities due to changes in the marine environment, permafrost thaw, coastal and river erosion, increasing wildfires, and glacier melt. Impacts to human health, particularly in rural areas, may stem from smoke inhalation, storm damage and flooding, damage to water and sanitation systems, disrupted traditional practices and associated loss of food security, and new infectious diseases. Economic costs are likely to accrue due to infrastructure damage (Markon et al. 2018).

From the 4th National Climate Assessment from 2018, the report on Alaska states, “the impacts for climate change will likely affect all aspects of Alaska Native societies, from nutrition, infrastructure, economics, and health consequences to language, education, and the communities themselves” (Markon et al. 2018, 1188).

Table 1: Change in mean temperature by climate station statewide

Total Change in Mean Seasonal and Annual Temperature (°F), 1949-2018						
Region	Location	Winter	Spring	Summer	Autumn	Annual
Arctic	Barrow	9.8	6.7	3.7	7.3	6.8
Interior	Bettles	8.7	5.0	1.7	2.8	4.9
	Fairbanks	8.1	3.8	2.4	1.5	3.9
	Delta Junction	9.9	3.4	1.4	1.4	4.9
West Coast	McGrath	9.7	5.3	3.0	3.2	5.3
	Kotzebue	9.0	3.2	3.8	4.0	4.9
	Nome	6.1	3.7	2.8	2.0	3.6
	Bethel	8.5	5.1	2.4	1.8	4.4
	King Salmon	10.2	4.6	2.1	2.6	4.8
	St. Paul Island	1.7	2.2	3.1	2.2	2.3
	Cold Bay	2.5	2.0	2.4	1.9	2.0
South Central	Talkeetna	9.7	5.6	3.1	3.7	5.6
	Gulkana	8.4	2.6	1.3	0.6	3.3
	Anchorage	8.0	3.9	2.4	3.7	4.2
	Homer	7.4	4.4	3.8	3.0	4.7
	Kodiak	2.0	2.5	1.9	0.7	1.8
South East	Yakutat	6.0	3.3	2.7	1.4	3.4
	Juneau	6.8	3.2	2.5	1.5	3.5
	Annette	3.9	2.7	2.2	0.9	2.5
Average		7.2	3.9	2.6	2.4	4.0

Alaska Climate Research Center

Geophysical Institute, University of Alaska Fairbanks

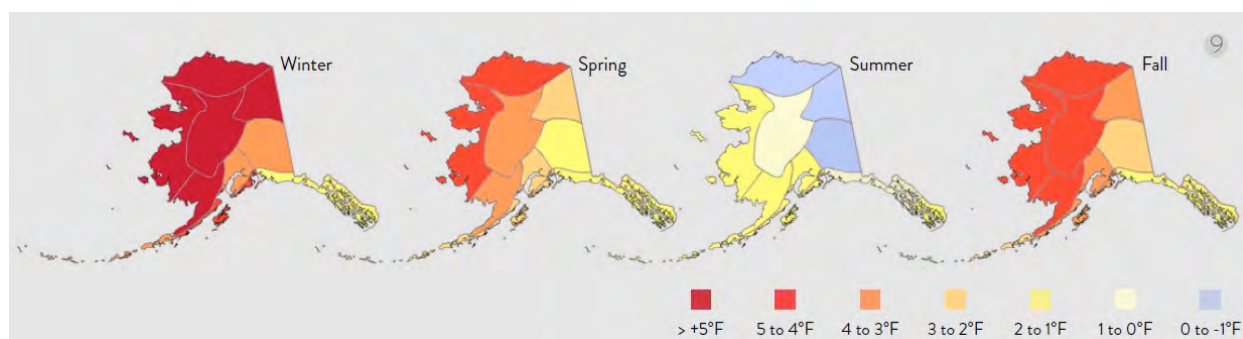


Figure 3: Climate warming statewide by season (Thoman and Walsh 2019)

The hot, dry conditions spurred by climate change also increase fire risk not only in areas of Interior Alaska where fires have been common, historically, but also in

regions less prone to fire in the past. Fires are returning more frequently, burning longer and hotter, and putting more people's lives and health in danger (Fresco 2019).

Much of Alaska is coastal, and the entire state is linked to the ocean via weather patterns, presence and absence of ice, and the passage of salmon from river to ocean and back again. In recent years, changes in sea ice and shore-fast ice have been profound (Figure 4). Homes have slipped off cliff edges and hunters have lost their lives due to thin ice. Community relocation is a costly and culturally damaging. Walruses, seals, and polar bears are no longer finding the ice they need to rest, hunt, mate and breed, and the shortening sea ice seasons are threatening traditional hunting practices (Markon et al. 2018). Decreasing sea ice is also opening up Arctic shipping routes that were not previously available (Champine 2018). While this could boost some economies, it could also pose a threat to traditional practices and environmental health and safety.

Even for inland residents, the health of the ocean is crucial, because the salmon caught in Alaska's rivers spend two to three years developing in the open ocean. Should climate change render the ocean too acidic due to changing atmospheric carbon, pterapods -- the tiny sea snails on which salmon feed -- would be at risk, because they may no longer be able to form their shells (Fresco 2018).

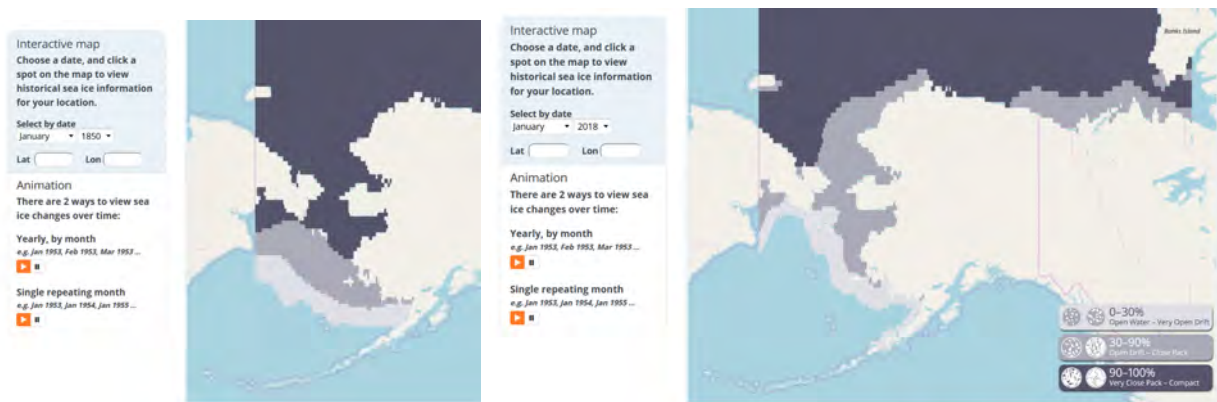


Figure 4: Change in sea ice coverage

In many areas, loss of permafrost is posing hazards to infrastructure, traditions, and food security. About half of Alaska has permanently frozen soils, and about half of that area may thaw by the end of the century (Markon et al. 2018). Frozen soils stabilize buildings, roads, pipelines, and coastlines, preventing storm erosion and slumping. Permafrost is also used for safe food storage by subsistence hunters.

Many of the effects of climate change in the far north also create feedback loops that exacerbate the problem by speeding the release of yet more greenhouse gases into the atmosphere. Fires release huge quantities of carbon dioxide, and thawing organic soils and lakebeds release methane, a powerful contributor to global warming.

CLIMATE CHANGE IN IGIUGIG

This section outlines climatic changes observed and reported for Igiugig and the Lake area. While the first part mainly draws on scientific research, the second part, which identifies subsistence resources of special concern, draws considerably from Indigenous knowledge and observed changes by community members.

Air Temperature

Historical Air Temperature Data

The climate in Igiugig, as in all of Alaska, has already changed markedly in recent decades. For purposes of comparison, baseline data from the nearest climate stations are shown in Table 2.

Although there is no lengthy official record from a local climate station, Indigenous knowledge of weather patterns supports the broader data available for the region, which show increases of temperature in all months, not only on land but also in lake and river waters.

Table 2: Recent historical average climate data (1981-2010) from the climate stations closest to Igiugig.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average daily maximum temp., °F	Iliamna	23.5	26.2	30.6	39.9	51.5	59.3	62.7	61.2	53.9	40.7	30.4	26.8	42.3
	King Salmon	23.6	26.8	32.7	42.4	53.8	61.0	63.8	62.6	55.5	41.3	30.5	26.4	43.4
Average daily mean temp., °F	Iliamna	17.5	19.7	23.5	33.1	44.0	51.7	56.1	54.8	48.0	35.1	24.7	20.8	35.8
	King Salmon	16.2	18.8	24.1	33.7	44.2	51.5	55.5	54.6	47.6	33.5	22.9	18.6	35.2
Average daily minimum temp., °F	Iliamna	11.5	13.2	16.4	26.2	36.5	44.2	49.4	48.5	42.1	29.4	19.0	14.8	29.3
	King Salmon	8.8	10.9	15.6	25.0	34.5	41.9	47.3	46.6	39.7	25.7	15.3	10.8	26.9
Rain equivalent, inches	Iliamna	1.3	1.1	0.8	0.9	1.2	1.3	2.9	4.2	4.6	3.2	2.1	1.5	24.9
	King Salmon	1.0	0.8	0.7	1.0	1.3	1.7	2.3	3.0	3.2	2.1	1.4	1.2	19.5
Snowfall, inches	King Salmon	10.2	6.0	6.4	3.9	0.8	0.0	0.0	0.0	0.1	2.8	6.9	9.5	46.6

Future Temperature Predictions

Air temperature is projected to increase across all of southwest Alaska, and in all months. Note that greater changes are projected for winter months than for summer months.

Notably, by the end of this century, temperatures for every winter month—November, December, January, February, and March—are projected to average near or above freezing, in stark contrast to historical data for all those months. While this does not suggest a complete lack of frost or snow, it does indicate a profound landscape change—and associated changes in the types of activities that will be able to occur in winter.

Summer shifts show a rise from July temperatures averaging about 56°F to about 62°F by the end of the century. While this warmth may not seem extreme, it could drive large changes in vegetation, fire, moisture, and the ecological relationships of the region.

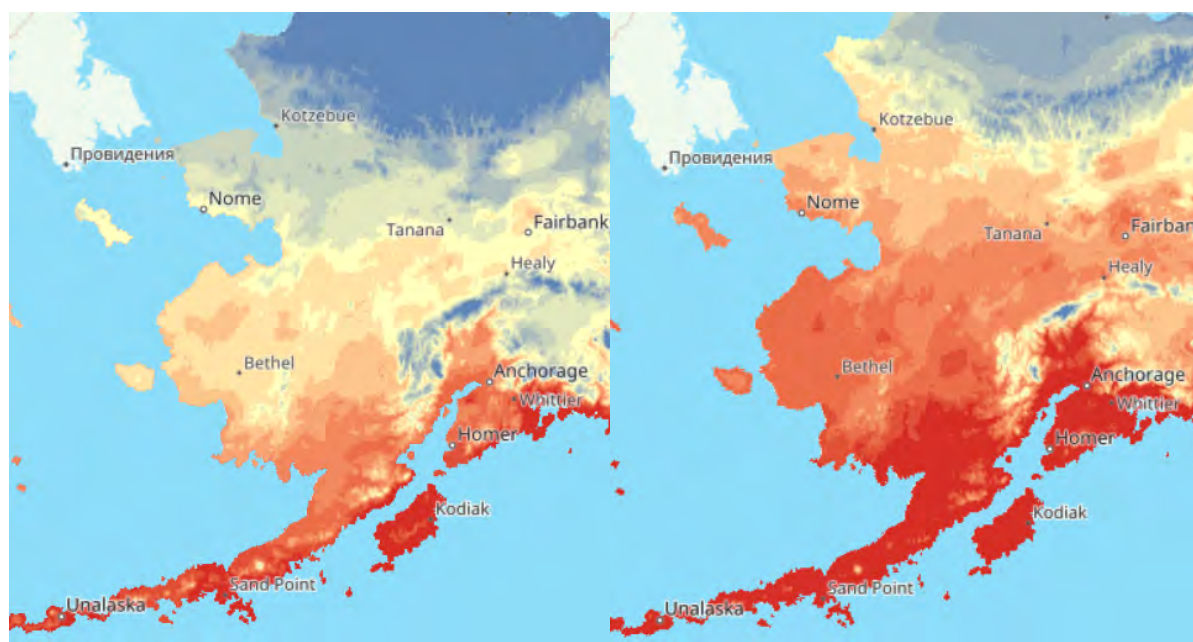


Figure 5: Projected change in air temperature, regional, between the 2010's and the 2090's.
(See online map tool at <http://mapventure.org/#/map/snap-data-intro>)

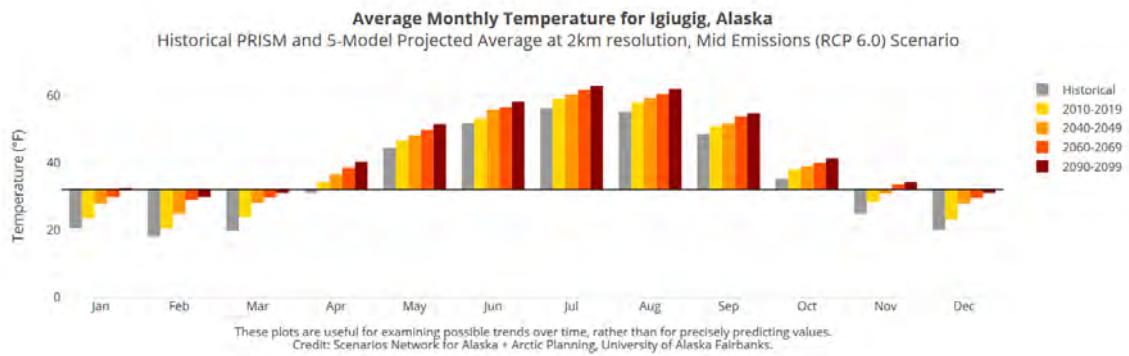


Figure 6: Historical and projected air temperature, monthly, for Igiugig

Wildfire

Historical Wildfire Records

Historically, Igiugig has been less fire-prone than more forested regions to the north and east. Figure 8, showing a close-up of the Lake area, shows that only a few fires have burned a significant area in the region in the past sixty years.



Figure 7: Wildfires in southwest Alaska near Igiugig (SNAP 2019).

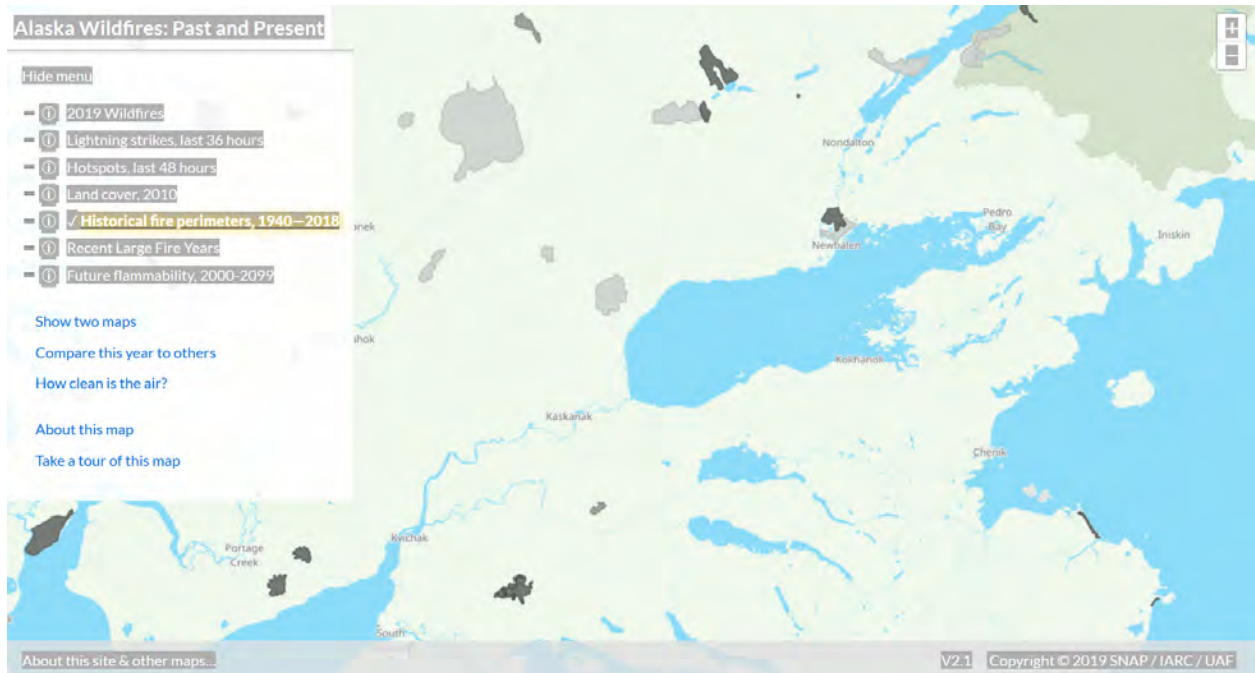


Figure 8: Fires near Igiugig 1940-2018.

However, in 2019 this pattern showed signs of change. An extremely hot, dry summer drove a high fire year statewide, with an increased number of fires in the Igiugig region (Figure 9), including wildfires relatively close to the community.



Figure 9: Wildfires near Igiugig in 2019 (SNAP 2019).

Future Fire Predictions

Climate warming is driving a projected increase in fire in two ways (Figure 10). First, warmer temperatures are causing an increase in woody shrubs and trees. Second, warmer temperatures and associated drying are increasing the risk of fire starts and fire spread.

Based on future climatic trends, and assessment of future wildfire predictions within areas surrounding Igiugig, wildfire mitigation plans may be necessary to protect impacts to subsistence resources, building infrastructure, economies, water and air quality, and human health. The community has expressed interest in developing a wildfire mitigation plan that may include prescribed burns, water access points, and vegetation management. Possible outreach groups mentioned in developing this plan include The Alaska Wildland Fire Coordinating Group (AWFCG) and the US Fish and Wildlife Service (FWS).

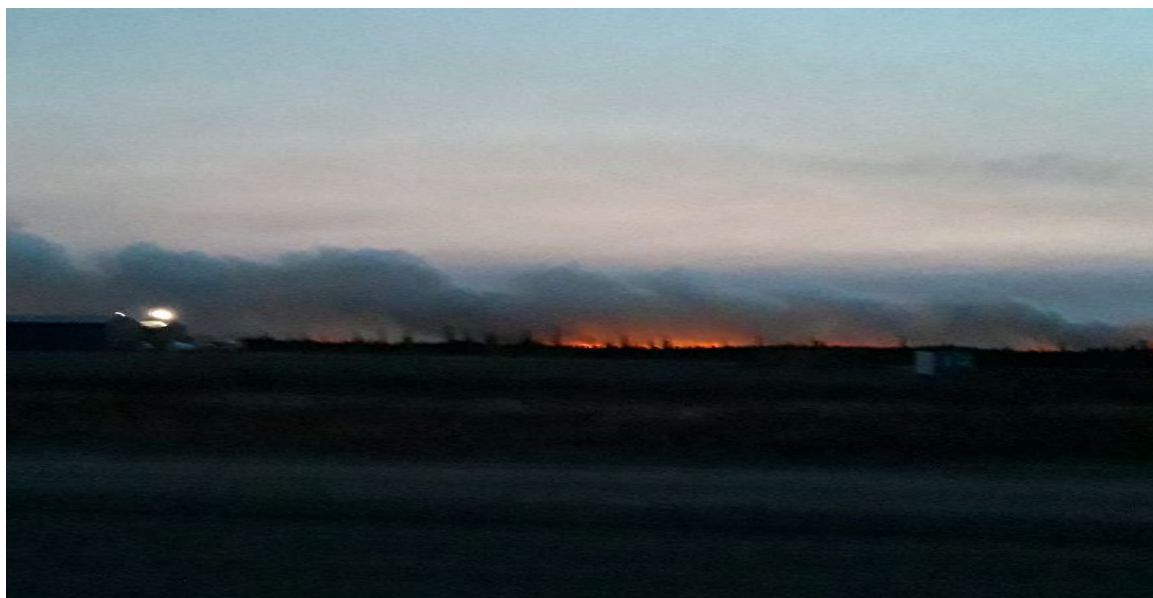


Image 4: Wildfire outside of Levelock, neighboring village to Igiugig, August 2019. Photo credit – Janice Chukwak

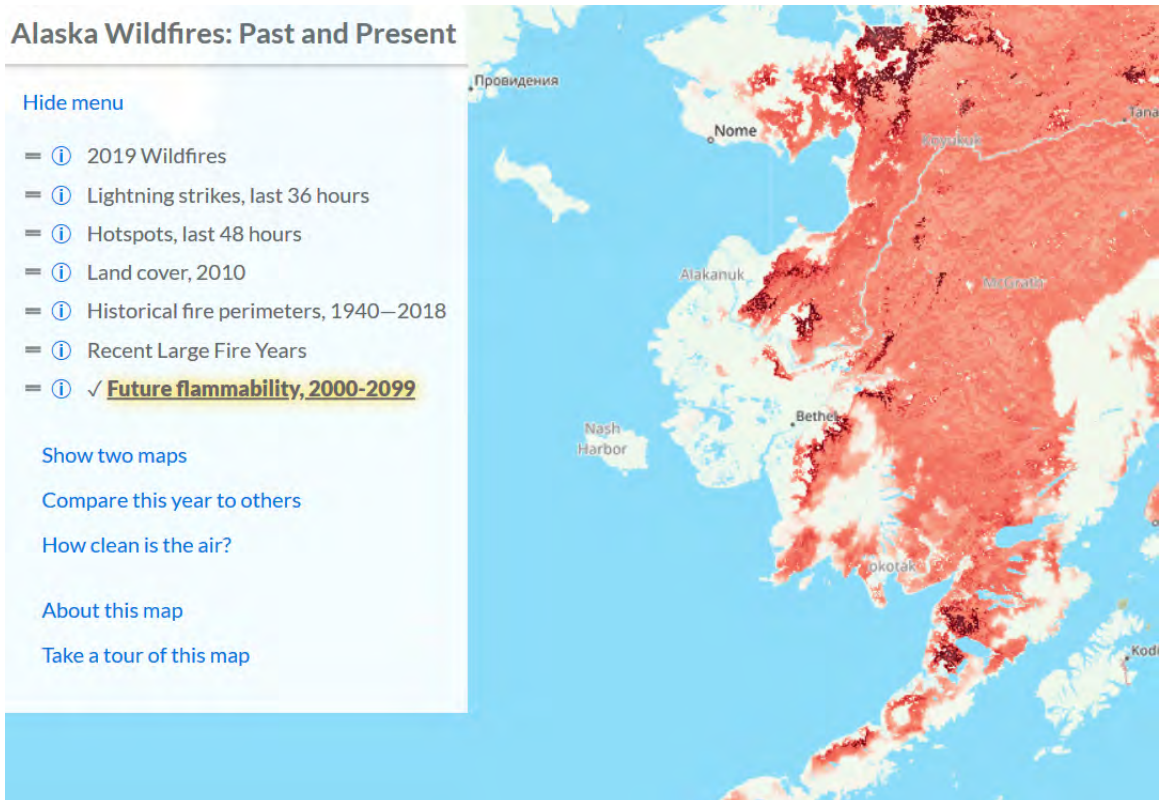


Figure 10: Projected future fire risk in southwest Alaska

Vegetation Change

Natural Vegetation

Changes in fire patterns drive changes in vegetation. After burning, vegetation may return as early-succession species (e.g. fireweed, berries, willow) and then be gradually replaced by later-succession species (e.g. spruce). In the Igiugig region, warmer, drier weather is likely speeding the transition from tundra to shrub/forest (Dettermand and Reed 1973).

Village elders Georgie and Annie Wilson have commented at several meetings concerning the rapid succession of alders and other woody vegetation and its impact on wildfire potential, animal migration, water supply, effects on edible/medicinal plants, and alterations to the native flora and fauna. “We used to be able to see over into the Mulchatna Hills, now we can’t see anything but alders” (George Wilson Sr., September 2019).

The Igiugig Village funds maintenance crews who put in multiple hours each summer cutting back alders from roadsides, building infrastructure, and bogs and tundra habitat.

Agricultural Plants

New models linking climate warming to agricultural variable suggest that Igiugig’s ongoing efforts in gardening and community agriculture may see new opportunities

in the future. Although the time from last frost in the spring to first frost in the fall is variable, as is the duration of continuous temperatures above the 40°F growing threshold for many crops (Figure 11), models point toward marked increases in this functional growing season as the century continues.

When warming summer temperatures are considered in terms of growing-degree days (the cumulative sum of daily temperatures above a given threshold), the change becomes even more apparent (Figure 12). At the same time, the coldest temperatures experienced on any given day are likely to become, on average, significantly warmer (Figure 13). Winter extremes that used to reach twenty below zero Fahrenheit may, by the end of the century, be a mild twenty above.

These changes could greatly expand the crops grown locally. However, such shifts are also an indicator of the influence of both summer temperatures and winter temperatures on wild plants. As seasons lengthen and temperatures warm, expansion of shrubs and trees and incursion of new species formerly limited by cold winters and short cool summers is likely to continue.

Ongoing, detailed data collection from Igiugig’s greenhouses and production fields will be of importance in increasing production levels and self-reliance during climatic change.

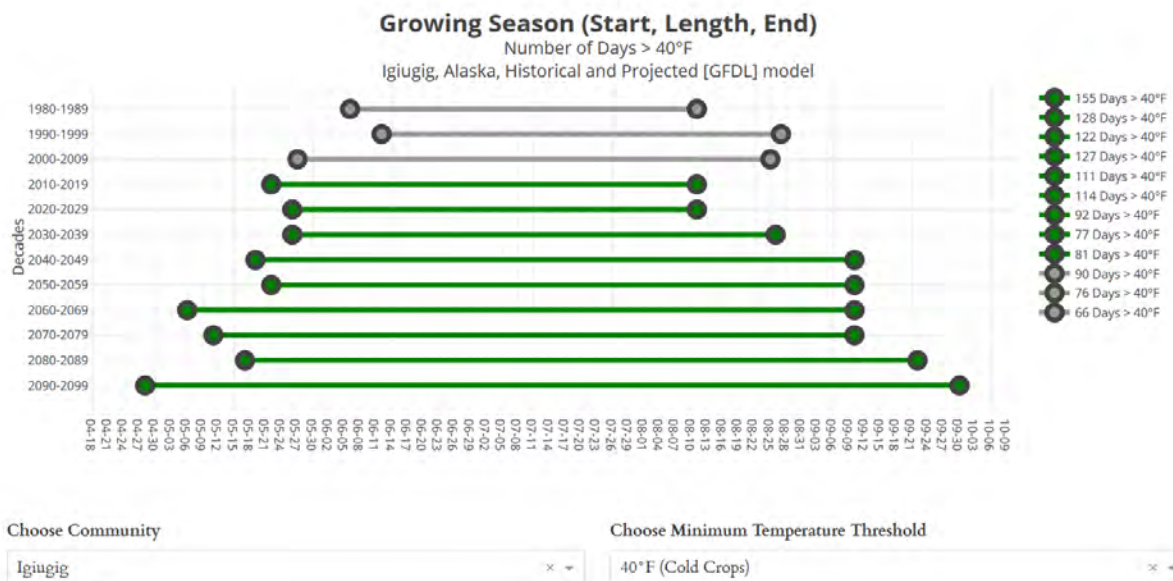


Figure 11: Historical and projected growing season length for Igiugig

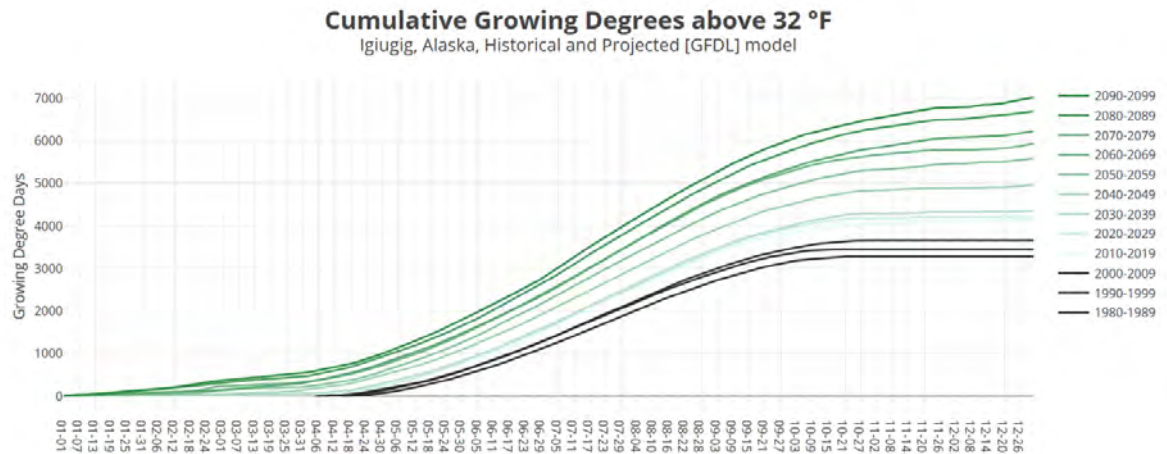


Figure 12: Historical and projected growing degree days for Igiugig

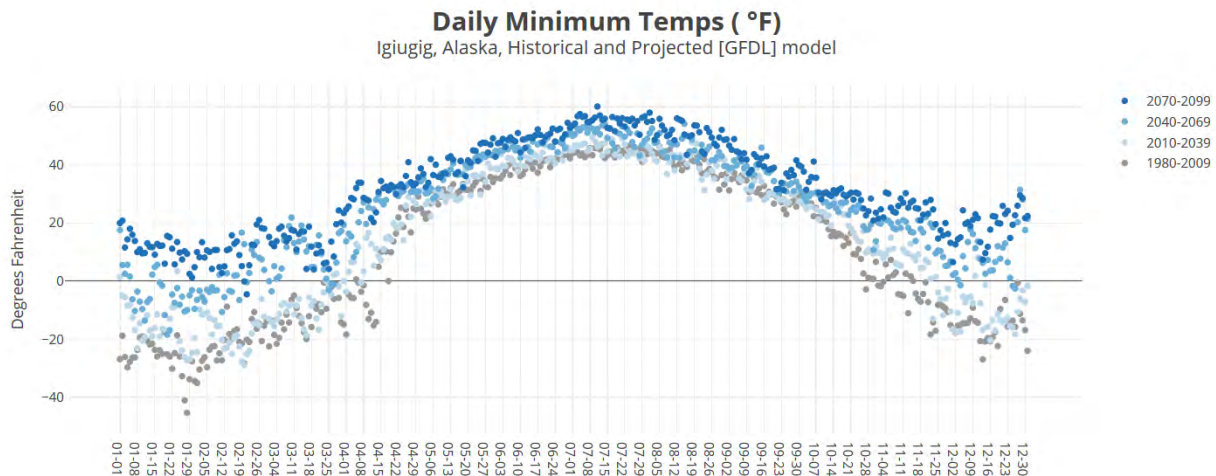


Figure 13: Historical and projected daily minimum temperatures for Igiugig

Water Temperature and Lake Ice

Warming water temperatures have been recorded in the Iliamna Lake system over recent decades and this change has had a direct impact on salmon. The combined effects of water temperature change and changing competition dynamics have resulted in a 60% reduction in adult fish, as of a decade ago, as compared to densities between the 1960s and the early 1990s (Rich 2009). Researchers attribute lower survival at sea to a higher percentage of fry leaving at one year instead of two years of age (Quinn 2005).

Because this dynamic is complex, and involves not only water temperature but also competition among fry and predation at sea, the results are not the same in different systems; for example, sockeye salmon from the Wood River system increased in

productivity during the same decades when Iliamna salmon have declined (Hilborn et al. 2003).

Water Data and Glacial Melt

Across Alaska, glaciers are melting at unprecedented rates. According to NASA data, forty-six billion metric tons of ice from Alaskan glaciers were lost on average each year from 2003 to 2010 (NASA 2019). It is unclear, to date, how this excess water is affecting the hydrology of Lake Iliamna and its inlet and outlet rivers.

Kendal et al. (2010) found a correlation between air temperature and growth of mussels in Lake Iliamna, suggesting that warming air temperatures are directly causing warmer water temperatures, regardless of any possible confounding effects from glacial melt. Schindler (2005) and Rich (2009) found similar effects in studies of juvenile sockeye salmon in the watershed; faster growth is correlated with warmer summer temperatures, suggesting warmer water in lakes, rivers, and streams.

Although the USGS offers extensive records on daily water flow in Kaskanak Creek (Figure 14) and the Kvichak River (Figure 15), corresponding data on water temperature are unfortunately unavailable. Flow data, as can be seen in the graphs, suggests strong seasonal cycles and some degree of year-to-year variability, with a few major outliers, but no clear trend over time that could be attributed to glacial melt and/or changing climate.

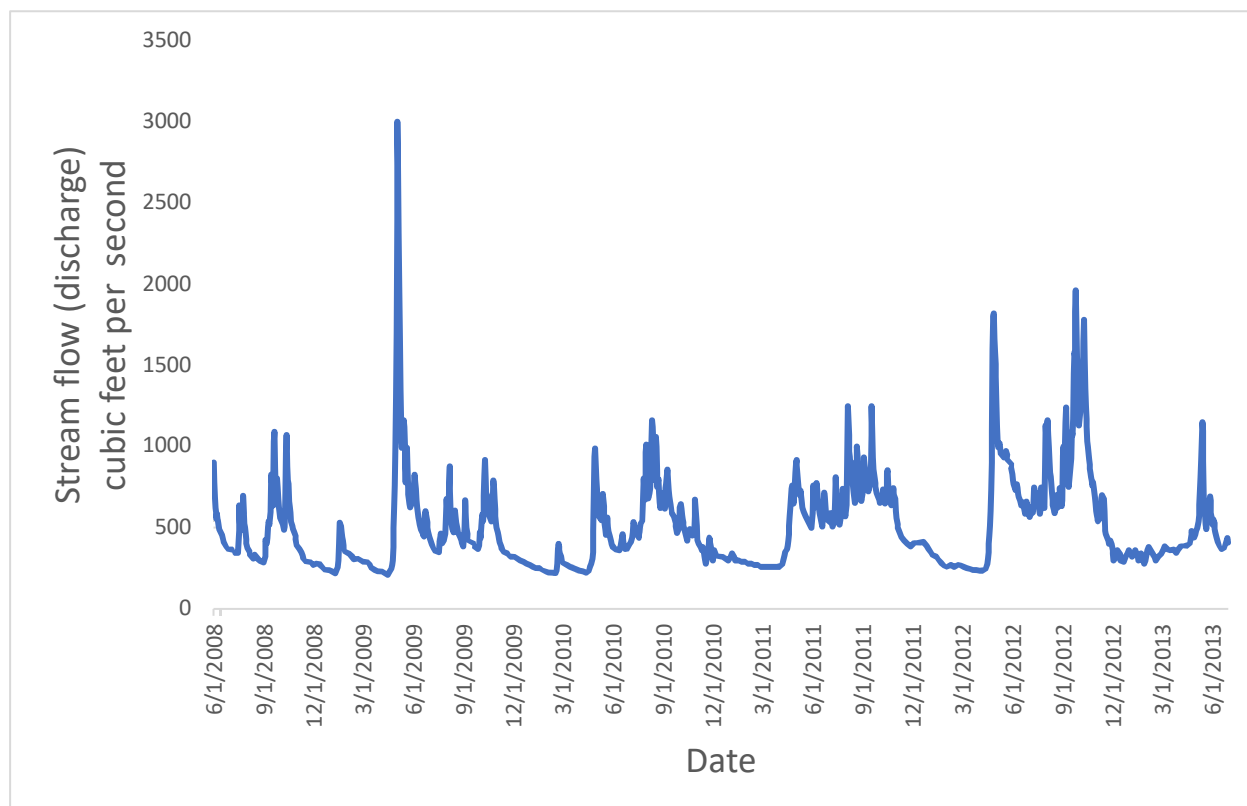


Figure 14: Stream flow data available from USGS (USGS 1530052 Kaskanak Creek near Igiugig, AK).

Igiugig residents have noted that Iliamna Lake water levels are much lower than in previous years. Lake levels have historically been observed where the water/vegetation interface begins. Recently, lake levels are much lower with typically more than 100 feet of lake bottom rocks and gravel exposed in between the usual interface of water and vegetation. Only during storm surges with towering east winds does the water level rise to its historic norm. Residents are unsure of the causes of low lake levels, but hypotheses include lack of winter snow melt and increasing evaporation from warming air and water temperatures. Investigations are needed to better understand the hydrology of Lake Iliamna and its effects on the biology. Questions have arisen about melting glaciers that feed the Iliamna watershed. Further studies with USGS are needed to answer questions concerning glacial melt and its effects on the ecosystem and its geochemistry.

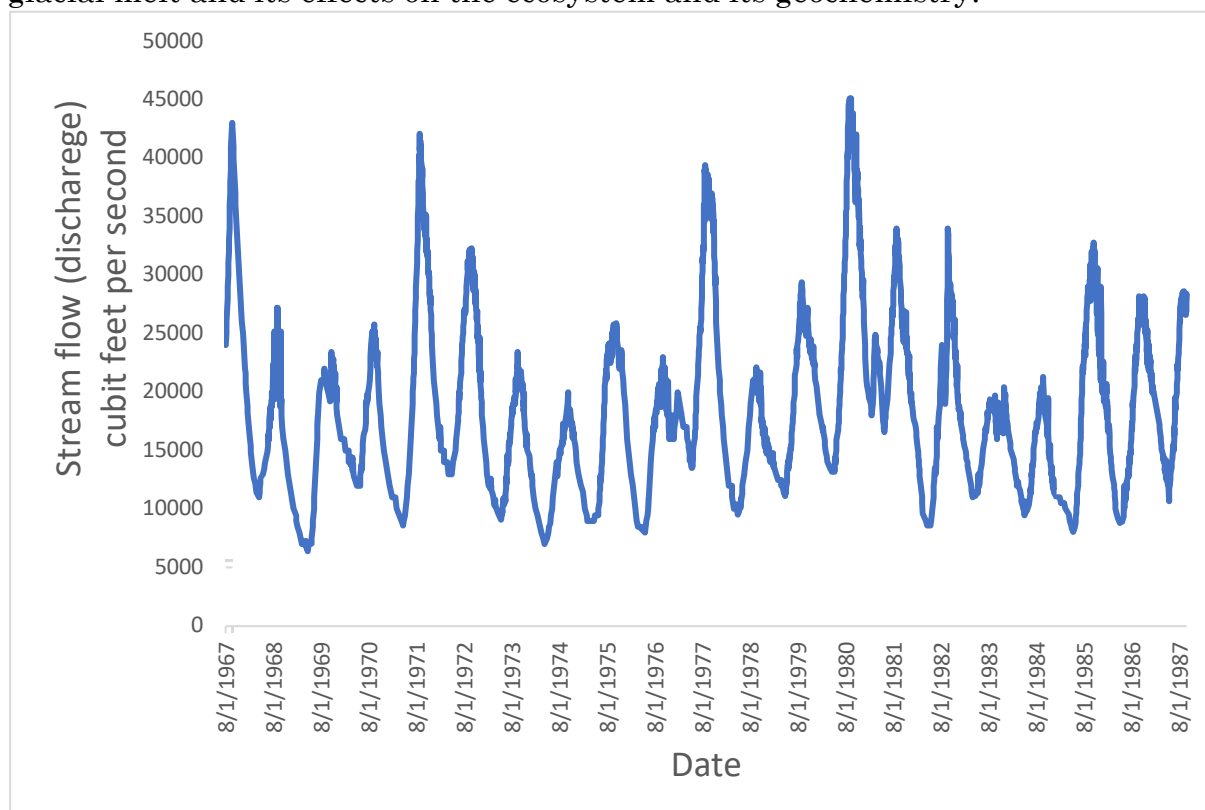


Figure 15: Stream flow data available from USGS (USGS 15300500 Kvichak River at Igiugig, AK).

Reduced Lake Ice

A comprehensive study of the region surrounding Lake Iliamna was performed by the USGS in 1973, providing an excellent baseline for data on soils, geology, vegetation, and bodies of water (Dettermand and Reed 1973).



Image 5: Winter fishing on Iliamna Lake, Igiugig

According to local knowledge, photos, published literature (e.g. Quinn et al. 2009) and extensive records, Lake Iliamna was historically partially or completely frozen every winter (see Image 5). This freezing affects wildlife and human activities in the area, including the behavior of lake seals. Ice duration and extent on the lake is decreasing; the date at which the lake becomes ice-free in the spring has, on average, become progressively earlier, shifting from around the end of May in the 1950s to around the end of April today (Quinn et al. 2009).

No predictive model currently exists for lake ice in Lake Iliamna, but the air temperature (Figure 2) and sea ice projections (Figure 4) shown earlier suggest that by the end of this century lake ice may be at best partial and sporadic in winter months, with little to no opportunity for safe travel on the lake.

Up until recently, Igiugig residents have used the lake ice for travel, for subsistence ice fishing locations, for harvesting firewood, and for visiting neighboring villages on the Lake. Lake ice formation historically happened in October, but now residents are boating in November and December with no lake ice. In the last ten years, Iliamna Lake has frozen adequately to allow ice travel two years out of the ten-year period.

Algal Blooms and Water Quality

Harmful algal blooms are exacerbated by turbidity, pollution from sewage runoff, or floating plastics (Limpinsel et al. 2017), but the relationship between these events and changing climate are still not well understood – not only in regard to Lake Iliamna, but worldwide (Michalak 2016).

Explaining the difficulty of pinpointing the role of climate change in water quality, Michalak (2016, 350) noted that changes are the result of an extraordinarily complex interplay of human activities and weather patterns:

“Complex chains of causative steps must be understood. These start with how climate change affects factors such as precipitation, temperatures and wind patterns for given regions and watersheds. Next, we must understand how these conditions alter the flow of water, nutrients, contaminants and other constituents to water bodies. Finally, we need to assess how these inputs, combined with meteorological

conditions that influence freshwater and coastal systems directly, will change water quality. We do not yet know how to put the pieces of this puzzle together.”

Igiugig set-netters have expressed concerns with their Fall Subsistence Whitefish nets being swamped by algae and aquatic vegetation making them unable to harvest Humpback Whitefish (*Coregonus pidschian*). This is likely attributed to warmer water and later frost/freeze dates that typically reduce aquatic vegetation. Fishermen have also noted that the runs of whitefish are later and later each year and that the runs and the individual fish are smaller.

Community members have also expressed concerns over water quality issues ranging from changes in swamps – some drying up, while new swamps being observed in new locations. Concerns over how water quality will be impacted by future climate trends has been a key thread throughout assessment meetings.

Rain on Snow Events

Local residents have noticed an increase, in recent years, of rain on snow events. Such events can have deleterious impacts on roads, infrastructure, and wildlife. As winter temperatures continue to warm, and average temperatures in the months of November through March hover close to the freezing point (Figure 6), the likelihood of rain on snow events will continue to increase. See affects noted under *subsistence resources of special concern – Ptarmigan*.

Flooding

A flood occurred on the Kvichak River at Igiugig on September 12, 1980 (Perry et al. 2001). More regularly, erosion is occurring along the lakeshore, requiring movement of structures. Linkages, if any, between flooding and climate change are unclear. How flooding and erosion impact spawning salmon is an area of special concern for the community.

Invasive Species

Climate change can drive range expansion and range shifts, as discussed in other sections of this report. Human activities can also introduce species from far-flung regions that once might not have been able to survive in Alaska’s harsh climate, but which now can thrive and compete with local species.

The State of Alaska recognizes that “invasive species pose a major threat to Alaska’s native flora and fauna. Invasive species can harm native species of fish, wildlife, and plants, resulting in ecosystem disruptions that could cause severe economic harm to the people of Alaska. It is in the best interest of Alaska and Alaskans that both purposeful and unintentional introduction of invasive species be prohibited.” (Fay 2002, v). Aquatic invasive species in Alaska are managed under the Alaska Aquatic Nuisance Species Management Plan (Fay 2002). The Alaska Invasive Species

Prevention and Response Program includes provisions calling for protocols for early detection, monitoring, and eradication; education and outreach plans; and participation and input from tribes, communities, and other members of the public.

Invasive plants in Alaska may include *Hydrilla verticillata*, hydrilla, water thyme; *Landoltia* (*Spirodela*) *punctata*, dotted duckweed; *Lythrum salicaria*, purple loosestrife; *Myriophyllum spicatum*, Eurasian water-milfoil (present); *Phalaris arundinacea*, Reed Canary grass (present); *Polygonum cuspidatum*, Japanese knotweed (present); *Spartina alterniflora*, salt marsh cordgrass; *Spartina densiflora*, dense-flowered cordgrass; and *Utricularia inflata*, swollen bladderwort. Invasive fish and other aquatic species include Northern pike and Atlantic salmon, Ornamental aquarium fish, yellow perch, green crab, New Zealand mudsnail, Chinese mitten crab, Zebra mussels, Signal crayfish, and spiny water flea (Fay 2002).

Although many of these are unlikely to appear near Igiugig, vigilance and preventative actions are important. The Alaska Department of Fish and Game provides clear and complete recommendations for how to prevent the spread of invasive species on their website¹. Recommendations include identifying pathways for spread, increasing vigilance, and actively cleaning gear. This is an area of educational focus that will need to be incorporated into our school and community.

¹ <http://www.adfg.alaska.gov/index.cfm?adfg=invasive.prevention>

IMPACTS OF CLIMATE CHANGE ON VULNERABILITY

Impacts on Subsistence and Quality of Life



Image 6: Subsistence net on Kvichak River, Igiugig 2019

In 2019, the hottest year on record for Bristol Bay, massive fish die offs were seen on many drainages. The migratory salmon were observed to be crowding at the bottom of rivers where water temperatures remained cooler. The Alaska Department of Fish and Game reported fish not moving past counting towers as the in-river water temperature was too warm. Some drainages of the Bristol Bay region reported die-offs of over 100,000 fish due to the heat (Ross 2020).

Other climate-related challenges are starting to threaten rural communities. The extreme heat and drought of the summer of 2019 caused reservoirs to dry and villages to run out of potable water. Residents were forced to boil drinking water and community managers struggled in Seldovia, Chignik Lagoon, Nanwalek and Tatitlek (Swann 2019). These same drought conditions affect the plants and animals – entire ecosystems – upon which humans rely.

During assessment meetings, community members and tribal leaders decided to focus on the four keystone species Sockeye Salmon (*Oncorhynchus nerka*), Moose (*Alces alces*), Ptarmigan (*Lagopus species*), and Cloudberry (*Rubus chamaemorus*). These species represent water, land, and air and are of specific importance as vital subsistence resources. The four species were chosen from a long list of important subsistence resources with the intention that monitoring vulnerability of the critical four would indirectly encompass others, including: rainbow trout, Lake Iliamna freshwater seals, black fish, sucker fish, blackberries, blueberries, migratory species of ducks, geese, arctic tern, seagull, and caribou.

Community members voiced concerns over changes observed with the four keystone species due to changing and shifting patterns in climate, vegetation, and other factors that require more observation and research. As residents noted shifts and disruptions

to the seasonal subsistence calendar, it was agreed that a vulnerability assessment would be created for Sockeye Salmon, Moose, Ptarmigan, and Cloudberry (see Table 6).

Salmon, *Sayak*

A dialogue for “Indigenizing Salmon Management” was hosted with youth and elders in Newhalen in May 2018, and this is a short summary of some of the Indigenous knowledge shared:

- We used to have lots of dogs, so we put up lots of salmon. We would even hang fish backbones to dry for the dogs, “Never waste anything.” There were no caribou or moose nearby, but if you break down, there is food out there: “*Yungnaqluteng yulluamek*” – “They eat anything.”
- “*Kallirakan*, when it thunders, the salmon wake up. The more mosquitoes there are, the more fish there will be.”
- “We were not allowed to waste anything. Everything is changing. The salmon nowadays have lots of deformities and infections. We don’t want to waste, but we can’t help it. Nowadays sometimes when we boil the salmon, the meat crumbles and falls off. Seems like it is farmed fish. Some fish, when you cut it open, will be full of water, or lots of worms. You have to throw it back.”
- Think about starvation times, and find out where starvation food like blackfish and suckerfish live, look for a place where there’s a creek flowing into a lake. The dried salmon egg, put one little egg under your tongue. That can get you by.
- Don’t waste, share what you have. If it is a first fish, invite people over. If it is the first fish for a boy, give it away to elders. Invite everyone, it will bring luck.
- Seasons are changing. Even animals (e.g. bears) are looking for food. Our tongues are changing, our taste buds are changing. Our kids eat too much microwave foods.

Every year, 2-10 million Sockeye Salmon make their way up the Kvichak River. Salmon are the life blood of the region, with Igiugig lands supporting all five species of salmon. This is the genetic source of life and livelihood for the Igiugig community. All nutrient cycling runs through the salmon run. All life runs through the salmon.

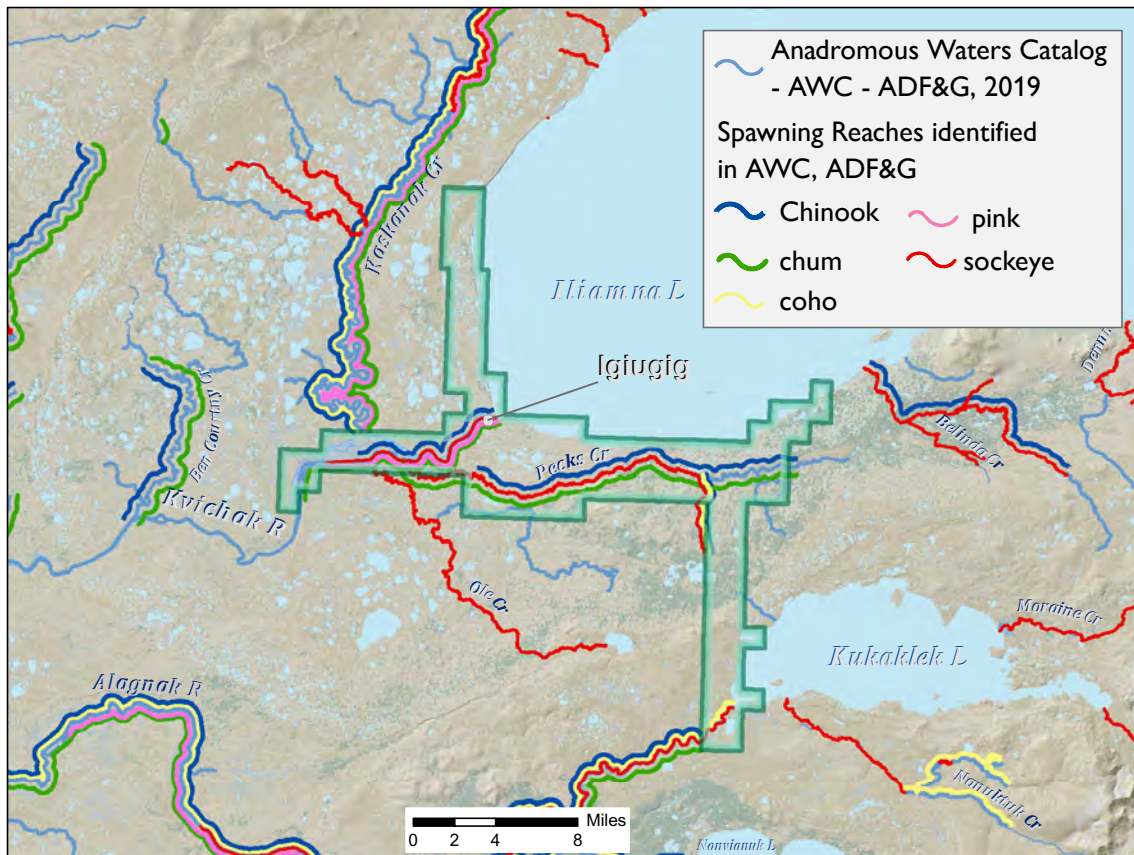


Figure 16: Igiugig Native Corporation lands outlined in green (Igiugig Conservation Planning Atlas, 2019).

Resident fishermen have noticed the size and weight of the individual fish have decreased in recent years. Historically young Sockeye Salmon fry will spend 2 years in the fresh water ecosystem before migrating to the ocean where they will spend another 2 to 3 years in the marine ecosystem. In the last 10 to 15 years the trend has

become for salmon to spend only one year in the freshwater system and two to three years in the marine system resulting in a smaller fish by weight and volume.



Image 7: Spawning Sockeye Salmon with Dolly Varden

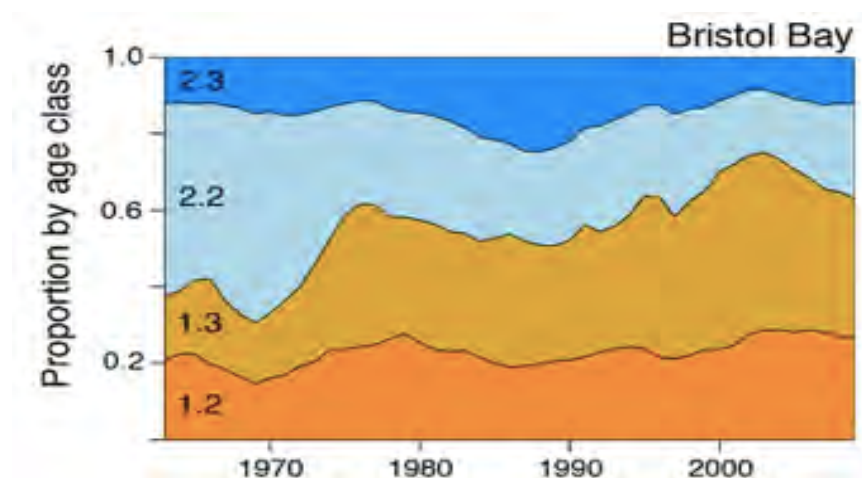


Figure 17: Age composition of Sockeye Salmon in Bristol Bay

Table 3: Predicted 2020 forecast of Sockeye Salmon by age class, ADF&G News release.

4:15 PM Fri Apr 3 68%

A of A

2020 Bristol Bay Sockeye Salmon Forecast November 8, 2019

Table 1 - Forecast of total run, escapement, and harvest of major age classes of sockeye salmon returning to Bristol Bay river systems in 2020.

DISTRICT	River	Millions of Sockeye Salmon					Forecasted		South	
		Forecasted Production by Age Class				Total	Escapement	Harvest	Peninsula	BB Inshore
		1.2	2.2	1.3	2.3					
NAKNEK-KVICHAK	Kvichak	5.07	2.23	3.04	0.07	10.42	4.00	5.92	0.50	9.92
	Alagnak	1.94	0.48	1.61	0.06	4.08	1.57	2.32	0.20	3.89
	Naknek	0.78	0.17	4.19	0.33	5.47	1.10	4.11	0.26	5.21
	Total	7.80	2.88	8.84	0.46	19.97	6.67	12.34	0.96	19.01
EGEGIK		1.88	3.13	4.66	1.08	10.75	1.70	8.53	0.52	10.23
UGASHIK		2.31	0.87	1.46	0.04	4.67	1.18	3.28	0.22	4.45
NUSHAGAK	Wood	5.81	0.14	2.68	0.04	8.66	1.53	6.72	0.42	8.25
	Igushik	0.37	0.00	0.68	0.01	1.07	0.28	0.74	0.05	1.02
	Nushagak	0.67	0.03	2.12	0.06	2.90 ^b	0.50	2.26	0.14	2.77
	Total	6.85	0.18	5.47	0.10	12.63	2.30	9.72	0.61	12.03
TOGLAK		0.30	0.01	0.61	0.01	0.93	0.20	0.69 ^c	0.04	0.88
BRISTOL BAY		19.14	7.06	21.04	1.68	48.95	12.04	34.56	2.35	46.60
		39%	14%	43%	3%	100%				

Note: This table is a summary. Slight differences may appear due to rounding.

^a Projected harvest is based on the current 5 year running average exploitation rate of 4.8%.

^b Nushagak River forecast total includes age-0.3 and age-1.4 fish.

^c Forecasts for Kulukak, Kanik, Osviak, and Matogak river systems are not included. These systems contribute approximately 50,000 sockeye salmon to Togiak District harvest each year.

4

Rising water temperatures in the freshwater environment has created an increase in the food source for juvenile salmon in the form of phytoplankton and zooplankton allowing one-year old fry to migrate to the marine system. The largest salmon runs are generally from fish who have spent two years in freshwater, which raises questions about the survival rate of one-year old salmon in the marine environment.

As concluded by Schindler et al. (2005), the relationship between climate change and salmon populations in southwestern Alaska is complex, but overall, increased zooplankton tends to enhance growing conditions for juvenile salmonids in large lakes such as Lake Iliamna. However, if juvenile salmon leave the lake at a younger age, overall survival to maturity may be lower, rather than higher. Questions arise as to effects of the ecological system that this flush of plankton and algal blooms have on the overall health of the salmon (i.e. nutrient/mineral composition of the salmon, nutrient mineral cycling of the watershed, dissolved oxygen levels, etc.)



Image 8: Sockeye salmon drying on the fish rack prior to being placed in the smokehouse, Igiugig

Changing ocean conditions may also affect salmon, either directly through the warming of waters, or indirectly through other related changes. Ocean acidification caused by climate change poses a threat to salmon in the north Pacific (Mathis et al. 2015).

Due to the many uncertainties involved, it is hard to predict exactly how local salmon populations will respond to climate change. Schindler et al. (2008) suggest that resource management and conservation policies need to be robust and flexible in the face of change. More research and observation is needed at the local level.

Moose, Tuntuvak

In many parts of the state, moose populations are expanding as tundra vegetation shifts to taller shrubby vegetation more favorable for moose browse. In the Arctic, such a shift has been clearly measured, and attributed to climate change (Tape et al. 2016).

Hunters in Igiugig have noted that increased moose habitat results in greater success in moose hunting. Traditionally, caribou (*Rangifer tarandus granti*) has provided the community with a source of winter protein. However, due to shifts from open ground tundra to woody biomass, as well as many other variables, the caribou population has decreased to a point where harvest limits have been reduced or closed altogether in regional hunting units. According to the Federal Subsistence Management Program, the summer 2019 population estimate of the Mulchatna Caribou Herd was approximately 13,500, which is about half of the estimated herd size from the

previous five years. This population estimate is well below the Alaska Department of Fish and Game's minimum population objective of 30,000.

In addition, fire can play a role in habitat creation or destruction. Joly et al. (2012) found that increased fire on the landscape can in some cases favor the creation of moose habitat, because the young regrowth of herbaceous plants and shrubs after fire provides high quality moose forage in a relatively short period of time.

Bowyer et al. (1998) found that moose are unable to time the births of their calves in response to prevailing weather and climate conditions, and thus may be susceptible to negative impacts if climate changes rapidly, because calves may be born at non-optimal seasons.



Image 9: Moose fat drying, Igiugig 2016

Kofinas et al. (2010, 1347) suggest that, “In the face of future climate and socioeconomic changes, communities have limited but potentially effective mitigation and adaptation opportunities. The extent to which residents can realize those opportunities depends on the responsiveness of formal and informal institutions to local needs.” They suggest co-management strategies for moose hunting to reduce conflict and increase flexibility.

As one Moose will feed many families, this resource is of special concern to Igiugig community members.

Ptarmigan, Qangiig

“We used to see Ptarmigan for a quarter of a mile, now we don’t see any.”

– Igiugig Village Elder

Ptarmigan numbers have seen a reduction in recent years. Indigenous knowledge in Igiugig suggests that there are a number of factors involved including vegetative succession and shifting climatic patterns.

There are two similar species of Ptarmigan that inhabit Alaska, the Willow (*Lagopus lagopus*) and Rock (*Lagopus muta*) Ptarmigan. Ptarmigan are gallinaceous birds whose plumage molts to match seasonal changes in the birds’ habitat. Ptarmigan molt to become white in the winter and various shades of brown in the summer. Ptarmigan are open country birds of the tundra nesting in areas with abundant rocks,

mosses, lichens, and dwarf woody vegetation. As many of these areas are experiencing rapid succession and transitioning to a woody complex of alders and willows, residents are concerned about habitat loss.

With inconsistent winters with little or no snow, and increasing frequency of snow followed by rain patterns, it is locally hypothesized that ptarmigan are threatened. Without snow they are no longer camouflaged and vulnerable to predators. Snow followed by rain forms a crust of ice that does not allow ptarmigan to dig through the snow for food or shelter. Winters and Spring with more rain and ice may be reducing nesting success. Recently, the Alaska Department of Fish and Game has shortened the season and reduced the harvest limit for Ptarmigan in Game Management Unit 9 of which Igiugig is a part. More outreach and research is needed in this area to determine future management plans as well as understand differences between the two species of ptarmigan.

Cloudberries (aka Salmonberries), *Atsalugpiat*

Cloudberries (*Rubus chamaemorus*), locally referred to as “salmonberries” or “gold of the Arctic,” are an important subsistence resource regularly used in traditional food dishes, not to be confused with *Rubus spectabilis*, which is also commonly called salmonberry.

Cloudberries inhabit wet bogs and tundra. Cloudberries are a keystone species for our area as the sensitive nature of their biology in an indicator of disruption or change. Their specific habitat of wet bogs and swamps put them at risk as moisture levels and the natural assemblage of plants change. Tribal members are witnessing cloudberry bogs being dried up and encroached on by woody vegetation, particularly alders (*Alnus* spp.)

Successful seed germination in cloudberries requires that seeds pass through the digestive track of birds and then have a cold stratification period where seeds are dormant and frozen for a period of two months. Because of this, *Rubus chamaemorus* has proven difficult to domesticate. More research is needed in this area.

The Winterberry Project² is a citizen science project that Igiugig residents could join, in order to monitor changes in local berry crops and harvest dates. The project links UAF scientists and community volunteers – including school children – to investigate how shifting seasons may affect when berries are available to humans and animals.

During assessment meetings, residents echoed that Igiugig is situated close to the southern latitude that cloudberries grow, and that climate change can cause them to move northward.

² <https://sites.google.com/alaska.edu/winterberry/home>



Image 10: Cloudberry harvest, Igiugig 2016

Vulnerability Assessment

Based on Indigenous and scientific knowledge about the four subsistence resources identified above, a vulnerability assessment was developed for each of the species. The vulnerability assessment is based on two variables: sensitivity level and adaptive capacity, with high sensitivity and low adaptive capacity indicating high vulnerability and low sensitivity and high adaptive capacity indicating low vulnerability.

Table 4: Sensitivity Levels, TCCAPT

Adaptive Capacity Levels	
AC0	System is not able to accommodate or adjust to impact
AC1	System is minimally able to accommodate or adjust to impact
AC2	System is somewhat able to accommodate or adjust to impact
AC3	System is mostly able to accommodate or Adjust to impact in a beneficial way
AC4	System is able to accommodate or adjust to impact in a beneficial way

Table 5: Adaptive Capacity Levels, TCCAPT

Sensitivity Levels	
S0	System will not be affected by the impact
S1	System will be minimally affected by the impact
S2	System will be somewhat affected by the impact
S3	System will be largely affected by the impact
S4	System will be greatly affected by the impact

Table 6: Vulnerability Assessment. TCCAPT

Vulnerability Assessment					
	S0	S1	S2	S3	S4
AC0				Salmon/Cloud Berry	
AC1					Sockeye Salmon
AC2				Ptarmigan	
AC3			Moose		
AC4					

From the vulnerability assessment, it becomes clear that salmonberry and sockeye salmon are highly vulnerable, while ptarmigan is moderately vulnerable. Moose is the least vulnerable species of the four.

Other Notable Subsistence Resources

Other important subsistence resources that the community discussed at length during meetings include seals, other wild edible/medicinal plants, and migrating waterfowl. These are briefly discussed below.

Seals

Lake Iliamna seals play a significant role in local subsistence and Burns et al. (2012) worked with community members to gather broad local knowledge on the use, behavior, and physiology of Lake Iliamna seals.

However, unlike Lake Baikal's freshwater seals, Lake Iliamna seals are not considered to be a separate species, fully distinct from Pacific harbor seals. Therefore, NOAA has concluded that Lake Iliamna seals do not require protection under the Endangered Species Act. They are, however, still protected under the Marine Mammal Act (Boveng et al. 2016). NOAA's study noted that:

"The population was likely founded by marine seals swimming up the Kvichak River sometime in the past 200 to 5,000 years, which is a relatively short period for accumulation of novel genes in a small population of a species with a long generation time like harbor seals. The local traditional knowledge contends that there are differences in the size, coloration, and taste between the seals in the lake and the nearby marine seals, but these differences were in some cases not consistently described among local experts and not clearly identifiable as traits that would be heritable or otherwise important to the broader taxon."

Unfortunately, no clear data are available on the effects of warming temperatures or other climate impacts on Iliamna Lake seals. Moore et al. (2009) suggest that the freshwater seals of Lake Baikal will be affected by the rapid climate change occurring in the region, due to changes in ice cover and transparency, warming water temperature, altered wind dynamics and mixing of different lake layers, and changes in nutrient levels. While differences between the lakes and the species of seal makes comparison difficult, some of these changes are also likely to occur in Lake Iliamna.

Wild Edible/Medicinal Plants

A statewide study on berry use found that salmonberry (*Rubus spectabilis*) and high-bush blueberry (*V. ovalifolium* and *V. alaskensis*) were most frequently identified as very important for communities in maritime (coastal) regions (Hupp et al. 2015). Across the state, participants from different communities reported that 7 of the 12 berry species on the survey were becoming either scarcer or more variable. In particular, declines in high-bush blueberry were reported in maritime regions.

Migrating Waterfowl

Hupp et al. (2013) found that migrating Taverner's cackling geese (*Branta hutchinsii taverneri*) used areas with high densities of crowberries preferentially. This suggests that as berry crops shift and change, in terms of timing and density, these changes are likely to also change the habits and movements of migratory waterfowl.

Some waterfowl may decrease, but others may increase as the climate warms. Ward et al. (2009) found a northward shift in the winter range of Pacific Flyway Brant (*Branta bernicla nigripennis*) in recent years, and conclude that numbers of Brant in Alaska during winter are likely to continue to increase as temperatures warm and ice cover decreases.

Igiugig hunters have noted Greater White Fronted Goose (*Anser albifrons*) numbers to be strong. One hunter reported that ducks such as Mallards (*Anas platyrhynchos*) and Northern Pintails (*Anas acuta*) seem to be decreasing. More research is needed in this area.



Image 11: Geese hunting, the flats, Kvichak River 2019

RECOMMENDATIONS AND ADAPTATION STRATEGIES

Based upon this assessment, recommended future projects to include:

- Detailed analysis of water quality in the Iliamna/Kvichak watershed with emphasis on algal growths and aquatic vegetation and its effects on water chemistry, salmon ecology, drinking water, and building infrastructure.
- Conduct detailed experiments and research on the hydrology of Lake Iliamna and the Kvichak River. Focus areas of concern: 1) Annual temperature gradients and salmon habitat; 2) Identify flows and catalogue levels and compare to historical data (if any).
- Research potential cultivation and biology of *Rubus chamaemorus*. Conduct seed trials and rhizomatic root transplants.
- Analyze glacial melt of ice fields that feed the Iliamna/Kvichak watershed. Investigate effects that melting glaciers have on the water geochemistry, temperature, and lake levels.
- Population dynamic studies on Sockeye Salmon (*Oncorhynchus nerka*), Willow Ptarmigan (*Lagopus lagopus*), Rock Ptarmigan (*Lagopus muta*), and Humpback Whitefish (*Coregonus pidschian*).
- Climate impacts and biological surveys on Lake Iliamna freshwater seals. Comparison studies of Iliamna freshwater seals and Pacific Harbor Seals (*Phoca vitulina*).
- Conduct experiments on productivity of wild blueberries (*Vaccinium species*), and crowberries (*Empetrum nigrum*) with respect to changing temperature and precipitation models.
- Start a seed bank of important subsistence plants and fruits.
- Investigate public health concerns in regards to infectious disease. Submit detailed village response plan.
- Research trends in Moose (*Alces alces*) and Caribou (*Rangifer tarandus granti*) in regards to vegetative succession, warming temperatures, and forage nutrient quality.

CONCLUSION AND REFLECTIONS

This report marks the first step in Igiugig’s climate change adaptation planning efforts with a special emphasis on the impacts on important subsistence resources. The report exhibits the resilience and adaptive capacity of Igiugig while also highlighting the very real challenges that climate change poses to the continued sustainability and well-being of the community. When speaking about community resilience, it is important to recognize that no community exists in a vacuum. Despite Igiugig’s high degree of resilience, economic and social policies and trends happening at various scales have very real implications for the community’s ability to thrive and become more sustainable.

In exploring needs and capacities for adapting to climate change, it becomes important to broaden the scope of the challenge by placing these efforts in a larger cultural and political context. McNeeley (2012) examined potential climate change adaptation strategies for Alaska Native communities using a vulnerability and adaptive capacity assessment approach that focused on integrating local Indigenous observations and understanding with western sciences. The study found that rigidity in the regulatory system has negatively impacted communities by rendering them less able than they were traditionally to respond to variability and change via mobility and flexibility. This rigidity threatens food security and community health. The study concluded that wildlife management must be more flexible and adaptive, and much more responsive to both climate variability and long-term climate change. These concerns and recommendations are echoed in much contemporary climate change adaptation research in Alaska (Herman-Mercer et al. 2019; Ristroph 2019).

Thus, while building community resilience and adaptive capacity is important, it is not *the* solution to climate change or other environmental and socio-economic issues. In order for community efforts to result in long-term positive impacts, this work must be coupled with supportive processes happening at other scales, including supporting the large-scale societal transitions and transformations that will have to happen to curb climate emissions (Gram-Hanssen 2019; Mackinnon and Berickson 2013; Kirmayer et al. 2009).

Founded on deep-rooted Yup’ik values and traditions, the community of Igiugig is always in the process of getting ready for what might come next and aims for a high degree of self-sufficiency and cultural integrity.

“The grandpa’s and grandma’s spoke to us, what we got *coming* behind us...we can remember and we could pass it on, what’s *coming* behind us” – Igiugig elder Mike Andrew Sr.



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ⁱ Bristol Bay Regional Visioning Plan, <https://www.bristolbayvision.org/>

ⁱⁱ Iliamna Lake Seals Local and Scientific Understanding, North Pacific Research Board, Bristol Bay Native Association, and ADF&G Division of Subsistence. http://www.adfg.alaska.gov/index.cfm?adfg=wildlifeneews.view_article&articles_id=553

ⁱⁱⁱ Mulchatna Caribou Herd study, Alaska Department of Fish and Game Division of Subsistence, http://www.adfg.alaska.gov/index.cfm?adfg=wildlifeneews.view_article&articles_id=864

^{iv} MicroFEWS collaboration, <http://ine.uaf.edu/projects/microfews/project-highlights/blog/2019/blog-post-july-2019/>

^v To access The Tribal Climate Change Adaptation Planning Toolkit (TCCAPT), see: <http://www7.nau.edu/itep/main/tcc/Resources/adaptation>