National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Climate Change Scenario Planning for Southwest Alaska Parks

Aniakchak National Monument and Preserve, Kenai Fjords National Park, Lake Clark National Park and Preserve, Katmai National Park and Preserve, and Alagnak Wild River

Natural Resource Report NPS/AKSO/NRR— 2014/832

Scenarios Network
FOR ALASKA & ARCTIC PLANNING

ON THE COVER

Three Hole Point, Kenai Fjords National Park
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July 2014

U.S. Department of the Interior
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Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the NPS Alaska Regional Office Climate Change website (http://www.nps.gov/akso/nature/climate/index.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Executive Summary

Changing climatic conditions are rapidly impacting environmental, social, and economic conditions in and around National Park Service (NPS) areas in Alaska. With over 50 million acres of parklands to administer, Alaska park managers must better understand possible climate change trends in order to better manage Arctic, subarctic, and coastal ecosystems and human uses of these areas. As such, NPS managers undertook and exploration of scenario planning as an innovative approach to science-based decision-making in the face of an uncertain future. Climate change scenarios are defined herein as plausible yet divergent futures based on the best available current knowledge of driving climate variables. These scenarios will help prepare NPS Alaska park managers for impending changes to make informed decisions with least regrets for future outcomes.

This effort took off in 2010, when NPS national and Alaska Regional offices released climate change response strategies for the National Park System and the Alaska Region, respectively (NPS 2010a, NPS 2010b). Scenario planning was identified in both strategies as a high priority for understanding potential climate change impacts to park resources, assets and operations. As a result, NPS and the University of Alaska's Scenarios Network for Alaska and Arctic Planning (SNAP), a research group focused on climate change modeling and adaptation, embarked on a three-year collaborative project to help Alaska NPS managers, cooperating personnel, and key stakeholders consider potential consequences of climate change by developing plausible climate change scenarios for all NPS areas in Alaska. Final products include climate change scenario planning exercises, reports and other informational products for all NPS units in Alaska, with efforts organized around each of the four Inventory and Monitoring (I&M) networks.

The Climate Change Scenario Planning project began in August 2010, when the NPS Climate Change Response Program partnered with Jonathan Star of the Global Business Network (GBN) to initiate a series of scenario planning training workshops across the National Park System. A team of NPS Alaska Region and SNAP employees participated in the workshop, learning how to develop scenarios based on nested frameworks of critical uncertainties, and fleshing out the beginnings of climate change scenarios for two pilot parks.

Southwest Alaska was the first area in Alaska to be examined by NPS through a scenarios workshop on February 22-25, 2011. This workshop was based on the framework introduced by GBN, and led by a core team who had participated in at least one training session. This February 2011 workshop focused on Aniakchak National Monument and Preserve (ANIA), Kenai Fjords National Park (KEFJ), Lake Clark National Park and Preserve (LACL), Katmai National Park and Preserve (KATM), and Alagnak Wild River (ALAG).

Participants included representatives from the parks in question, NPS staff from the Alaska Regional Office, SNAP personnel, and key individuals from other agencies, nongovernment organizations, and communities with a stake in this region. These individuals contributed a wide range of perspectives and expertise to the process and outcomes of the workshop.

Participants, divided into coastal and riverine groups, identified key issues facing the parks in Southwest Alaska. Key issues included the many possible effects of glacial retreat, ocean acidification, and storm damage. More specifically, future scenarios focused on potential impacts

to ecosystems and humans who rely on them, particularly with regard to impacts to commercial and subsistence fishing. Loss of frozen soils, loss of ice, increased storms, and general warming trends may cause community-threatening and landscape-altering erosion, as well as changes in vegetation, hydrology, wildlife, and subsistence species.

General findings and recommendations include predictions of potential changes in species and their assemblies, disappearance or changes to subsistence resources, loss of cultural resources, risks to infrastructure, and changes in interpretation opportunities. Participants agreed that most or all potential scenarios pointed toward a need for coordinating communication and partnerships with other public and private entities, tuning planning processes to account for multiple possibilities, increasing the fluidity and connections between research and monitoring, and compiling seamless data sets.

Workshop participants further suggested the need for increased monitoring of the Pacific Decadal Oscillation (PDO), ocean acidification, and ecosystems; science outreach and education to multiple audiences; use of portable, flexible structures rather than permanent infrastructure; and collaborative promotion of energy efficient technologies.

The climate change scenario planning process does not end with these workshops, reports, and presentations. Rather, they are intended to stimulate creative thinking to address changing but still undetermined future environmental and socio-political future conditions. The process should be refreshed periodically as important new information becomes available. In summary, park managers, park neighbors, and stakeholders can be best prepared for the future by using the best available scientific information and climate projections to create plausible, divergent, relevant, and challenging future climate change scenarios. These scenarios can help us all better prepare for uncertain future conditions in the face of changing climate.

Acknowledgments

All of the National Park Service Scenario Planning Workshops were highly participatory, relying on input from every attendee. We would like to thank each of the individuals listed in Appendix B, as well as the organizations and communities that made it possible for them to attend.

List of Terms & Acronyms

ALAG	Alagnak Wild River, Southwest Alaska Network Park
ANIA	Aniakchak National Monument & Preserve, Southwest Alaska Network Park
CCSP	Climate Change Scenario Planning
Climate driver	A climate variable that drives changes in weather, vegetation, habitat, wildlife, etc. Also referred to as a *climate force or scenario driver.*
Climate effects	Existing or potential consequences, outcomes, or results of changes in climate. Can appear beneficial or deleterious, depending on perspectives.
Critical force	A climate variable that drives changes in weather, vegetation, habitat, wildlife, etc. Also referred to as a *climate driver or scenario driver.*
ENSO	El Nino-Southern Oscillation. A climate pattern that occurs across the tropical Pacific Ocean on an approximately 5-year time scale, which can cause extreme weather events in many regions of the world.
Impact	A forceful or particularly significant consequence. An effect that is likely to warrant a response.
KATM	Katmai National Park & Preserve, Southwest Alaska Network Park
KEFJ	Kenai Fjords National Park, Southwest Alaska Network Park
LACL	Lake Clark National Park and Preserve, Southwest Alaska Network Park
Narrative	In scenario planning, a story, in any variety of formats, used to visualize potential future circumstances.
Nested scenario	A set of projected future environmental conditions "nested" within a sociopolitical framework.
PDO	Pacific Decadal Oscillation. A pattern of Pacific Ocean climate variability that shifts between a cool (negative) phase and warm (positive) phase on a 20-30 year time scale.
Potential effects	Inherently possible, likely, or expected, but not necessarily certain, effects.
Scenario	A projected course of events or situations, used to understand different ways the future might unfold.
SWAN	Southwest Alaska Network, the National Park Service's Inventory & Monitoring network of parks in southwest Alaska

TEK	Traditional Ecological (or Environmental) Knowledge. A cumulative body of knowledge built up by a group of people over many generations of close contact with nature. Sometimes distinguished from other forms of local knowledge, developed over fewer years or generations of experience.

Introduction

In this paper, we describe the Climate Change Scenarios Planning (CCSP) effort at several different levels. First, we introduce the rationale and need for such an effort, at the national, statewide, and local level. Next, we provide background on the particular Global Business Network (GBN) methods used in this project – as well as in parallel projects for the other park networks in Alaska. This background places GBN methods in the context of other possible planning tools. In this context, we discuss modifications that were necessary to best address the particular challenges of climate change planning.

In the Workshop Group Products section, we provide significant detail with regard to the products and outcomes of the scenarios process. This includes intermediate data from the brainstorming processes that took place during the three-day Scenarios Planning Workshop, although some of these products are linked only via appendices. These details are included in order to allow this paper to serve as not only a project summary, but also a roadmap or case study for any similar efforts that may take place in the future, either in Alaska or elsewhere.

The Common Implications, Actions, and Needs section of the paper pulls together these products into a more cohesive summary of outcomes. Finally, we discuss the ramifications of these outcomes from the perspective of management, future collaboration, and future research.

Project Rationale

Climate change is occurring at a global scale, and its effects are felt very strongly in Alaska (Chapin et al. 2005). We can no longer manage for old goals and priorities assuming a static climate. Given the complexities and multiple disciplines involved with climate-change challenges, collaboration and knowledge sharing among multiple disciplines are essential. Scenario planning is an educational process that helps park employees and others understand climate trends; anticipate future changes that may affect resources, assets, and operations in parks and surrounding areas; and consider a range of possible climate change response strategies. This effort represents a collaboration between the National Park Service (NPS) and the Scenarios Network for Alaska and Arctic Planning (SNAP), whose mission is to "develop plausible scenarios of future conditions through a diverse and varied network of people and organizations, which allow better planning for the uncertain future of Alaska and the Arctic" (www.snap.uaf.edu).

The focus of the workshop described in this report was largely on examples from the Southwest Alaska Network (SWAN) National Parks (Figure 1). However, concerns and effects of climate change are clearly not limited by property lines. The results from this scenario planning workshop can be equally relevant to residents and managers of surrounding areas.

Focal Question

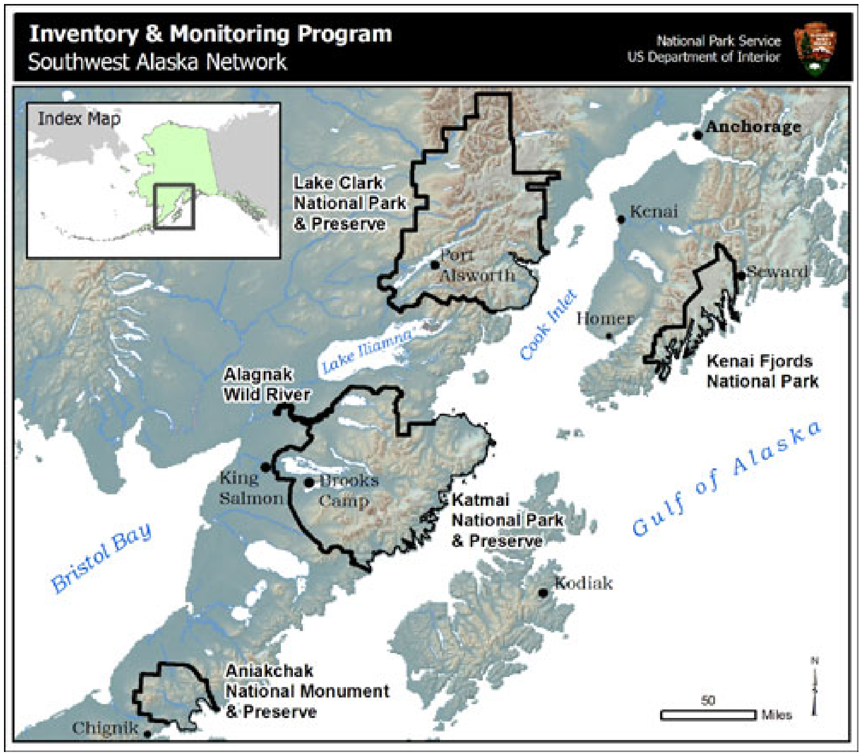


Figure 1: Southwest Alaska Network (SWAN) national parks.

The focal question of this workshop was "How can NPS managers best preserve the natural and cultural resources and other values within their jurisdiction in the face of climate change?" Although parks were a primary focus, participants were also invited from affiliated communities, other areas for broader perspectives. Answers to the focal question were intended to be advisory rather than in any way binding. As will be discussed, the focal question was intended to be addressed in the context of scenario planning. Thus, some recommendations for managers are robust to all possible futures, while some are more heavily weighted toward preventing negative outcomes (or enhancing positive outcomes) associated with only one of several possible futures.

Scenario Planning Process

Natural resource managers and others have explored multiple methods for making management decisions in the face of uncertainty and/or ongoing change. In cases where the future can be predicted via predictive modeling with a relatively small error margin, managers generally choose to seek optimal control. However, in the real world, natural systems uncertainty is often more uncontrollable and irreducible (Peterson et al. 2003, Schwartz 1996).

Under highly uncertain conditions, action based on a single predictive forecast can be extremely risky. Other available planning methods include adaptive planning (Walters 1986) and scenario planning. The two methods have some similarities, in that both recognize the role of uncertainty and the need for resilience in the face of unknown futures. However, in the case of scenario planning, management experiments are built into the models, rather than playing out over time.

Scenario planning explores multiple possible futures based on the best available information of future conditions. Peterson et al. (2003) note that: "Ideally, scenarios should be constructed by a diverse group of people for a single, stated purpose. Scenario planning can incorporate a variety of quantitative and qualitative information in the decision-making process. Often, consideration of this diverse information in a systemic way leads to better decisions. Furthermore, the participation of a diverse group of people in a systemic process of collecting, discussing, and analyzing scenarios builds shared understanding." This combined goal of building understanding and sharing high-quality information in a diverse group was key to this project.

Scenario planning, as outlined by the Global Business Network (GBN) has been used successfully by corporations, government and nongovernmental organizations, and was selected as the most effective way to create management tools and frameworks that would be both useful and flexible in the face of uncertainty (Schwartz 1996).

Unlike forecasting, scenario planning emphasizes multiple possible futures (Figure 2). Forecasts assume that the future is fairly predictable, at least within some range of variability. Scenarios conversely, are possibilities rather than predictions about the future. Scenarios can use modeling output, but they recognize the inherent unpredictability of complex systems. Scenarios envision a range of plausible, relevant, divergent and challenging futures and then ask the question "What if this was to happen?" Consequently, the scenarios provide a richer background for planning and decision making than traditional forecasting methods. These scenarios should be created and selected to be relevant, plausible, divergent, and challenging.

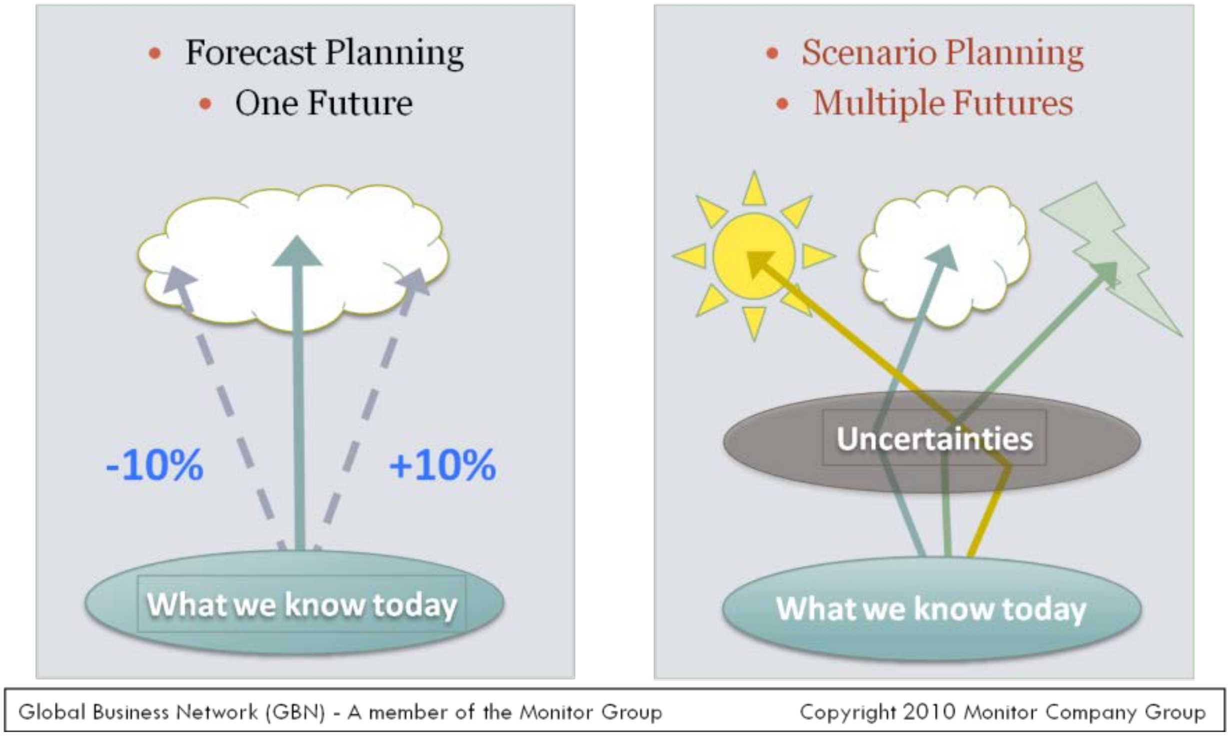


Figure 2: Difference between forecasting and scenario planning. Diagram courtesy of GBN.

The scenario planning process asks participants to orient on a focal question; explore and synthesize potential scenarios; act, by identifying and implementing actions appropriate to address potential outcomes; and monitor the results of these actions (Figure 3). The latter two steps (Act and Monitor) occur after the CCSP workshop.

Scenario synthesis is dependent on a multi-step process in which participants select two key drivers of change that are both important (likely to cause multiple significant effects) and uncertain (in terms of the magnitude or direction of the change). These drivers, when intersected, yield four possible futures (Figure 4). By selecting the drivers with the greatest importance and uncertainty, workshop participants insure that these four futures represent highly divergent scenarios that approximate the full range of possibilities worth exploring in depth

In this workshop, the primary drivers were biophysical drivers of climate change. Participants first fleshed out some of the details of the four outcomes suggested by these primary drivers, by creating bulleted lists of potential effects to humans, ecosystems, and infrastructure in and around parks. They then took the scenarios process to a higher level by examining each possible future in a sociopolitical framework that incorporated a wide range of societal concern and an equally wide range of institutional support (Figure 5). Selected divergent scenarios from this framework were fully described in both summary and narrative forms, and management actions were suggested based upon each selected scenario.

Scenario planning offers participants the opportunity to search for actions that perform well under all scenarios (often called "no-regrets" or "robust" actions), current actions the park should continue, and actions that are unlikely to make sense in any future scenario. These actions are often among the immediate and powerful scenario outcomes. There are also a variety of other strategic approaches that offer different levels of risk when developing a range of actions as illustrated in Figure 6.

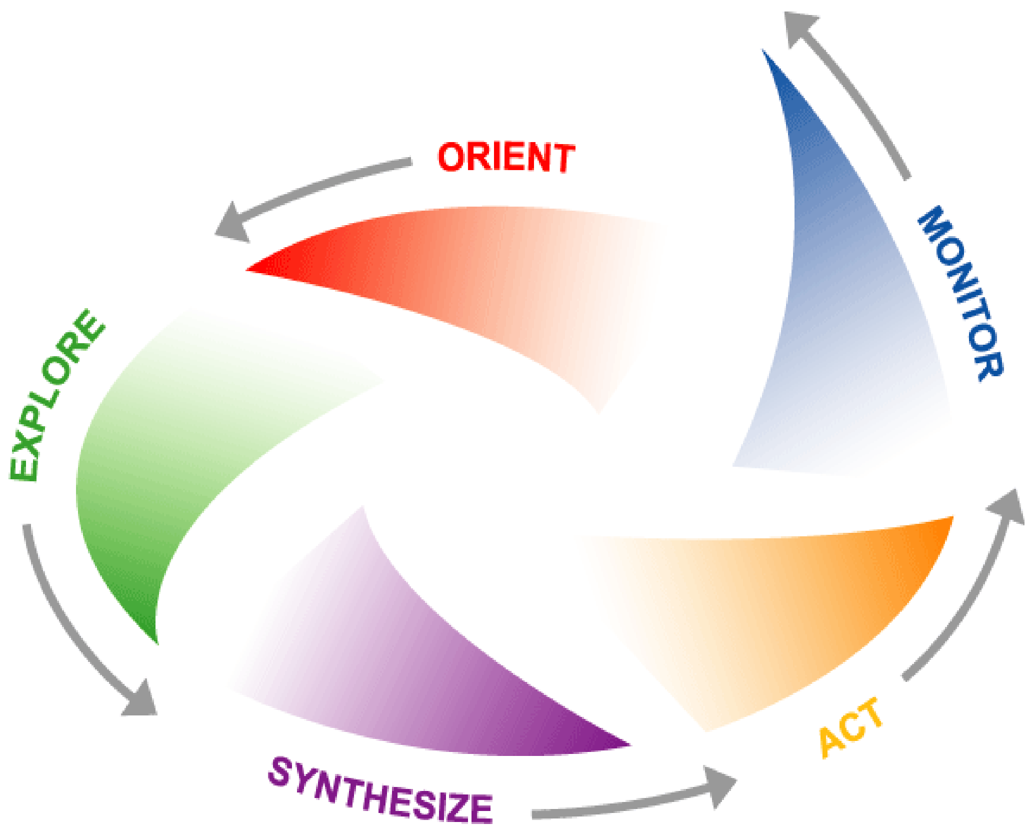


Figure 3: Stages in the scenarios building process. Diagram provided by the Global Business Network (GBN).

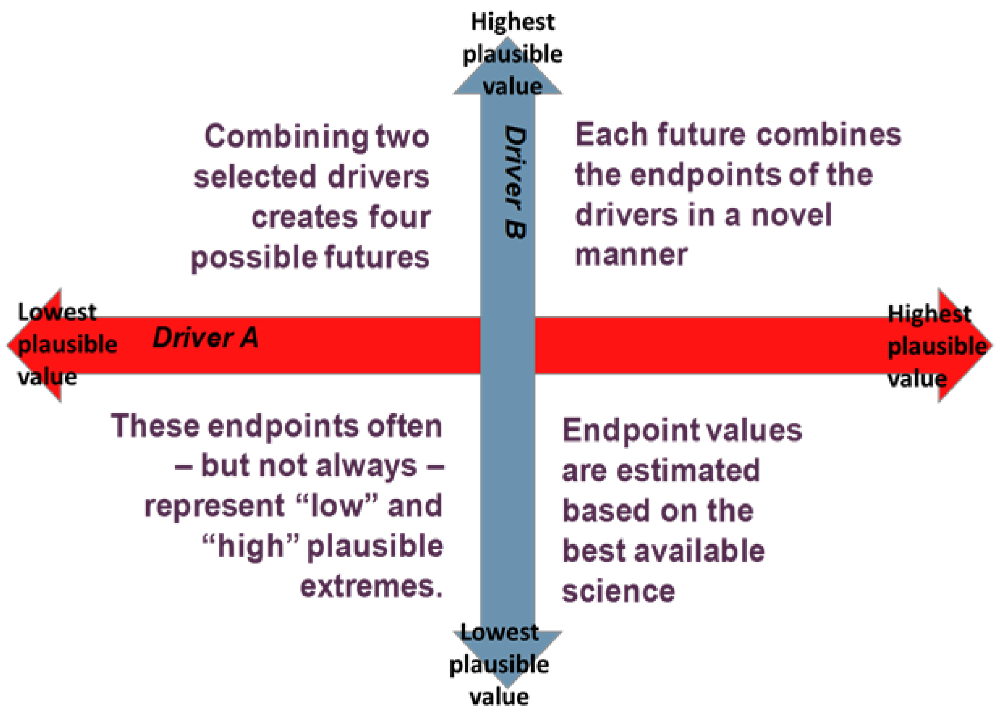


Figure 4: Creating a primary scenarios matrix. Two key climate-related drivers of change are crossed to create four possible futures.

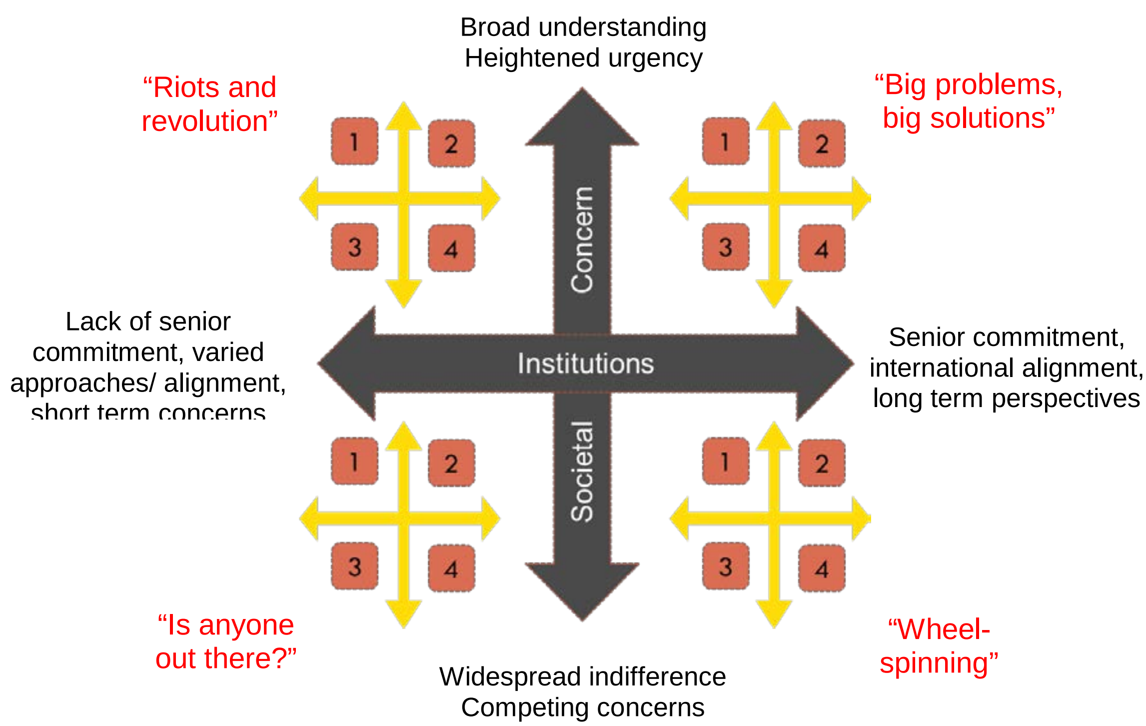
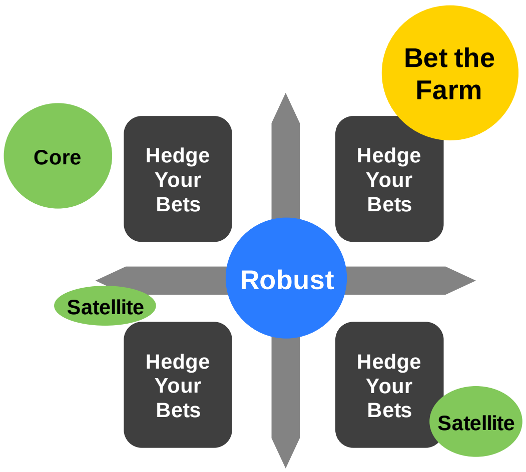


Figure 5: General design for a socio-political framework that incorporates the degree of societal concern in the future and the nature of future leadership. Adapted from the Global Business Network (GBN).



Robust: Pursue only those options that would work out well (or at least not hurt you too much) in any of the four scenarios

OR

Bet the Farm / Shaping: Bet the Farm / Shaping: Make one clear bet that a certain future will happen — and then do everything you can to prepare for that scenario becoming a reality

OR

Hedge Your Bets / Wait and See: Make several distinct bets of relatively equal size

OR

Core / Satellite: Place one major bet, with one or more small bets as a hedge against uncertainty, experiments, and real options

Figure 6: Categorizing options to help set strategy. Adaptive planning depends on weighing choices based on their short-term and long-term comes. Diagram adapted from the Global Business Network (GBN).

Adapting the Scenarios Process to CCSP in Alaska

This report provides a detailed description and case study illustrating how managers can use scenario planning for land management in the face of climate change. In order to implement the strategies described above in the context of climate change planning in Alaska's National Parks, the project leadership team – consisting of individuals from the NPS Alaska Regional Office, NPS staff from outside Alaska already trained in scenarios planning, and SNAP climate modelers – set up a scenarios planning effort intended to meet the goals of diverse and intensive participation and reliance on the best available information.

As such, the leadership team pulled together project participants to participate in a three-day workshop preceded by informational webinars. These participants were intentionally selected to include NPS employees, local residents, and representatives from other agencies and businesses that had a stake in the region. The team also gathered, prior to the initiation of the webinars, extensive scientific information from published literature, climate models, and expert knowledge. These were summarized into tables and brief documents in order to facilitate access by all participants.

Pre-Workshop Webinars

Prior to the workshop, participants were invited to take part in three one-hour webinars. The goals of these webinars were to orient participants on the scenario planning process, introduce climate change maps and data, and share existing knowledge among the group. These webinars contained information summarized from scenarios planning training with Alaska Region NPS staff, other NPS staff, and SNAP researchers, conducted in August 2010 by Jonathan Star of the Global Business Network (GBN) and Leigh Welling (NPS).

Webinar 1, led by Nancy Fresco of SNAP, covered an introduction to scenarios planning. Webinar 2, also led by Nancy Fresco, focused on climate drivers (key forces driving climate change) in the Southwest Alaska National Parks. (See Appendix F for a table of Southwest Alaska climate drivers). Webinar 3, led by Robert Winfree of NPS, was focused on climate change effects in the Southwest Alaska parks. Participants were asked to help rank the relative importance of these effects. (See Appendix G for the Southwest Alaska climate change effects table.) Powerpoint presentations and recordings of each webinar are available in the "Webinar 1," "Webinar 2" and "Webinar 3" folders at: http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Southwest_Alaska/

Models, Data, Maps, and Other Information

To help inform consideration of a range of possible futures, workshop participants were provided with data, maps, and summaries of climate projections specific to Southwest Alaska (**Appendix D**, Appendix E). Other climate change information, including drivers of change (Appendix F) and effects of those drivers (Appendix G) were shared during the webinars and workshop. This information was drawn from multiple sources. Prior to embarking on the project, NPS prepared regional summary documents on climate change impacts, including talking points on impacts to Alaska's maritime and transitional regions: **http://www.nature.nps.gov/climatechange/docs/MaritimeTransitionalTalkingPoints.pdf**. More quantitative assessments of ongoing change and projected future change to multiple climate variables were obtained from SNAP data and from peer-reviewed scientific literature.

Additional knowledge was drawn directly from project participants, including NPS employees and local residents, and Alaska Natives who were familiar with the landscapes and the management issues facing those landscapes. This traditional, historical, and experiential ecological knowledge provided much of the core information and many of the key insights in the workshop process.

Partnering with SNAP allowed NPS access to cutting-edge climate data, maps, and models. SNAP employs a variety of modeling and research methods that have been approved by the scientific community through large-scale research programs and peer-reviewed publications (see Appendix C). Core SNAP climate data are derived from historical Climate Research Unit (CRU) data and from the five Global Climate Models (GCM) that have been shown to perform best in Alaska and the Arctic. Outputs from these models are downscaled using PRISM data—which accounts for land features such as slope, elevation, and proximity to coastline. A more complete description of SNAP methodology is available at **http://www.snap.uaf.edu/methods.php**. SNAP also contributed links to sources available via their many partners and collaborators, such as those at the University of Alaska Fairbanks (UAF) Geophysical Institute Permafrost Lab (**http://permafrost.gi.alaska.edu/content/modeling**).

In particular, SNAP provided data summaries from climate models (contained within the Climate Summary reports for individual parks, and incorporated into the Climate Drivers table in Appendix F). SNAP also provided maps depicting baseline (recent historical) climate and projections of future change to key variables, including monthly mean temperature, monthly mean precipitation, date of freeze, date of thaw, summer season length (Figure 7), and mean annual ground temperature at one meter depth (Figure 8). Updated versions of a subset of these maps are available in Appendix E, and the complete set is available in the SNAP maps folder at http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Southwest_Alaska/

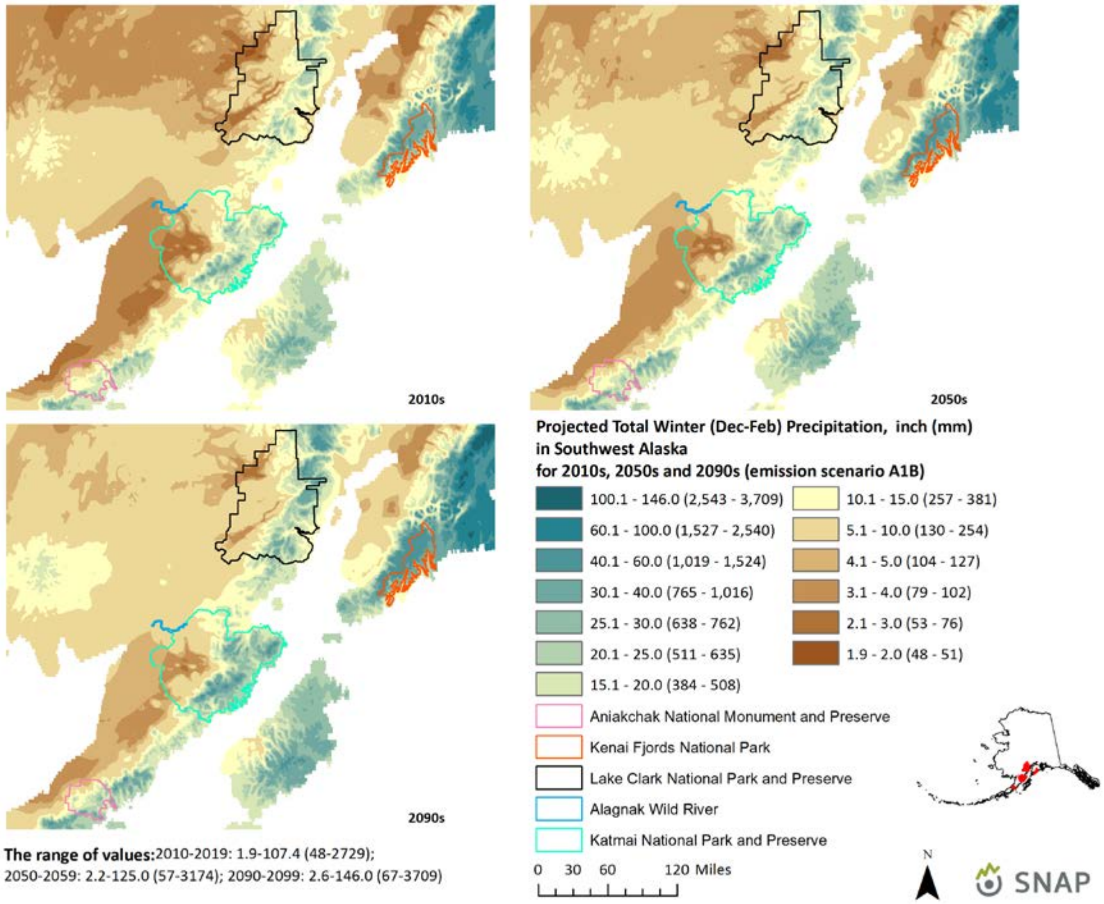


Figure 7: Mean winter precipitation. These maps show the projected precipitation for December, January, and February for selected decades. Although increased precipitation is expected, warmer temperatures may result in less snow. For additional maps, see Appendix E.

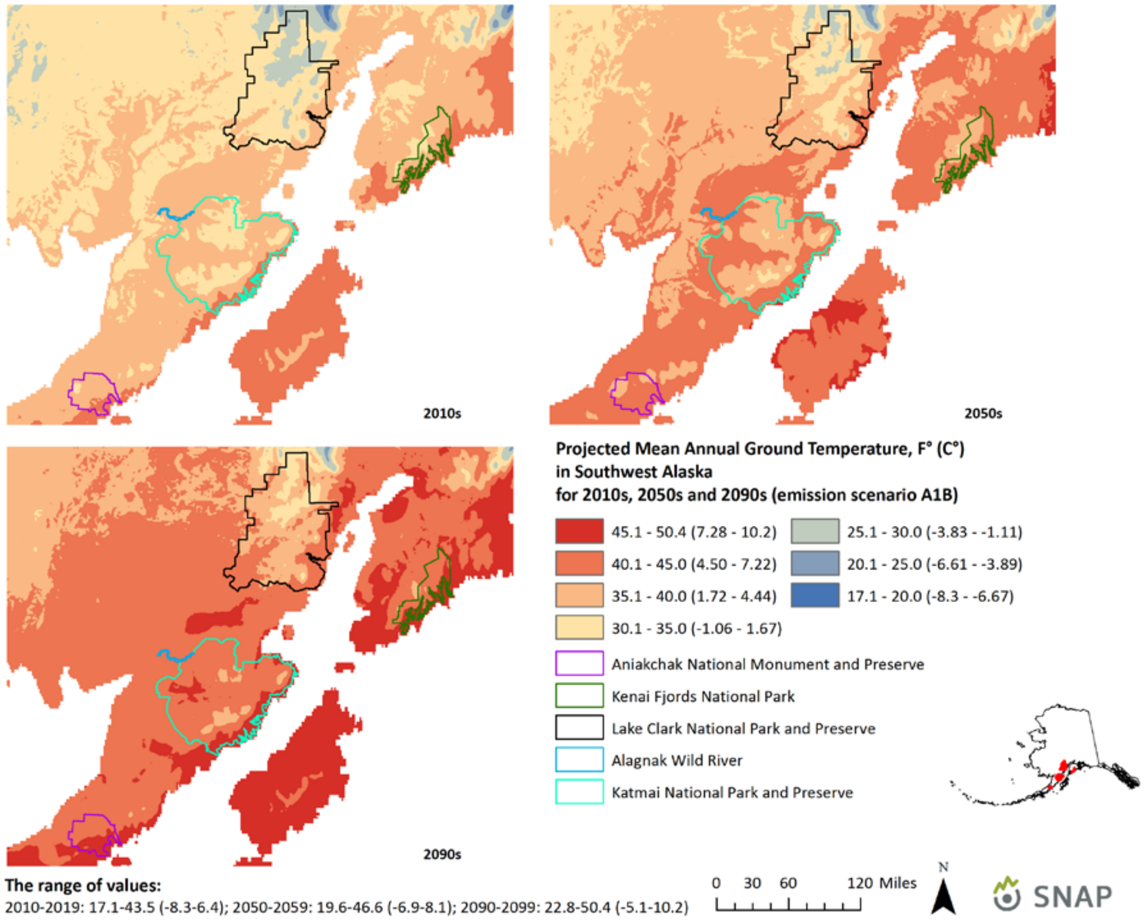


Figure 8: Mean annual ground temperature at one meter depth. Based on SNAP climate data and GIPL permafrost modeling, these maps depict likely ground temperature conditions. Widespread loss of frozen ground is likely by the end of the century.

Additional Workshop Documents, Maps, & Reference Materials

A reading list was provided before the workshop to orient participants (Schwartz 1996, Cole and Yung 2010, Jezierski et al. 2010, and Marris 2011). Further details about the workshop described in this document are contained in the summary PowerPoint "SWAN workshop summary," available in the Reports and Products folder at http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Southwest_Alaska. Workshop documents are also posted online at: http://www.nps.gov/akso/nature/climate/scenario.cfm

Plenary Sessions

Three plenary talks were given by workshop organizers in order to flesh out topics introduced in the pre-workshop webinars, explain and clarify the available background information, and introduce new topics. Plenary sessions were interspersed with collaborative (working group) sessions, which comprised the bulk of the workshop.

Nancy Fresco of the Scenarios Network for Alaska Planning (SNAP) presented scientific information relevant to climate change, climate drivers and uncertainties, including climate modeling, downscaling, and available SNAP data for the parks. Nancy also introduced the project background and scenario planning process. This information familiarized participants who did not attend the pre-workshop webinars, and served as a review and elaboration for those who did.

Jeff Mow of the National Park Service discussed implications for park management and potential decisions and actions to which park managers can apply insights from scenario planning, using examples from Assateague Island National Seashore. Jeff also provided tips on communicating scenarios and formulating no-regrets actions.

These presentations are available at the above NPS site or as Powerpoint or PDF files in the "Workshop documents western Arctic" folder at: http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Southwest_Alaska/

Workshop Work Group Products

Workshop participants divided into two work groups for breakout sessions. Participants divided not by park affiliation, but rather based on the disparate issues faced by inland managers and stakeholders and coastal managers and stakeholders. Thus, one group focused on ocean and shoreline ecology and impacts (coastal group) and the other on riverine ecology and impacts (riverine group). Work group efforts included several stages of analysis, discussion, brainstorming, and creative effort, covering both the "explore" and "synthesize" components of the scenarios planning process.

Participants first assessed the relative importance and uncertainty of climate-related scenario drivers, and then selected two drivers with relatively high importance (in order to maximize the relevance of resulting scenarios) and relatively high uncertainty (in order to maximize divergence).

Crossing these two drivers produced four quadrants, each representing a different future or scenario. The biophysical effects or implications of all four different scenarios were fleshed out by workshop participants. Next, the four scenarios were nested in a social/institutional matrix (Figure 5), which yielded sixteen different scenarios that take into account the future socio-political environment as well as the biophysical effects of future climate. The participants in each group then selected two of the most divergent, plausible, relevant and challenging futures out of the sixteen nested scenarios and developed a narrative – as a story, play, song, skit, etc. – to describe the selected nested scenarios. These full-fledged scenarios were then assessed in terms of their management implications. Participants were asked to suggest what management actions and research opportunities were suggested by each selected future. Finally, these actions were examined across all scenarios to determine what no-regrets choices might be common to all the selected futures.

Climate drivers, scenarios, implications, research needs and actions that emerged from each group's discussions are presented below, followed by management implications and actions that were common to both groups.

Coastal Group

Coastal Climate Driver Selection

Each group started by considering potential drivers in the context of their certainty and importance (Table 1). These critical forces were initially termed "climate drivers," but when this caused confusion regarding cause and effect – given that these forces do not drive climate, but are driven by it – they were renamed "scenario drivers based on climate." For the purposes of scenario planning, drivers that are highly important and highly uncertain are considered the most crucial. Although this table was initially given the headers "uncertain" and "predetermined," both groups were uncomfortable with those labels. Several participants suggested that both importance and certainty should be viewed on sliding scales, rather than as absolutes.

Table 1: Drivers as rated for certainty and importance by the coastal group.

Climate Drivers (or, "Scenario Drivers based on Climate")	Uncertain	Highly certainty	Important
Temperature	X		X
Precipitation	X		X
Freeze-up		X	
Length of growing season		X	
Seal Level	X		
Water availability	X		
Relative Humidity	X		
Wind Speed (separate from Aleutian Low)	X (duration)	X (increase)	
PDO	X		
Extreme Events (temperature)		X	
Extreme Events (precipitation)	X	X	
Extreme Events (storms)		X	X

Importance has multiple dimensions. A driver can be important because it causes effects across a broad area (oceans, rivers, uplands); because it affects multiple sectors (tourism, subsistence, cultural sites) or because the effects in any one sector could be potentially catastrophic. In selecting drivers, the Coastal group considered not only the effects that were discussed in the third webinar and in the workshop plenary session, but also effects that came up during workshop discussions. Additional drivers introduced by the Coastal group included ocean acidification, salinity (onshore/near shore), the Aleutian Low, extreme wind events, and the Alaska Coastal Current.

The group further explored four drivers by partially fleshing out impacts associated with them. Then the group voted on which of these to pursue. The first of these was ocean acidification, with a range of pH change from a slight increase in acidity (-.1 pH) to a major increase in acidity (-.4 pH). This received ten votes. Second was temperature, with a range of +2°C by 2050 and +3°C by 2100 (slight increase) and +4°C by 2050 and +6°C by 2100 (large increase). This received nine votes. Third on the list was storms, with a range from slight or no change to "frequent pummeling". This earned six votes. Finally, mean annual precipitation, with a range from unchanged (or some local decreases) to overall increase, earned nine votes.

Ultimately, the Coastal group decided to focus on ocean acidification crossed with a combination of storms and precipitation (or "water availability") (Figure 9).

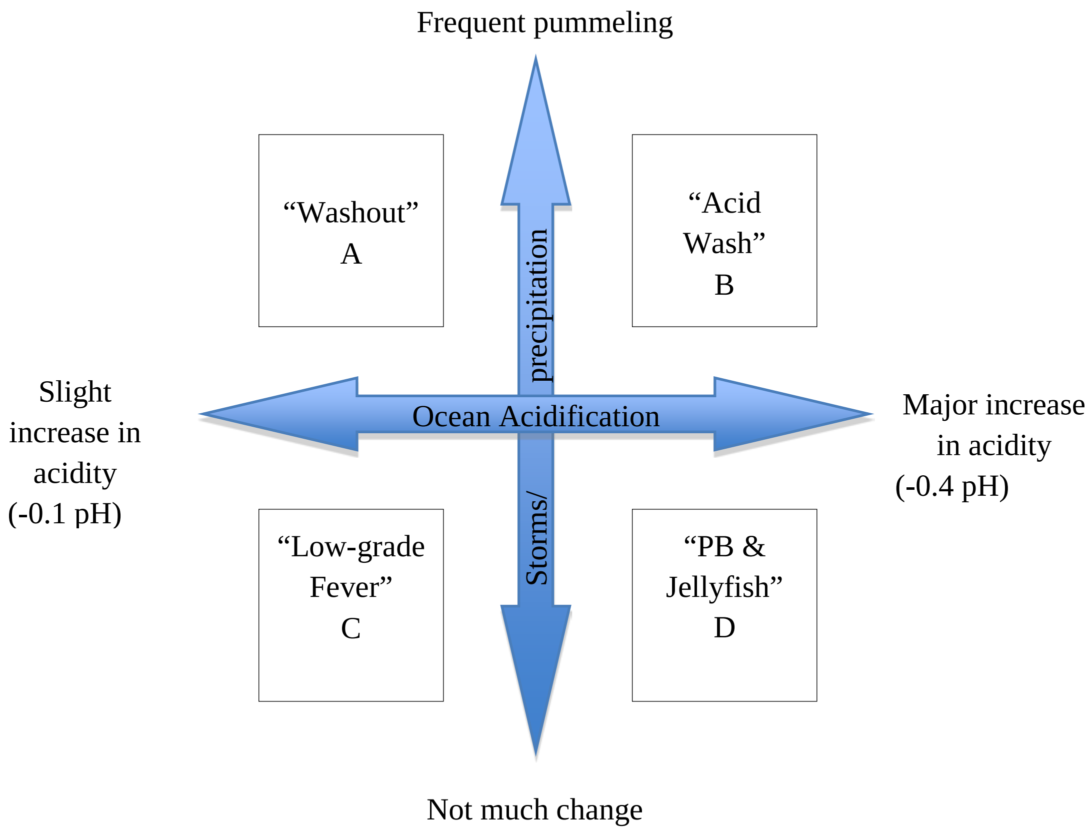


Figure 9: Matrix showing the intersection of changes in storms and precipitation and changes in ocean acidification, as each pertains to coastal regions. Each quadrant yields a set of future conditions which are plausible, challenging, relevant, and divergent. The details of each quadrant are described in the text.

Coastal Bio-physical Scenarios Developed from Selected Drivers
Each quadrant resulting from selected drivers represents a different scenario of potential future temperature and storm/precipitation conditions (Figure 9). In order to flesh out each of these scenarios, participants referred back to the effects tables derived during the pre-workshop webinars, as well as the scientific literature, maps, and other information shared during both the webinars and plenary sessions. The diversity of each working group also allowed for expert knowledge input from those with first-hand knowledge of the parks, the surrounding area, and climate impacts already occurring.

The resulting scenarios for the Coastal group were:

A. “Washout”, with frequent pummeling from storms and a slight increase in ocean acidity;
B. “Acid Wash”, with frequent pummeling from storms and a major increase in ocean acidity;
C. “Low-grade Fever”, with not much change in precipitation or storms and a slight increase in ocean acidity; and
D. “PB and Jellyfish” with not much change in precipitation or storms and a major increase in ocean acidity.

The potential effects of each of the four future biophysical scenarios, as defined by the group, are fleshed out below.

<u>Coastal group scenario A: “Washout”</u>

- Changes to habitat (influx of salt water)
- Trail /road washouts
- Regular riparian disturbances
- More dynamic/changing coast leading to erosion
- Larger floodplains and wetlands
- Less appealing destination
- Destruction of cultural resources due to coastal erosion (communities/ facilities)
- Possible need to relocate communities

<u>Coastal group scenario B: “Acid Wash”</u>

- Ecotourism crash
- Removal of biota (fish, birds, sea mammals)
- Spawning areas destroyed
- Subsistence/recreation opportunities changed
- Coastal erosion
- Catastrophic collapse of salmon
    - Collapse of fishing (subsistence, sport, commercial)
    - Collapse of community cohesion/culture
- Destruction of cultural resources/infrastructure

- Loss of clam/mussel habitat and marine mammals that rely on them
- Requests from communities to introduce species for subsistence/sport
- Change in species composition (more deer?)
- Possible need to relocate communities.

<u>Coastal group scenario C: “Low Grade Fever”</u>
(note: temperature change dominates)

- Increased drying of upland areas
- Change in habitat (veg./animal composition)
- Biomass may increase or decrease depending on location and vegetation
- Increased growing season
- Less soil moisture
- Increased glacial wasting?
- Vegetation expansion into deglaciated coastal areas
- Redistribution of terrestrial mammals

<u>Coastal group scenario D: “PB & Jelly Fish”</u>

- Loss of coastal species with exoskeletons causes cascading effects for seabird populations and subsistence uses (both egg collecting and salmon)
- Increase in jellyfish
- Changes in fisheries (perhaps from salmon to tuna)
- Change could shift appeal to visitors
- Dramatic habitat change

Coastal Scenarios Nested in a Socio-Political Matrix

The coastal group nested the four climate scenarios described above in the social/institutional matrix (Figure 5). This framework explores how each story might play out in a world with greater or lesser degrees of societal concern and institutional commitment. Note that this framework was altered slightly from that presented by GBN, in which the horizontal axis was defined as “governmental” rather than “institutional” and was thus interpreted to take place at a national and international scale rather than at a national, state, and local scale.

While this theoretically yields 16 scenarios, they are not likely to all be divergent or plausible, and the group did not elaborate upon all of them. Instead, they first discussed the nature of the new matrix and the ramifications and plausibility of various combinations, then selected three nested scenarios to explore further. This narrowing of the field is in keeping with the scenarios planning methods outlined by GBN; the goal is to avoid redundancy and unnecessary use of time and effort, while maximizing the range of possibilities under consideration.

Points of discussion included the question of whether a high level of social and institutional engagement (Figure 10, upper right quadrant) was truly plausible, and whether the idea of public disinterest (Figure 10, lower half) would be plausible in the context of extreme change, especially given the fact that local communities have already been talking about and experiencing climate change for 30 years. The group decided that public disengagement might result from people feeling overwhelmed, dispersing, and "giving up," so that all quadrants were plausible. Through voting and additional discussion, the Coastal group selected three scenarios for further development discussion. The three nested scenarios that received the most total votes are marked by blue stars in Figure 10 and described in further detail below.

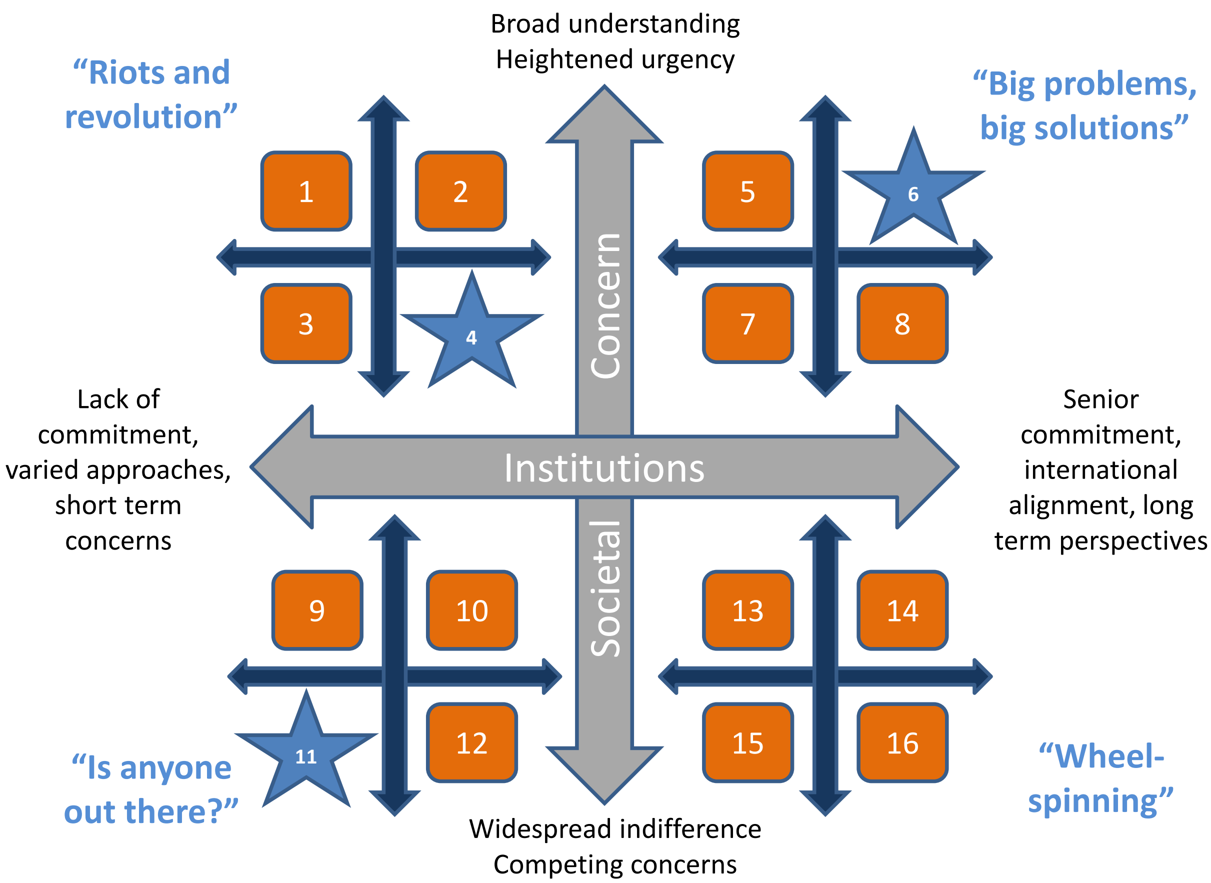


Figure 10: Matrix showing Coastal climate scenarios nested in a social/institutional framework. Each quadrant yields four linked scenarios; three are selected in red. The details of these three are described in the text.

First Coastal nested scenario: "Jellyfish Jamboree, Fishing Fiasco"

The Coastal group identified the following as potential impacts, implications, and management actions in the case of the "PB & Jelly Fish" scenario (increased ocean acidification with decreased storminess) nested in the "Riots and Revolution" (high societal concern, with a less integrated government) quadrant of the socio-political matrix (Figure 5). The Coastal group named this nested scenario "Jellyfish Jamboree, Fishing Fiasco."

Natural Resources

- Pest and disease: increased parasite loads for marine mammals, ungulates
- Plant diseases: vegetation dieback
- PSP (paralytic shellfish poisoning) increase

- Glacial retreat or disappearance
- Vegetation shifts with impacts to ungulates: increased black spruce, woody upright vegetation (alder/willow)
- Major fisheries and ocean trophic restructuring
    - Failing: salmon, halibut
    - Gaining: unknown
- Invasive species
    - Marine: range extensions from BC/WA of tunicates and green crab
    - Terrestrial: new invasives, rapid proliferation in distribution and diversity. Range extensions.
- Species of concern: migratory birds and marine mammals

Cultural Resources

- Archaeological site loss
- Cultural disconnect of sacred or significant sites

Facilities/Infrastructure

- Fire-safe communities become a priority
- Changing priorities for facility funding as use patterns change and resource attractions shift location

Communication

- Communications budgets cut; face-to-face interaction lessens
- Public demands info; managers unable to meet demands (lack of funding, decentralized info)
- Visitor (external audience)
    - Lack of changing venues to engage visitors
    - Fewer tour boat visitors
    - Poor access to glaciers
    - Bear viewing moved or diminished

Social/Economic/Subsistence

- Oil and gas development: potential for mining, operational season changes
- Alcoholism and disease in people with dietary and social changes
- Decline and conflicts in commercial and sport fisheries; struggles with permitting and regulations for historic and/or emerging fisheries
- Village population declines with loss of subsistence and traditional economic base
- Reduced interest in marine wildlife viewing
- Impacts on transportation options (overland, river boat, float plane access) due to loss of snow and ice
- Loss/decline of traditional hunting species; some replacement species

- Increase in occurrence of paralytic shellfish poisoning: health impacts to local population
- Collapse of salmon in both maritime and riverine lifeways
- Plant/berry harvest: change in timing (phenology) and species
- Loss of language and traditions as local demographic changes (e.g. marine mammal customs and crafts)

Important Management Actions

- Energy development—renewable village development
- Economic development (local and community ventures and employment)
- Partnerships with non-governmental organizations and community groups (Landscape Conservation Cooperatives, Resource Advisory Councils, development groups, local government, Native organizations)
- Convert to local resource use
- Streamline public engagement by issues rather than by jurisdiction
- Implement facility standards for green energy use and efficiency
- Provide forums for sharing scientific efforts and expertise

Research and Information Needs

- Develop relevant communication strategies to feed into existing networks; assign accountability
- Resource monitoring: shared responsibility and protocols between communities and agencies
    - Water quality
    - Fish and wildlife populations
    - Invasive species
- Trophic interaction linkages research
- Ocean acidification research
- Facilitation of academic research with clearly communicated needs
- Economic/energy development: emphasize mitigation options and build planning (NEPA) capacity

<u>Second Coastal nested scenario: “Acid Wash” in “Big Problems, Big Solutions”</u>

The Coastal group identified the following as potential impacts, implications, and management actions in the case of the “Acid Wash” scenario (increased ocean acidification with increased storminess) nested in the “Big Problems, Big Solutions” (high societal concern and more integrated institutions) quadrant of the socio-political matrix (Figure 5). The Coastal group named this nested scenario “Acid Reflux.”

Natural Resources

- Benthic community decline
- Food web shift

- Local extinction, mass redistribution
- Coastal erosion
- Extremely moist conditions
- Unknown glacial dynamics

Cultural Resources

- Flooding and wave action lead to loss of known historic sites
- Loss of historic record (undiscovered sites)

Facilities/Infrastructure

- Increased risk of flood/mudslide/erosion effects on structures
- Access to roads and trails more frequently compromised
- Potential effects on coastal communities and way of life (bridges/roads/river swell)
- Private ecotourism accessibility (inholdings, lodges, docks, etc.) compromised

Communication

- Media/public involved at every step
- Need for a highly evolved communication network
- Potential misaligned message delivery

Social/Economic/Subsistence

- Questions of prioritization re: private vs. public aid
- Livelihoods stressed, leading to industry shift (tourism, fishing)
- Natural resource development—need for energy and jobs
- Community relocation?
- Loss of fish, game, "revenue" (community asset)
- Shift in way of life
- Search for surrogates

Important Management Actions

- Mission Statement evolution
- Removal of artificial barrier between research/monitoring/management loop
- Fostering public/private partnerships (e.g. ecosystem cooperatives/LCCs)
- Protecting and providing access to sacred cultural sites
- Comprehensive risk assessment for roads, bridges, trails, structures
- Temporary/portable facilities
- Species specific mitigation planning (economic driver species)
- Foster transitional community coping mechanisms
- Synchronize public/private education and outreach

Research and Information Needs

- Overall, more robust monitoring and research
- Acidification research
- Alternative energy/ alternative facilities research
- Exploratory husbandry
- Glacial monitoring
- Robust benthic, fish, seabird, mammal monitoring
- Mapping of cultural resources
- Coastal engineering
- Increased capacity re: acquisition and grants
- Develop disaster response capacities (e.g. evacuation plans, interagency coordination)

Third Coastal nested scenario: "Low Grade Fever (Cold PDO)" in "Is Anyone Out There?"
The Coastal group identified the following as potential impacts, implications, and management actions in the case of the "Low Grade Fever" scenario (increased ocean acidification with decreased storminess) nested in the "Is Anyone Out There" (competing local concerns and less coordinated institutions) quadrant of the socio-political matrix (Figure 5). The Coastal group named this nested scenario "Is There a Doctor in the House?"

Natural Resources

- Vegetation changes
    - Shrubs increase
    - Forest fuel loads increase
    - Animal movements impeded
    - Moose increase
    - Caribou decrease
- Fisheries
    - Shellfish increase
    - Salmon decrease

Cultural Resources

- Living cultural resources and traditional lifeways around subsistence fishing and hunting supported/enabled until 2030
- Climate change mitigation and adaptation funds sent to other areas with more pronounced change
- Competition for fish and wildlife intensifies between subsistence/commercial/sport users
- Eroding budgets lead to shifts in priority
- Alaska resources increase in value (e.g. fish, clean water, clean air, energy resources) thus increasing appeal as visitor destination

Facilities/Infrastructure

- Visitation increase leads to need for visitors facilities (e.g. trails, lodging, VCs, access, marinas)

- Replace old or build new facilities with new sustainable technologies
- Energy resources development: pressure to develop oil and gas (Bristol Bay), coal (Chitina), wind farms, tidal facilities, geothermal, hydro

Communication

- Climate change hard to sell in SWAN area, but rest of world suffering
- New communications technologies emerge, presenting challenges and opportunities
- Public disbelieving re: climate change in SWAN
- Scenario planning becomes widely used

Social/Eeconomic/Subsistence

- Climate change mitigation and adaptation funds sent to other areas with more pronounced change
- Competition for fish and wildlife intensifies between subsistence/commercial/sport users
- Eroding budgets lead to shifts in priority
- Alaska resources increase in value (e.g. fish, clean water, clean air, energy resources) leading to increased appeal as a visitor destination
- Subsistence resources remain available until 2030, but rural lifestyles are more expensive and less viable
- Traditional lifeways around subsistence fishing and hunting supported/enabled until 2030

Important Management Actions

- Reach out for interagency cooperation to effectively communicate PDO oscillations and imminent climate change
- Advocate for more flexible and responsive management of fish and wildlife
- Develop flexible, portable infrastructure
- Model desired green behaviors
- Due to shrinking budgets, use partnerships to address management needs

Research and Information Needs

- Thorough ethnographic studies of subsistence lifeways
- Ecosystem mapping to identify critical near shore areas
- Monitor elements of PDO shift (e.g. air and ocean temps, precipitation, fisheries, benthos, coastal wildlife)

Riverine Group

Riverine Climate Driver Selection

The methods and procedures for the Riverine group were nearly identical to those described for the Coastal group. However, the two groups' preferences and discussions produced different results. The Riverine group began by ranking the certainty and importance of each climate driver (Table 2). These drivers had been presented and discussed during the pre-workshop webinars and workshop plenary sessions. For the purposes of scenario planning, the goal was to select two drivers with high importance (in order to maximize the relevance of resulting scenarios) and high uncertainty (in order to maximize divergence).

Table 2: Climate drivers as rated for certainty and importance by the Riverine group.

Climate Drivers (or, "Scenario Drivers based on Climate")	Uncertain	Highly certainty	Important
Temperature		X	X
Precipitation	X		X
Freeze-up date		X	
Length of ice free season (rivers/lakes)		X	
River/Stream temperatures		X	
Water availability (stream flow)		X	
Relative Humidity	X		
Wind Speed		X	
PDO	X		
Extreme Events (temperature)		X	
Extreme Events (precipitation)	X		
Extreme Events (storms)	X		
Soil Moisture			

Additional drivers introduced by the group included volcanic eruptions (which might cause local acidification); The Pacific Decadal Oscillation (PDO) and Arctic Oscillation (AO); and variable Stream Flow. After extensive discussion, the group narrowed down the list to four top choices, with which it did some preliminary exploration of effects. These four included precipitation (variability); temperature (variability); thaw days (more/less) and PDO (warm/cold phase).

Ultimately, the riverine group opted to focus on thaw days (more/less) crossed with precipitation (low/high variation) (Figure 9). The group decided that PDO would be included, but not as a main driver. Instead, it would be included as a factor affecting thaw days. In other words, a cold phase PDO was coupled with the possibility of a thaw days and a warm phase PDO with more thaw days to push the extreme possibilities.

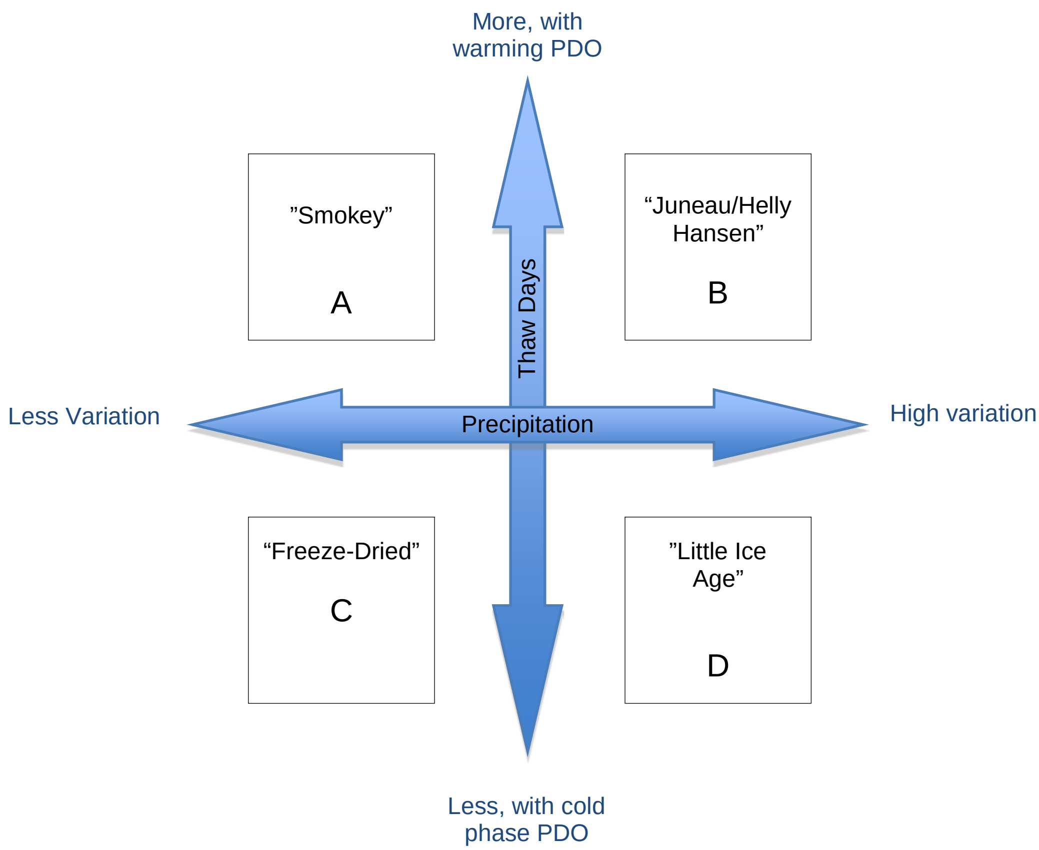


Figure 11: Primary matrix of climate drivers produced by the Riverine group. Each quadrant represents a different combination of potential future conditions with respect to precipitation and length of summer season (number of thaw days). Details of each scenario are in the text.

Riverine Bio-physical Scenarios Developed from Selected Drivers

Each quadrant resulting from the selected drivers represents a different scenario of potential future precipitation and thaw days (Figure 11). In order to flesh out each of these scenarios, participants referred back to the effects tables derived during the pre-workshop webinars, as well as scientific literature, maps, and other information shared during both the webinars and workshop plenary sessions. The diversity of each working group also allowed for expert knowledge input from those with first-hand knowledge of the parks, the surrounding area, and climate impacts already occurring.

The resulting scenarios for the Riverine group were:

A. "Smokey", with more thaw days, a warming PDO, and less variation in precipitation;
B. "Juneau/Helly Hansen", with more thaw days, a warming PDO, and high variation in precipitation;
C. "Freeze Dried", with fewer thaw days, a cold phase PDO, and less variation in precipitation; and
D. "Tiny Ice Age" with fewer thaw days, a cold phase PDO, and high variation in precipitation.

The potential effects of each of the four future biophysical scenarios, as defined by the group, are fleshed out below.

Riverine group scenario A: "Smokey"

- Drought-stressed vegetation
- Increase in disease/pests
- Longer growing season
- Maximum shrub expansion (less overland access)
- Long-term reduction stream flow
- Initially higher stream flows from seasonal glacial melt
- Reduction/loss glaciers
- Increased fire on landscape
- 40% reduction in salmon fry due to smaller fry
- KATM Brooks Camp barge requires glacier melt for high lake levels; this world would minimize access with warming and less precipitation
- Fewer biting insects
- Decrease in waterfowl
- Exposure of cultural resources
- Lowering of groundwater tables
- More fugitive dust with Pebble Mine
- Decrease in stream flow
- Increase competition in water
- Decrease in subsistence (difficult winter travel)

Riverine group scenario B: "Juneau/Helly Hansen"

- Increase in rain on snow events (increased flooding events)
- Thicker vegetation
- Increased erosion
- Increased lightening
- Increase evaporation (soil drying)
- More berries (good habitat for bear, moose, caribou)

- Decrease in alpine tundra
- Arrival of black bear
- Increase in waterfowl
- Increase in park infrastructure impacts
- Decrease in backcountry visitation (increase in rain, reduction of flying days)
- Increase in hurricanes
- Increased rain on snow events (flooding)…decrease in salmon
- Increase difficulty in controlling contamination (runoff)
- Increase in avalanches

Riverine group scenario C: "Freeze Dried"

- Permafrost persists
- Decrease in productivity (plants, berries); impact on wildlife
- Overland access continues
- Competition of water resources (mining, communities)
- Facilities/infrastructure stable
- Slow retreat of tundra ponds
- Extend range of Dall sheep
- Lichens stable, supporting caribou
- High wind potential
- Brown bear decrease

Riverine group scenario D: "Tiny Ice Age"

- Increased damage risk in cultural resources/infrastructure
- Increased bear activity for Brooks Camp (KATM)
- Decrease in ungulates
- Decrease in bark beetle and fire
- KATM Brooks Camp barge has adequate Naknek Lake water depth to access
- Stable glaciers
- High summer stream flows
- Increase in winter access

The following lists summarize the significant ways in which the Riverine group's scenarios diverged from each other.

Scenario A: "Smokey"

- Increased fire potential (conversion of non-fire-adapted ecosystems to fire)
- Conversion of ponds, riparian systems/structure to new ecosystems
- Reduction in glaciers
- Significant restriction to winter access

- Broad landscape-level habitat/ecosystem shifts/changes

Scenario B: "Juneau/Helly Hansen"

- Wildlife generally doing well (caribou may be impacted)
- Extreme events/flooding may impact (storms, mudslides, avalanches)
- High threats to infrastructure
- Impacts to visitor use access

Scenario C: "Freeze Dried"

- At extreme may impact salmon fry (decrease)
- Limited vegetation growth
- Significant economic cost-of-living issues

Scenario D: "Tiny Ice Age"

- Glaciers stable/growing
- Winter travel (access) good
- Moderate level of pests/disease
- Extreme events may impact salmon

Riverine Scenarios Nested in a Socio-Political Matrix

As with the Coastal group, the Riverine group nested each biophysical scenario within a larger social/institutional framework, as shown in Figure 12. This framework explores how each story might play out in a world with greater or lesser degrees of societal concern and institutional commitment. Note that this framework was altered slightly from that presented by GBN, in which the horizontal axis was defined as "governmental" rather than "institutional" and was thus interpreted to take place at a national and international scale rather than at a national, state, and local scale.

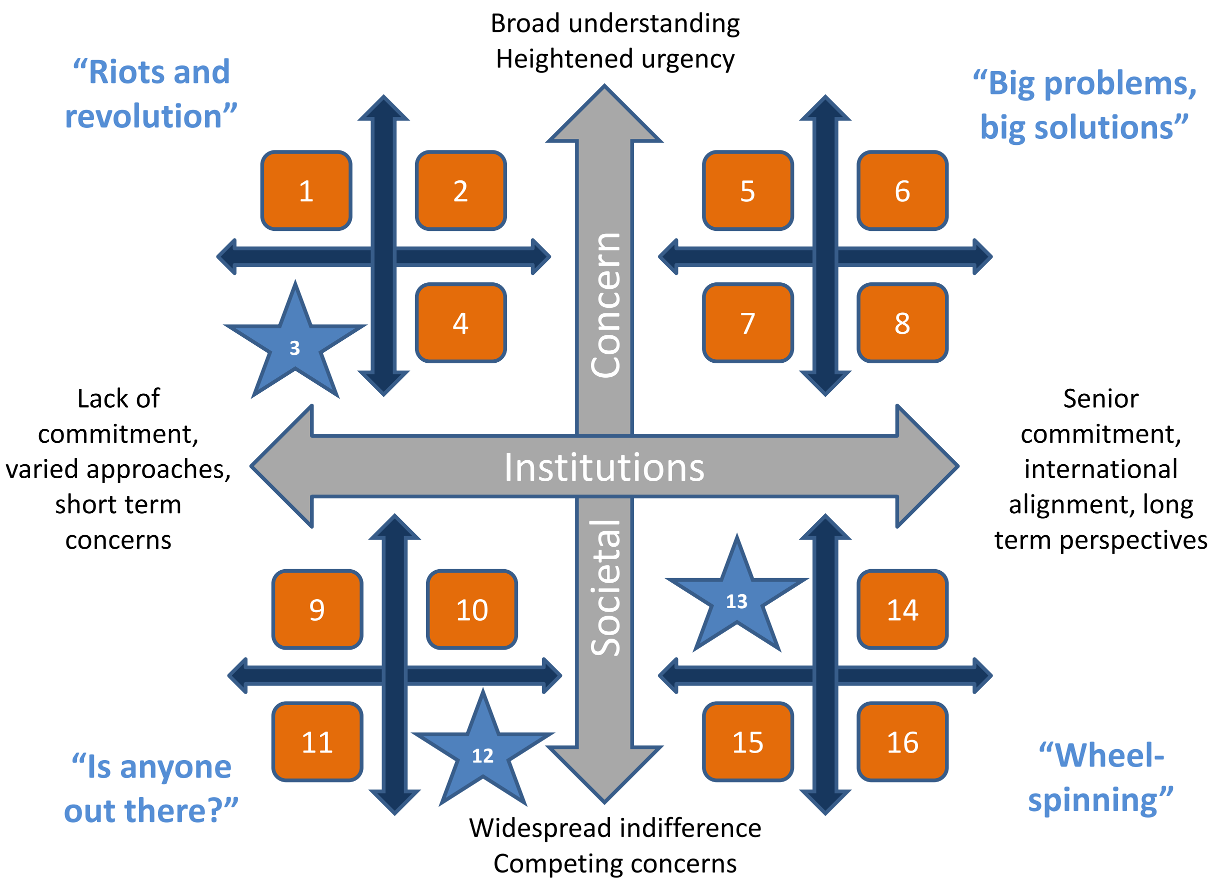


Figure 12: Riverine group nested scenarios. The three nested scenarios selected by the riverine group are marked by blue stars.

While this theoretically yields 16 scenarios, they are not likely to all be divergent or plausible, and the group did not elaborate upon all of them. Instead, group members first discussed the nature of the new matrix and the ramifications and plausibility of various combinations, then selected two nested scenarios to explore further. This narrowing of the field is in keeping with the scenarios planning methods outlined by GBN; the goal is to avoid redundancy and unnecessary use of time and effort, while maximizing the range of possibilities under consideration.

After fleshing out the potential effects and future implications of selected nested scenarios, the Riverine group assessed possible management actions and research needs to address those implications.

The Riverine group selected two nested scenarios to explore voting as the Coastal group had done. The two scenarios selected by the Riverine group are marked by blue stars in Figure 10, and are described below, including their implications, important management actions, and research and information needs.

First Riverine nested scenario: "Smokey" in "Wheel-Spinning"

The Riverine group identified the following as potential impacts, implications, and management actions in the case of "Smokey" scenario (warm phase of the PDO, more thaw days, and less variation in precipitation) nested in the "Wheel-spinning" quadrant (low societal concern and more integrated institutions) of the socio-political matrix (Figure 5).

Natural Resources

- Hydrological cycle changes
- Reduction in available water
- PDO phase (which phase the PDO is in is an implication)
- Major biome shift
- Increase in fire, increase in pests/disease
- Pond conversion to uplands
- Endangered Species Act issues and species management concerns
- Fish and wildlife regulations, harvest quotas, seasons

Cultural Resources

- Exposure of artifacts

Facilities/Infrastructure

- Infrastructure risks, fire protection costs
- Melting permafrost, damage to infrastructure (buildings)
- Fire management, public safety risks

Communication

- Maintaining relevant agency in-reach efforts
- Public/visitor education costs and challenges
- Greater need for public application of ecosystem services

Social/Economic/Community/Subsistence

- Conservation of fish and wildlife for subsistence and recreation
- Access and transportation issues

Important Management Actions

- Re-evaluation of agency mission
- Environment planning: What is the purpose of the land?
- Secure water rights and implement water conservation
- Include anticipated increase in fire proofing, natural resource engineering
- Increase in fire-proofing

Research and Information Needs

- Natural resource engineering
- More monitoring data

Second Riverine nested scenario:" Tiny Ice Age" in "Is Anyone out there?"

The Riverine group identified the following as potential impacts, implications, and management actions in the case of the "Tiny Ice Age" scenario (cold phase of the PDO, fewer thaw days, and high variation in precipitation) nested in the "Is Anyone Out There?" quadrant (competing local concerns and less coordinated institutions) of the socio-political matrix (Figure 5).

Natural Resources

- Glaciers stable
- Water levels high
- Water front erosion increases
- Increase in storm damage
- Salmon decrease
- Bears increase
- Ungulates

Cultural Resources

- Storm damage increases

Facilities/Infrastructure

- Increase storm damage
- Increase facility maintenance costs
- Significant budget decrease
- Maintenance access good

Communication

- Audiences unaware of masking PDO
- Subsistence connection to resources decrease
- Harvest management more critical

Social/Economic/Community/Subsistence

- Access is good
- Tourism is stable
- Decrease in commercial fisheries
- Decreased demand in subsistence
- Municipal tax revenue decreases
- Snowmachines, etc. → emerging recreation

Important Management Actions

- Identify/manage infrastructure based on charging demand and reduce costs
- Identify opportunities for shared technical expertise
- Interagency partnerships

Research and Information Needs

- TEK → critical element to facilitate subsistence
- Water and climate data
- Fish and wildlife population data

Other

- Institutional barriers to subsistence use (human movement, species availability)
- Marketing ecological services (local – national)

<u>Third Riverine nested scenario: "Freeze Dried" in "Riots and Revolution"</u>

The Coastal group identified the following as potential impacts, implications, and management actions in the case of the "PB & Jelly Fish" scenario (increased ocean acidification with decreased storminess) nested in the "Riots and Revolution" (high societal concern, with a less integrated government) quadrant of the socio-political matrix (Figure 5). The Coastal group named this nested scenario "Jellyfish Jamboree, Fishing Fiasco."

The following narrative was developed by the Riverine group based on the "Freeze-Dried" scenario (cold phase of the PDO, fewer thaw days, and less variation in precipitation) nested in the "Riots and Revolution" quadrant (high societal concern and less integrated institutions) of the socio-political matrix (Figure 5).

Natural Resources

- Less fish management
- Subsistence/extraction conflicts
- Wildlife shifts

Cultural Resources

- Stable archaeology

Socio/Economic

- Difficult access
- Fewer local owned fish permits
- Deficits, inflation, less real $ for land/resource management
- Population (out migration), lost TEK and local culture
- Less salmon harvest
- Higher cost of living and energy

Facilities

- Greater fire risk, but facilities OK

Interpretation and Education

- Hard to put Southwest AK in climate change context with cool PDO
- Loss of TEK and culture

- Regulatory fish and wildlife bottlenecks (access, seasons, allocations)

Important Management Actions
- Intensive management triggers Title 8 harvest preference
- Protect current and future critical habitats, migration routes, ecosystem services
- Get missing players to the CC scenario table at subsequent workshops
- Adjust regulations to harvest realities (more flexible process)
- Resume ANILCA local hire authority
- Long-term funding for invasive species management

Research and Information Needs
- Science outreach and education to multiple audiences
- Need higher understanding of AK protected areas in global context
- Funding for interdisciplinary studies
- Social scientist for LCC and DOI CSC and agencies
- Communication in LCCs
- All of Bristol Bay should be in one LCC, not split
- Enhance ethnography program
- Explain relevance of resource protection when developable resources become scarce (ecosystem services)
- Validate CC models with I&M data going forward

Other
- Is this a paradigm shift from naturalness? What does this tell us?

Narratives

Climate change scenarios can be used to create multiple outreach tools to assist land managers and to educate the public. One such product is a set of narratives or stories that help to visualize and synthesize a range of plausible yet divergent futures.

The fictional narratives created by participants in this workshop (included in Appendix H) were a collaborative and creative effort to turn relatively dry lists of bulleted climate change impacts into vibrant and memorable stories. The format for these stories was open to interpretation and imagination. Thus, within the coastal group, one narrative describes a conversation between a boy and his grandfather; another is a text chat between a young couple in a future village; while a third group wrote two narratives for one nested scenario: a conversation at a Southwest planning meeting and a report of future conditions under that same scenario. A fourth group wrote a travelogue of a retired physician spending the summer at Katmai; another group elaborated on an ecologist's perspective after 30 years in Alaska; and the last group drafted a letter to a senator from the Kenai Peninsula Mayor's Council.

While such products could be considered unscientific, or even frivolous, from a management perspective, they serve several useful purposes. First, they offer an opportunity for workshop participants to make their own immersive experience more memorable through creative collaboration. Second, they create products – or ideas for products that might be further developed later – that speak directly to the public, with minimal jargon and the strongest possible emotional connection. Although care must be taken to present such stories within a scenarios context, they can bring home the message that while climate change may seem abstract, its effects will be very real to those who are impacted in and around Alaska's national parks.

Common Implications, Actions and Needs

A good set of common needs can be an excellent starting point for responding to change through "no regrets actions" that would make good sense under any conditions, such as when determining safe locations for new facilities.

Scenario planning enables participants to assess potential vulnerabilities (effects and implications) and identify appropriate responses to address the implications and manage risks. Divergent scenarios typically yield different effects and implications. Serious differences in implications typically warrant different responses, especially when the effects could be catastrophic. When the same actions are listed for multiple scenarios, either a suite of no regrets actions has been identified, or the scenarios were not sufficiently divergent.

If the recommended actions appear to closely to reflect current practices, complacency can create a false sense of security. It is important to revisit the implications for the individual scenarios, and to flag any that could potentially be catastrophic if they were to occur (such as rapid erosion near critical facilities). Such effects warrant careful consideration of appropriate monitoring and responses. As shown in Figure 6, robust strategies are not the only ones that make sense in terms of policy selection. In many cases, the potentially negative results of climate change effects that appear in only one, two, or three of the outlined scenarios may nonetheless be serious enough to warrant hedging of bets.

Management actions and research needs identified by both work groups and common to all nested scenarios selected for this planning workshop are outlined below.

Common Implications

- Natural Resources (Physical): PDO phase, hydrological cycle
- Natural Resources (Biological): Wildlife shifts, increase fire, increase pest/disease, pond conversion to uplands
- Socio/Economics: Conservation of fish and wildlife for subsistence and recreation
- Access/transportation issues
- Facilities: Infrastructure risks, fire protection costs, increased facility maintenance costs
- Interpretation/Education: Audiences unaware of masking PDO, regulatory fish and wildlife bottlenecks (access, seasons, allocations), greater need for public appreciation of ecosystem services, maintaining relevant agency in-reach efforts
- Co-management of Bristol Bay region complicates and fragments subsistence lifestyle

Common No Regrets Actions

- Coordinating communication with other agencies
- Tune planning process to account for multiple possibility

- Need for seamless data sets
- Get missing players to the climate change scenario table at subsequent meetings and events
- Science outreach and education to multiple audiences

Discussion

The scenario planning process is not prescriptive; it does not set or determine policy. However, it does offer useful information for policymakers, land managers, and other stakeholders as they face the task of planning for an uncertain future.

The Southwest Alaska project began with the focal question, "How can NPS managers best preserve the natural and cultural resources and other values within their jurisdiction in the face of climate change?" Through the workshop process described in this report, not only was this question addressed, but so too was the broader question of protecting the natural and cultural landscape that includes three National Parks, a National Monument, and a Wild River.

Two important factors enriched and strengthened the process. First, the group that came together – first via teleconference and later in the workshop itself – represented a broad range of interests, experiences, and knowledge. Not only was NPS represented at the Park and regional level, but these experts were joined by modelers and climate researchers from SNAP; representatives of Alaska Native subsistence, and other local interests; representatives from nonprofit conservation organizations; and experts from other government agencies. Participants were engaged in the process, and contributed to the inputs, analysis, and outcomes. Second, although representation of uncertainty is built into the scenarios process – and is indeed integral to interpretation of the outputs – the analysis performed by workshop participants was based on the best available science. SNAP's maps, data, and tools offer cutting-edge climate science in formats that help stakeholders connect raw data to real landscape changes and pertinent environmental and human effects. Moreover, the maps created specifically for this project have uses and implications that extend beyond the limits of this project, since they are publicly available and have direct pertinence for stakeholders region-wide who are concerned about issues ranging from construction and development to ecological diversity, and human health and safety. (For all maps, including region-wide and park-specific maps, see Appendix E and http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Southwest_Alaska/.)

SNAP's website (www.snap.uaf.edu) offers further insights into the inherent uncertainties associated with climate modeling, including unknown future emissions rates of greenhouse gases; the complexity of creating and interpreting global circulation models (GCMs) that fully account for the distribution of heat and moisture via atmosphere and oceans; and the challenges of scaling down GCMs to the local level. Forecasts for precipitation are particularly challenging, because of the innate variability of rainfall and snowfall across fairly small-scale landscapes and short time periods. Given these uncertainties – but also given the existence of some clear trends and ongoing evidence of climate change – the scenarios process creates a unique way of exploring possible futures.

Because Alaska is such a geographically large and diverse state, spanning many cultures and many ecosystems, project outputs from climate change scenario planning workshops vary by region, although some recommended management actions may be applicable in all park networks. Holding these workshops on a regional basis proved an effective means of providing regional focus within a statewide framework.

Climate change impacts of particular concern in Southwestern Alaska, as identified via this process, include shifting wildlife populations, increased threat of fire and invasive pests and diseases, and drying of upland ponds. These changes threaten subsistence ways of life as well as NPS infrastructure. They hold the potential to drastically alter human experience for both visitors and locals, and are likely to complicate management choices, both inside and outside of National Parks.

As shown in Figure 3, the scenarios process is multi-step and iterative. The 2011 Southwest Alaska workshop took the process through the orienting, exploring, and synthesizing steps, and offered suggestions to promote or direct action. Near the end of the workshop process, participants referred back to the strategy-setting diagram provided by GBN (Figure 6). As outlined, the group assessed which management strategies and information needs were robust – common to all scenarios. However, discussion of strategies that offer ways to hedge bets or plan for uncertain but potentially catastrophic effects is also valuable, and should not be overlooked. An immediate "bet the farm" approach may be needed in places where severe effects from coastal erosion are a near certainty. "Wait and see" may be the preferable approach (and consistent with NPS policy) for dealing with range shifts in native species. Hedging might be the appropriate solution for exotic species: education, prevention, and control where the risks are high, while for low-risk species acceptance may be the best approach.

The climate change scenario planning process does not end with these workshops, reports, and presentations. Rather, these products are intended to stimulate creative thinking to address changing but still undetermined future environmental and socio-political future conditions. Post-workshop long-term monitoring and feedback to workshop outcomes are still necessary. Scenario planning is a learning process, and new or unexpected information can make it important to revisit or repeat the process. The planning steps should be refreshed periodically as important new information becomes available.

One of the most useful outcomes from this process can be the development of a suite of tools that can be used to communicate climate change impacts, choices, and potential outcomes to a wide range of stakeholders, including park staff, park visitors, administrators, Alaska Natives, schoolchildren, and the general public. Potential products include video productions, podcasts, interactive displays, posters, fact sheets, interactive web sites, and more.

In summary, park managers, park neighbors, and stakeholders can learn from the future by using the best available scientific information and climate projections and a thoughtful and creative group of stakeholders to create plausible, divergent, relevant, and challenging future climate change scenarios. These scenarios can help us all better prepare for uncertain future conditions in face of climate change.

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Appendix A: Participant Agenda

For videos and presentations from the workshop,
see http://www.nps.gov/akso/nature/climate/scenario.cfm

AK Regional Office, Anchorage, Room 309
February 22-25, 2011

Tuesday, February 22nd

12:30 pm		ARRIVAL and COFFEE
1:00 pm	Plenary (Bob W.) (John M.)	➢ Welcome: Include: building access/passes, restrooms, snacks, coffee, eateries, stipends, etc. ➢ Introductions & Participant Expectations ➢ Workshop Objectives, Agenda, Ground Rules
2:00 pm	Plenary (Don C.)	➢ Explain Scenario Planning
2:30 pm	Plenary (Don C.)	➢ Introduce the Focal Question(s) (*Address scale: park & bioregion)*
2:45 pm	Plenary (Nancy F.)	➢ Review process and pre-work in advance of workshop
3:00 pm		BREAK
3:15 pm	Plenary (Nancy F.)	➢ Present science information / overview o General insights o Climate drivers / uncertainties -> handouts o Potential impacts -> handouts
	Plenary (Nancy F.)	➢ How to create scenarios using uncertainties ➢ Drawing from drivers and impacts tables to build scenarios
4:00 pm	Groups (Don C./ John; Nancy F. & Nancy S.)	➢ Build scenario Frameworks: Breakout into 2 rooms (322 and 309) for Riverine systems and Coastal systems: *Identify key climate drivers that are relatively certain and those with "high uncertainty" but "high impact and importance" leading to challenging, plausible, relevant, and divergent futures*
5:00 pm	Bud or Don	ADJOURN for Day

Plenary session notes by Anna Schemper (UAF-SNAP)
Group breakout notes by Bud Rice and Don Weeks (NPS)

Wednesday, February 23rd

8:00 am		ARRIVAL and COFFEE
8:15 am 8:45 am	Plenary (Nancy S.) Groups	➢ Second thoughts and overnight insights ➢ Re-cap process (what we did and where we are going, including the next step to nest climate scenarios into a socio-political framework) ➢ Continue to build climate driver framework and scenarios *Select climate drivers and test matrix combinations. Draw from impacts table to detail implications for each scenario (natural resources, cultural resources, facilities, interpretation)*
10:00 am		BREAK
10:15 am 11:30 am	Groups Plenary (John M.)	➢ Build Climate Driver Framework and Scenarios (cont'd) ➢ Report-out: Groups share draft climate driver frameworks and resulting scenarios with each other
12:00 pm		LUNCH
1:00 pm 1:30 pm	Plenary (Don C.) Groups	➢ Describe Socio-Political Framework relevant to Alaska ➢ More fully explain nested scenarios ➢ Explore Socio-Political drivers and implications Combine "bioregional climate" and "socio-political" frameworks to select nested scenarios leading to challenging, plausible, relevant, and divergent futures. *Discuss all 4 scenarios within each quadrant for the socio-political framework. Select 3 to 4 nested futures to develop and build robust narratives for these scenarios.*
2:30 pm		BREAK
2:45 pm	Groups	➢ Continue building robust narratives and characters for the selected nested scenarios
4:00 pm	Groups	➢ Groups report out internally the process for climate driver selection and nested scenario selection and describe the selected nested climate futures (stories) and refine, as needed for report out in AM
5:00 pm	Plenary (Nancy S.)	FINAL THOUGHTS / QUESTIONS/ADJOURN for Day

Thursday, February 24th

8:00 am		ARRIVAL and COFFEE
8:15 am	Plenary (John M.)	➢ Groups re-cap selected scenarios and storylines (15 min each + discussion) *Groups share process for selecting 3-4 nested scenarios for challenging, plausible, relevant, and divergent futures*
9:00 am 9:30 am	Plenary (Jeff M.) Plenary (Jeff M. & John M.)	➢ Explain management implications & actions ➢ Presentation: From implications & actions to management decisions: various ways to use insights from scenarios; tips on communicating scenarios and formulating no regrets actions
10:00 am		BREAK
10:15 am	Groups	➢ Identify potential actions for each of 3-4 chosen nested scenarios.
12:00 pm		LUNCH
1:00 pm	Groups	➢ Develop findings and recommendations. *Focus on no-regrets actions that apply to all selected climate future, when possible.* Prepare for testing and scientific validation of scenarios, and consider the best way to communicate the issues.
3:00 pm		BREAK
3:15 pm	Groups	➢ Groups develop scenarios and storylines with actions and begin presentation preparation: Consider the overall messages and objectives.
5:00 pm	Plenary (Nancy F.)	FINAL THOUGHTS / QUESTIONS/ADJOURN for Day

Friday, February 25th

8:00 am		ARRIVAL and COFFEE
8:15 am	Plenary (Nancy F.)	➢ Groups report-out scenarios and storylines (15 min each scenario + discussion)
10:00 am		BREAK
10:15 am	Plenary (Don W.) (Bob W.) (Nancy F.) (John M.) (Jeff M.)	Next Steps: ➢ How do we use this work and where do we go with it? ➢ What actions apply to all scenarios => least regrets actions? ➢ Incorporate scenario planning into landscape-scale collaboration and adaptation (working with neighbors and across jurisdictions) ➢ Need for follow-up discussions/teleconferences to flesh out scenarios and actions and possibly up to 3 examples for each administrative unit ➢ Draft report from SNAP, web links and access to data ➢ Public Outreach and sharing CC scenarios within and outside NPS units. ➢ Final thoughts from Superintendents.
12:00 pm	(Bob W. or Bud R.)	FINAL THOUGHTS / THANKS/ ADJOURN

Appendix B: Workshop Participant List

Lead team

Bob Winfree	National Park Service, Alaska Regional Office, Regional Science Advisor
Bud Rice	National Park Service, Alaska Regional Office, Environmental Protection Specialist
Nancy Fresco	Scenarios Network for Alaska and Arctic Planning, Network Coordinator
Anna Schemper	Scenarios Network for Alaska and Arctic Planning, GIS Specialist
Don Weeks	National Park Service Natural Resource Program Center
Don Callaway	National Park Service, Alaska Regional Office, Senior Cultural Anthropologist
Jeff Mow	National Park Service, Park Superintendent, KEFJ
John Morris	National Park Service, Alaska Regional Office, Interpretive Specialist
Nancy Swanton	National Park Service, Alaska Regional Office, Subsistence, Planning

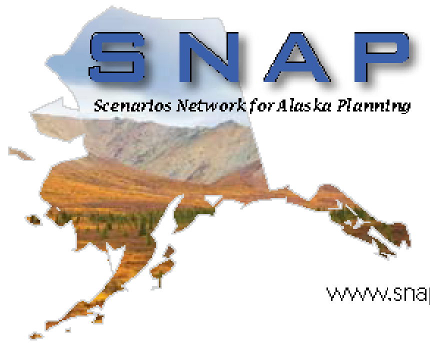
Participants

Randy Alvarez	Lake and Peninsula Borough Assembly, Community Leader, former Subsistence Council chairman, commercial fisherman
Ron Britton	US Fish & Wildlife Service, Wildlife Biologist, Migratory Birds
Kirk DeSermia	National Park Service, KEFJ, Facilities Manager
Brooke Edwards	Alaska Wildland Adventures, Program Director
Susan Flensburg	Bristol Bay Native Association, Environmental Manager
Charles Frost	Alaska SeaLife Center, Quantitative Ecologist
Troy Hamon	National Park Service, KATM, Natural Resource Manager
Joel Hard	National Park Service, LACL, Superintendent
Greg Hayward	US Department of Agriculture Forest Service, Regional Wildlife Ecologist
Fritz Klasner	National Park Service, KEFJ, Resource Manager
Mary McBurney	National Park Service, Subsistence Program Manager
Amy Miller	National Park Service, SWAN, Anchorage
Ralph Moore	National Park Service, KATM, Superintendent
John Morton	US Fish & Wildlife Service, Kenai NWR, Avian Ecologist
Daniel Noon	National Park Service, SWAN, Compliance & Planning
Liz O'Connell	Wondervisions, Videographer
Aaron Poe	US Department of Agriculture Forest Service, Chugach National Forest, Wildlife Biologist
Jim Pfeiffenberger	National Park Service, Ocean Alaska Science and Learning Center, Education Coordinator
Bill Schaff	US Fish & Wildlife Service, Refuge Manager
Jeff Shearer	National Park Service, SWAN, Program Manager
Michael Shephard	National Park Service, SWAN, Program Manager
Laura Sturz	National Park Service, KEFJ, Interpretive Operations Supervisor
David Ward	US Geological Survey, Wildlife Biologist, Migratory Birds

Appendix C: SNAP Tools for Planners

SNAP Climate Projections:

tools for planners



www.snap.uaf.edu

What are SNAP climate projections?

The Scenarios Network for Alaska Planning provides predictions of how average temperatures and precipitation may change in Alaska as a result of global climate change. Communities, businesses, and agencies work with SNAP to link these projections to ecological, social, and economic changes, and to plan for the future.

How are projections derived?

IPPC Global Climate Models

- The Intergovernmental Panel on Climate Change (IPCC) used fifteen different General Circulation Models (GCMs) when preparing its Fourth Assessment Report. Each model was created by a different nation or group using slightly different data and assumptions. Thus, models can be expected to perform with varying degrees of accuracy in any particular region. Accuracy can be checked by comparing model output for past years to actual climate data for the same time period.

Model Selection

- SNAP investigator Dr. John Walsh and colleagues analyzed how well each model predicted monthly mean values for three different climate variables (surface air temperature, precipitation, and sea level air pressure) over four overlapping northern regions (Alaska, Greenland, latitude 60-90°N an latitude 20-90°N) for the period from 1958–2000. They noted that models that performed well in one northern region tended to also perform well in others. SNAP climate models rely on output from the five models that provided the most accurate overall results.

Scaling down model results

- Results are scaled down to match local conditions using data from Alaskan weather stations and PRISM (Parameter-elevation Regressions on Independent Slopes Model), an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, and dew point.

Presentation of data

Data can be accessed via our website (www.snap.uaf.edu) as ASCII files for GIS, or as GoogleEarth maps. Data include mean monthly temperatures and precipitation, as well as derived values such as decadal means, thaw dates and growing season length. Data for 353 communities statewide are also available, in tabular form.

Time periods

SNAP offers climate projections from the present to the year 2099. We also have historical data derived from Climate Research Units and downscaled using PRISM. Data from 1980 onwards is available on our website.

Scale and resolution

Climate projections have been scaled down to 2km resolution. Thus, each pixel in a climate map represents a 4km² area.

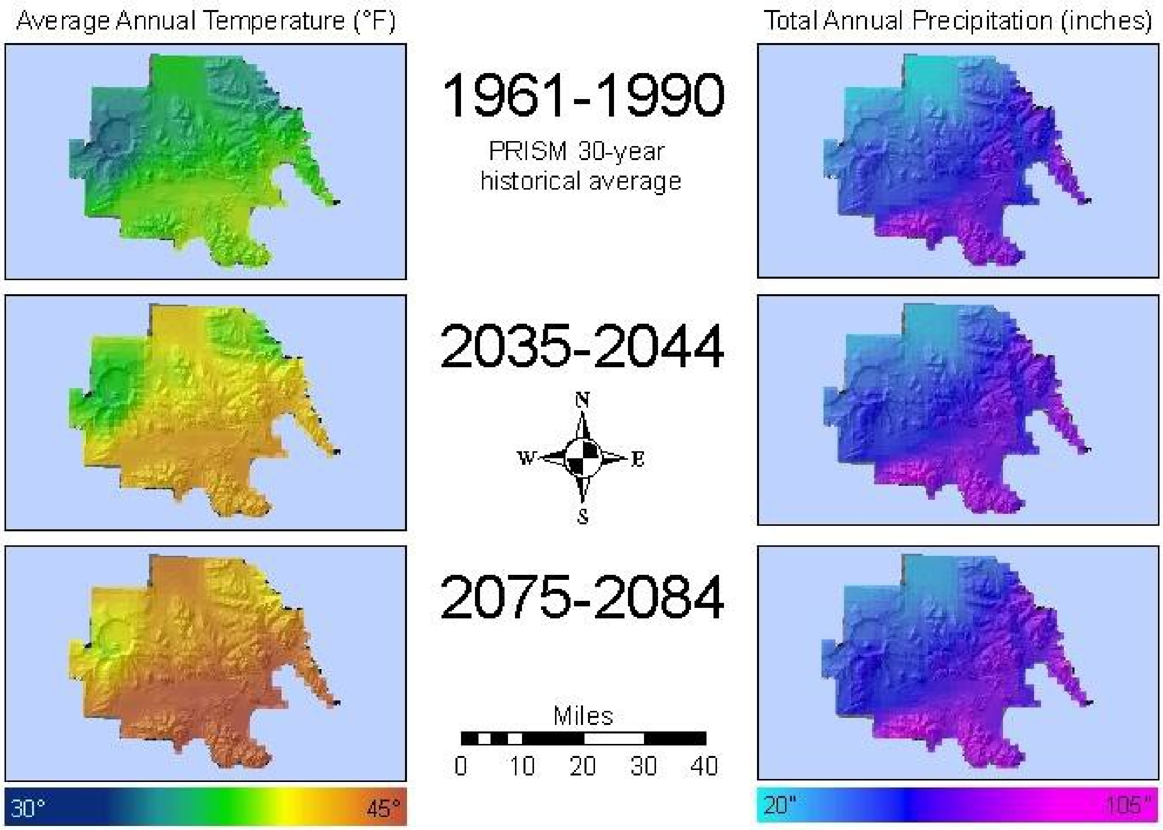
Linking climate to resources

Estimating future air temperature, rainfall, and snowfall are just the first steps towards planning for change. Stakeholders who want more detailed information can create collaborative agreements with SNAP in order to work on projects that link climate data to variables such as permafrost thaw; timing of autumn freeze-up and spring breakup; frequency of flooding events; sea level change; and changes in evapotranspiration. These changes can, in turn, be linked to factors of direct concern to communities and land planners, such as ecosystem shifts; forest fires; agricultural opportunities; risks to infrastructure; and movement of game animals.

for more information contact Network Coordinator Dr. Nancy Fresco:
nlfresco@alaska.edu • phone: 907-474-2405 • fax: 907-474-7151
University of Alaska Fairbanks, P.O. Box 757200, Fairbanks, AK 99775-7200

Appendix D: Climate Summary Reports

Projected climate change scenarios for Aniakchak National Monument and Preserve



Magnitude of climatic change

Projected Temperature (TEMP) Change (°F)				Projected Precipitation (PRCP) Change (in.)				
Season	Time	Avg. TEMP	Δ TEMP*	Season	Time	Total PRCP	Δ PRCP*	% Δ PRCP*
Annual	Hist	35.9 ± 0.6	NA	Annual	Hist	53.5 ± 5.4	NA	NA
	2040	40.1 ± 0.6	4.3		2040	59.1 ± 5.4	5.6	10%
	2080	43.1 ± 0.6	7.2		2080	61.8 ± 5.4	8.4	16%
Summer	Hist	47.5 ± 0.5	NA	Summer	Hist	21.4 ± 1.9	NA	NA
	2040	50.0 ± 0.5	2.5		2040	23.1 ± 1.9	1.6	8%
	2080	52.5 ± 0.5	5.0		2080	23.7 ± 1.9	2.2	10%
Winter	Hist	27.6 ± 0.7	NA	Winter	Hist	32.0 ± 3.5	NA	NA
	2040	33.1 ± 0.6	5.5		2040	36.0 ± 3.5	3.9	12%
	2080	36.3 ± 0.6	8.8		2080	38.2 ± 3.5	6.1	19%

* Δ PRCP/TEMP: change in decadal precipitation/temperature average from historic value

Climate Change Implications for Aniakchak National Monument & Preserve

Climate Change in Alaska

Many areas in Alaska are already showing signs of climate change. Scientists have reported observations of wetland drying, glacial and polar sea ice recession, spruce-bark beetle infestations, and an increase in fire frequency and intensity throughout the state. A better understanding of where and when such changes could continue to occur is needed to help decision makers identify how Alaska's ecosystems may respond in the future.

In order to understand what these changes may be like, data from a composite of five down-scaled global circulation models was used to estimate decadal averages of future temperature and precipitation values within the preserve. These models assume a steady increase in carbon dioxide (CO_2) emissions from fossil fuel combustion over the first several decades of the 21st century, followed by a gradual decline in emissions as several kinds of low-emission energy alternatives become more prevalent. This emissions regime is considered a "moderate" estimate[1]. Several other scenarios have predicted higher emission rates, and scientists have since determined current levels[2] are significantly greater than even the most extreme concentrations analyzed by the Intergovernmental Panel on Climate Change. Higher emissions rates will likely accelerate changes in climate and lead to more severe ecosystem impacts.

Temperature changes in Aniakchak National Monument & Preserve

Temperatures are projected to increase over the coming decades at an average rate of about 1°F per decade. Average annual temperature is expected to rise by about 4°F by 2040 and as much as 7°F by 2080.

Considering the natural variation in temperatures across the study area, this is likely to result in a transition from average annual temperatures near the freezing point (~36°F), to temperatures well above the freezing point (~43°F).

A likely outcome of these changes is a lengthening of the growing season, a change that could have profound affects on wildlife mating cycles, plant growth and flowering, water availability in soil and rivers, and hunting and fishing.

Winter temperatures are projected to change the most dramatically. Mean winter temperatures could reach a high of 36°F by 2080, a figure that represents more than an 8°F rise from the historical 28°F average. Average summer temperatures are projected to rise by almost 5°F by 2080 (from ~47°F to ~52°F). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their populations.

Precipitation changes in Aniakchak National Monument & Preserve

Precipitation is predicted to increase across the study area. Despite this area-wide increase, conditions are expected to become substantially drier in the summer and fall and potentially icier in winter. Although summer rainfall is expected to rise by 10%, this increase is unlikely to be enough to offset an increase in evapotranspiration caused by warmer temperatures and a longer growing season. Winter precipitation may increase by as much as 19% and could fall in the form of snow, ice, or rain, depending on the temperature. Ultimately, the timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of the Preserve.

Summary of findings

Aniakchak National Monument & Preserve is projected to become warmer and drier over the next century. Warmer temperatures and a longer growing season are expected to increase evapotranspiration enough to outweigh a regional increase in precipitation. Seasonal changes in climate will have profound impacts on the condition and health of wildlife habitat, lead to increased fire risk, and contribute to the likelihood of wetlands, steams, and lakes drying.

It is important to note that predicting changes in environmental variables is difficult, especially in Alaska where historical climate monitoring data is sparse. Increasing the scope of precipitation, temperature, and ecological monitoring throughout Alaska is one of the best strategies for improving our understanding of changes in climate and the response of ecosystems.

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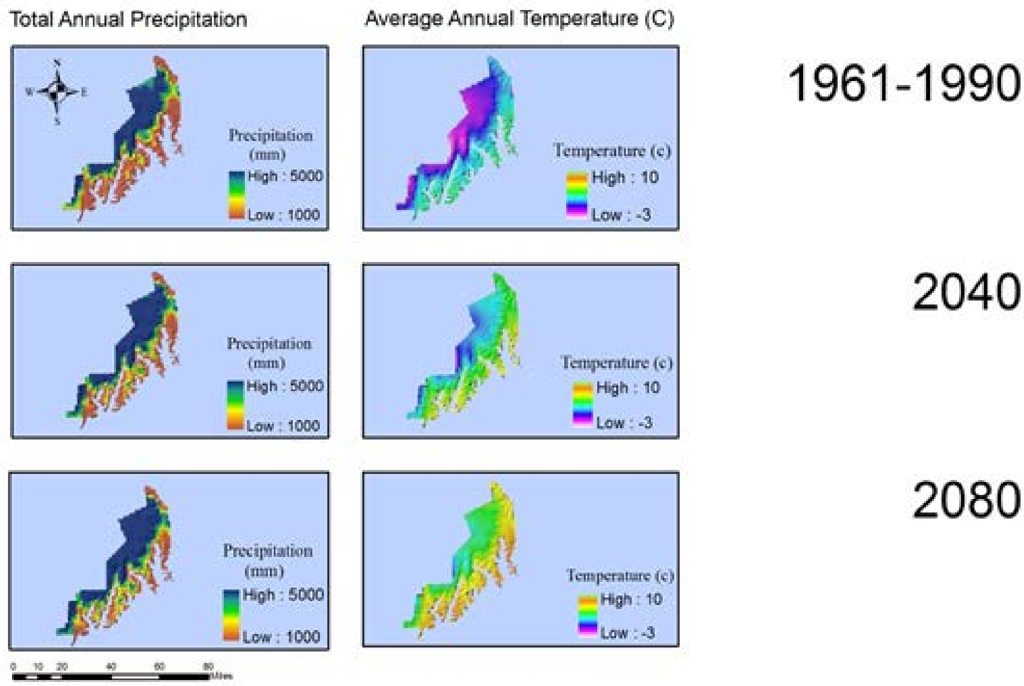
[1] *This emissions outlook is the "A1B" scenario from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1.*

[2] *Recent rates of global CO_2 emissions can be found on the Carbon Dioxide Information Analysis Center website (www.cdiac.esd.ornl.gov).*

Projected climate change patterns in Kenai Fjords NP



Magnitude of climatic change

Season	Time	Total PRC (mm)	Δ PRC	% Δ PRC	Season	Time	Avg Tmp (°C)	Δ Tmp
Winter	Hist.	1711	NA	NA	Winter	Hist.	-3.8	NA
	2040	1823	112	6.5%		2040	-0.9	2.9
	2080	1897	186	10.8%		2080	0.9	4.8
Summer	Hist.	923	NA	NA	Summer	Hist.	8.6	NA
	2040	990	67	7.2%		2040	10.0	1.4
	2080	1013	90	9.7%		2080	11.7	3.1
Annual	Hist.	2635	NA	NA	Annual	Hist.	1.4	NA
	2040	2813	179	6.8%		2040	3.6	2.3
	2080	2910	276	10.5%		2080	5.4	4.1

Climate Change Implications for Kenai Fjords National Park

THE WILDERNESS SOCIETY

SNAP

Climate Change and Alaska

Many areas in Alaska are already showing signs of climate change impacts, including wetland drying, spruce-bark beetle infestations, and increased fire frequency and intensity. A better understanding of how the land will respond to future changes is needed to help decision makers identify where and when changes are likely to occur.

In order to understand what these changes might be, we combined data from five down-scaled global climate models to estimate how temperature and precipitation values might change within Alaskan public lands in the near future. The models assumed steady increases in CO_2 emissions from oil and gas for the first several decades of the 21st century, followed by a gradual decline in emissions as several kinds of low-emission alternative energies come into use. This emissions scenario is considered moderate, with other models predicting much greater emissions levels, and thus impacts[1]. Here, we describe the projected changes in Kenai Fjords National Park and Preserve. Similar data exist for all parts of Alaska, and are available through the Scenarios Network for Alaska Planning (SNAP) at the University of Alaska, Fairbanks.

Temperature changes in Kenai Fjords NP

Temperatures in the park are projected to increase over the next few decades, averaging 0.5°c per decade. This translates into a rise in average annual temperature of 2.3°c by 2040 and 4.1°c by 2080.

Considering the natural variation in temperatures across the area, this increase is likely to result in a transition from average annual temperatures near freezing (1.4°c) to above freezing (3.6°c) by 2040 and well above freezing (5.4°c) by 2080.

A likely outcome of these processes is an increase in time between the first freeze and first thaw dates. This, in turn, could affect wildlife mating cycles, plant growth and flowering, hunting seasons, and water availability in the soil and rivers.

Seasonal changes

Winter temperatures (Oct. – Apr.) are projected to change the most, increasing by as much as 4.8°c by 2080, which would raise the mean winter temperature from a historical -3.8°c to 0.9°c. Summer temperatures (May – Sep.) are projected to rise by 3.1°c on average by 2080 (from 8.6°c to 11.7°c). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their population.

Precipitation changes in Kenai Fjords NP

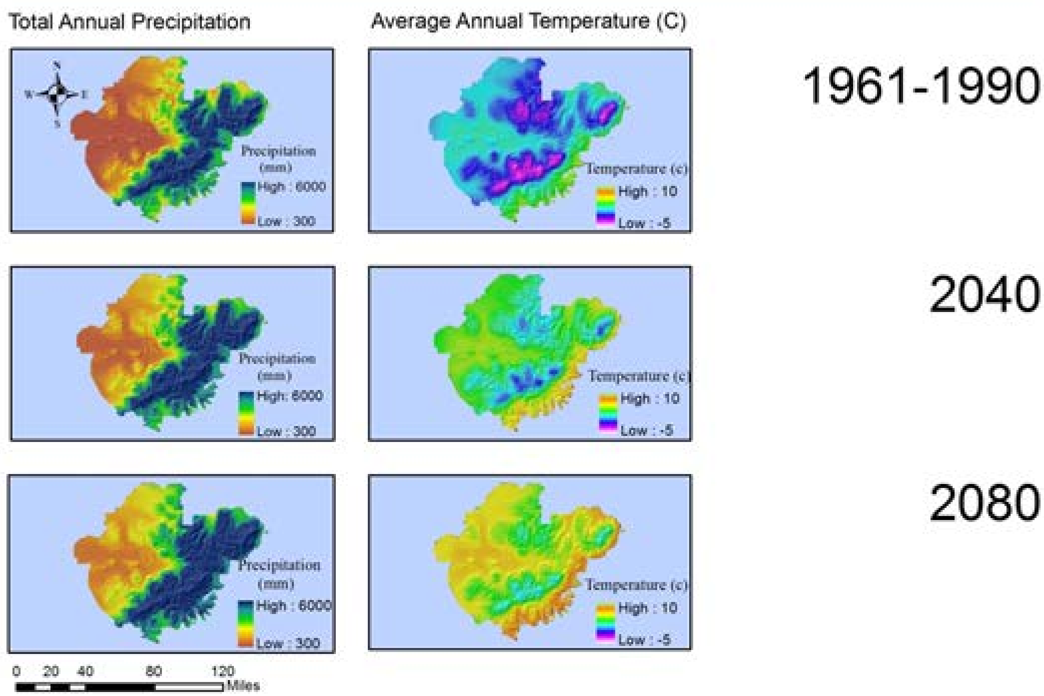
Precipitation is predicted to increase across the park, with 11% more snowfall in the winter and about 10% more rain in the growing season. The timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of the region.

Despite predicted increases in precipitation, conditions are expected to become drier in the summer and fall due to warmer temperatures and, most likely, a longer growing season--conditions which increase evapotranspiration.

It is important to note that predicting changes in precipitation is difficult. Increased monitoring of precipitation, temperature and stream flow within the Park would help managers better understand changes in climate and plan for the future with these changes in mind.

[1] *The emissions outlook is "A1B" scenario from the International Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1.*

Projected climate change patterns in Katmai NPP



Magnitude of climatic change

Season	Time	Total PRC (mm)	Δ PRC	% Δ PRC	Season	Time	Avg Tmp (°C)	Δ Tmp
Winter	Hist.	741	NA	NA	**Winter**	Hist.	-4.9	NA
	2040	848	107	14.5%		2040	-1.5	3.4
	2080	931	189	25.6%		2080	0.6	5.5
Summer	Hist.	600	NA	NA	**Summer**	Hist.	8.7	NA
	2040	657	58	9.6%		2040	10.1	1.4
	2080	671	71	11.9%		2080	11.8	3.0
Annual	Hist.	1341	NA	NA	**Annual**	Hist.	0.8	NA
	2040	1506	165	12.3%		2040	3.4	2.6
	2080	1602	261	19.4%		2080	5.3	4.5

Climate Change Implications for Katmai National Park & Preserve

Climate Change and Alaska

Many areas in Alaska are already showing signs of climate change impacts, including wetland drying, sprucebark beetle infestations, and increased fire frequency and intensity. A better understanding of how the land will respond to future changes is needed to help decision makers identify where and when changes are likely to occur.

In order to understand what these changes might be, we combined data from five downscaled global climate models to estimate how temperature and precipitation values might change within Alaskan public lands in the near future. The models assumed steady increases in CO_2 emissions from oil and gas for the first several decades of the 21st century, followed by a gradual decline in emissions as several kinds of lowemission alternative energies come into use. This emissions scenario is considered moderate, with other models predicting much greater emissions levels, and thus impacts[1]. Here, we describe the projected changes in Katmai National Park and Preserve. Similar data exist for all parts of Alaska, and are available through the Scenarios Network for Alaska Planning (SNAP) at the University of Alaska, Fairbanks.

Temperature changes in Katmai NPP

Temperatures in the park are projected to increase over the next few decades, averaging 0.6°c per decade. This translates into a rise in average annual temperature of 2.6°c by 2040 and 4.5°c by 2080.

Considering the natural variation in temperatures across the area, this increase is likely to result in a transition from average annual temperatures near freezing (0.8°c) to above freezing (3.4°c) by 2040 and well above freezing (5.3°c) by 2080.

A likely outcome of these processes is an increase in time between the first freeze and first thaw dates. This, in turn, could affect wildlife mating cycles, plant growth and flowering, hunting seasons, and water availability in the soil and rivers.

Seasonal changes

Winter temperatures (Oct. – Apr.) are projected to change the most, increasing by as much as 5.5°c by 2080, which would raise the mean winter temperature from a historical 4.9°c to 0.6°c. Summer temperatures (May – Sep.) are projected to rise by 3°c on average by 2080 (from 8.7°c to 11.8°c). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their population.

Precipitation changes in Katmai NPP

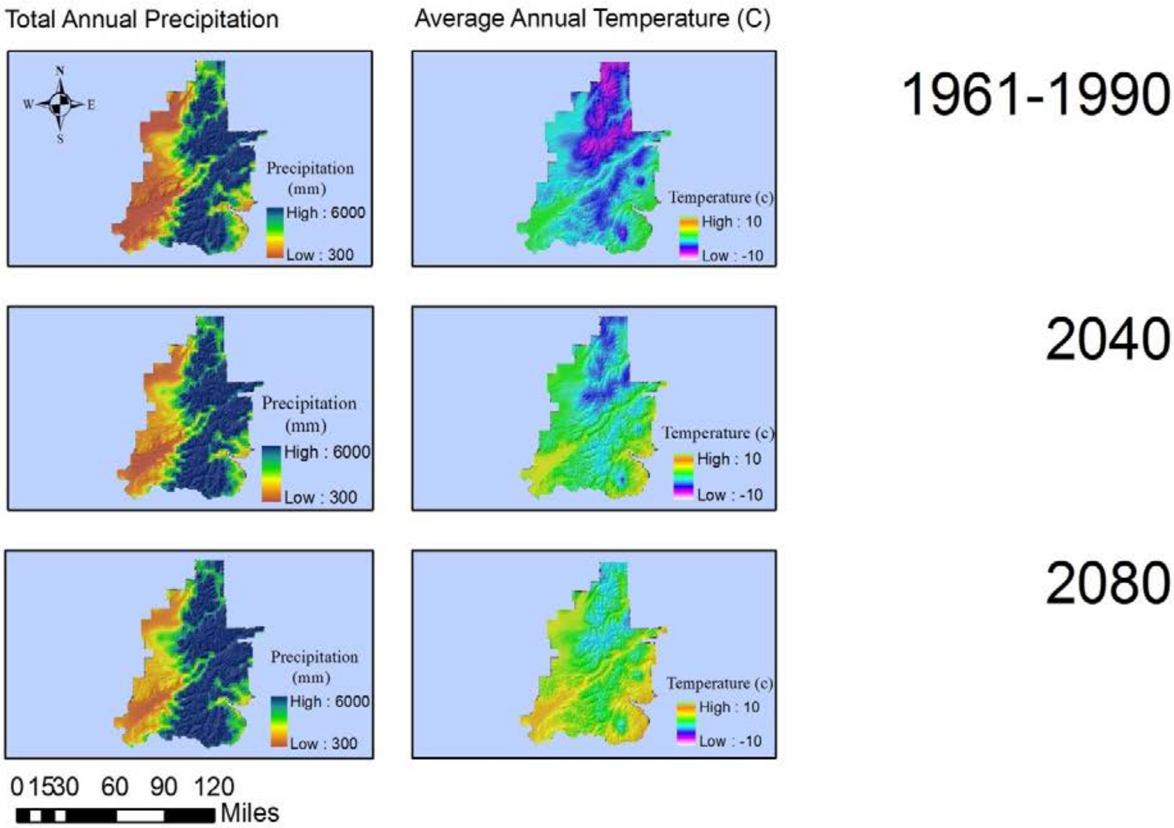
Precipitation is predicted to increase across the park, with 26% more snowfall in the winter and about 12% more rain in the growing season. The timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of the region.

Despite predicted increases in precipitation, conditions are expected to become substantially drier in the summer and fall due to warmer temperatures and, most likely, a longer growing seasonconditions which increase evapotranspiration. Growing season precipitation would likely have to double from historical levels to maintain current moisture conditions. Without this precipitation, lands and rivers are likely to become drier, increasing the risk of fire and of wetlands, lakes and streams drying.

It is important to note that predicting changes in precipitation is difficult. Increased monitoring of precipitation, temperature and stream flow within the Park would help managers better understand changes in climate and plan for the future with these changes in mind.

The emissions outlook is "A1B" scenario from the International Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1.

Projected climate change patterns in Lake Clark NP



Magnitude of climatic change

Season	Time	Total PRC (mm)	Δ PRC	% Δ PRC	Season	Time	Avg Tmp (^oC)	Δ Tmp
Winter	Hist.	868	NA	NA	**Winter**	Hist.	-9.2	NA
	2040	959	90	10.4%		2040	-5.8	3.4
	2080	1039	171	19.6%		2080	-3.7	5.4
Summer	Hist.	785	NA	NA	**Summer**	Hist.	7.4	NA
	2040	850	65	8.3%		2040	8.9	1.4
	2080	869	84	10.8%		2080	10.6	3.1
Annual	Hist.	1653	NA	NA	**Annual**	Hist.	-2.2	NA
	2040	1809	155	9.4%		2040	0.3	2.6
	2080	1909	255	15.4%		2080	2.2	4.5

Climate Change Implications for Lake Clark National Park

THE WILDERNESS SOCIETY

SNAP Scenarios Network for Alaska Planning

Climate Change and Alaska

Many areas in Alaska are already showing signs of climate change impacts, including wetland drying, spruce-bark beetle infestations, and increased fire frequency and intensity. A better understanding of how the land will respond to future changes is needed to help decision makers identify where and when changes are likely to occur.

In order to understand what these changes might be, we combined data from five down-scaled global climate models to estimate how temperature and precipitation values might change within Alaskan public lands in the near future. The models assumed steady increases in CO_2 emissions from oil and gas for the first several decades of the 21st century, followed by a gradual decline in emissions as several kinds of low-emission alternative energies come into use. This emissions scenario is considered moderate, with other models predicting much greater emissions levels, and thus impacts[1]. Here, we describe the projected changes in Lake Clark National Park. Similar data exist for all parts of Alaska, and are available through the Scenarios Network for Alaska Planning (SNAP) at the University of Alaska, Fairbanks.

Temperature changes in Lake Clark NP

Temperatures in the park are projected to increase over the next few decades, averaging 0.56°c per decade. This translates into a rise in average annual temperature of 2.6°c by 2040 and 4.5°c by 2080.

Considering the natural variation in temperatures across the area, this increase is likely to result in a transition from average annual temperatures below freezing (-2.3°c) to near or above freezing (0.3°c) by 2040 and well beyond freezing (2.2°c) by 2080.

A likely outcome of these processes is an increase in time between the first freeze and first thaw dates. This, in turn, could affect wildlife mating cycles, plant growth and flowering, hunting seasons, and water availability in the soil and rivers.

Seasonal changes

Winter temperatures (Oct. – Apr.) are projected to change the most, increasing by as much as 5.4°c by 2080, which would raise the mean winter temperature from a historical -9.2°c to -3.7°c. Summer temperatures (May – Sep.) are projected to rise by 3.13°c on average by 2080 (from 7.45°c to 10.58°c). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their population.

Precipitation changes in Lake Clark NP

Precipitation is predicted to increase across the park, with 20% more snowfall in the winter and about 11% more rain in the growing season. The timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of the region.

Despite predicted increases in precipitation, conditions are expected to become substantially drier in the summer and fall due to warmer temperatures and, most likely, a longer growing season--conditions which increase evapotranspiration. Growing season precipitation would likely have to double from historical levels to maintain current moisture conditions. Without this precipitation, lands and rivers are likely to become drier, increasing the risk of fire and of wetlands, lakes and streams drying.

It is important to note that predicting changes in precipitation is difficult. Increased monitoring of precipitation, temperature and stream flow within the Park would help managers better understand changes in climate and plan for the future with these changes in mind.

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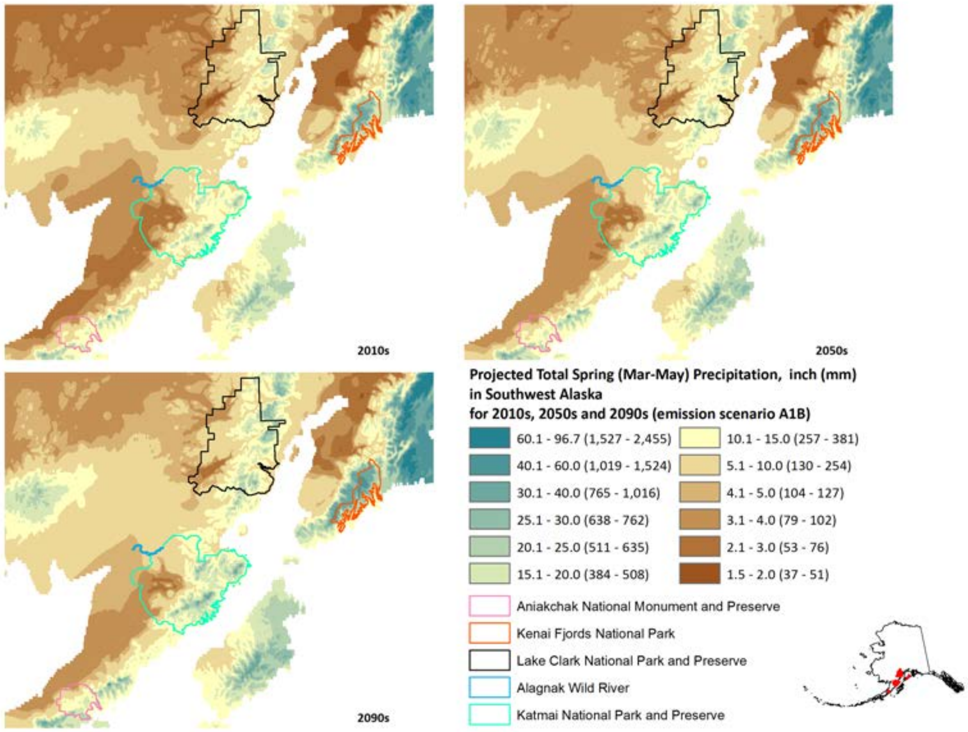
[1] *The emissions outlook is "A1B" scenario from the International Panel on Climate Change (IPCC) Fourth Assessment, published in 2007. The models used in this analysis included Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1.*

Appendix E: Southwest Alaska Modeled Climate Variables

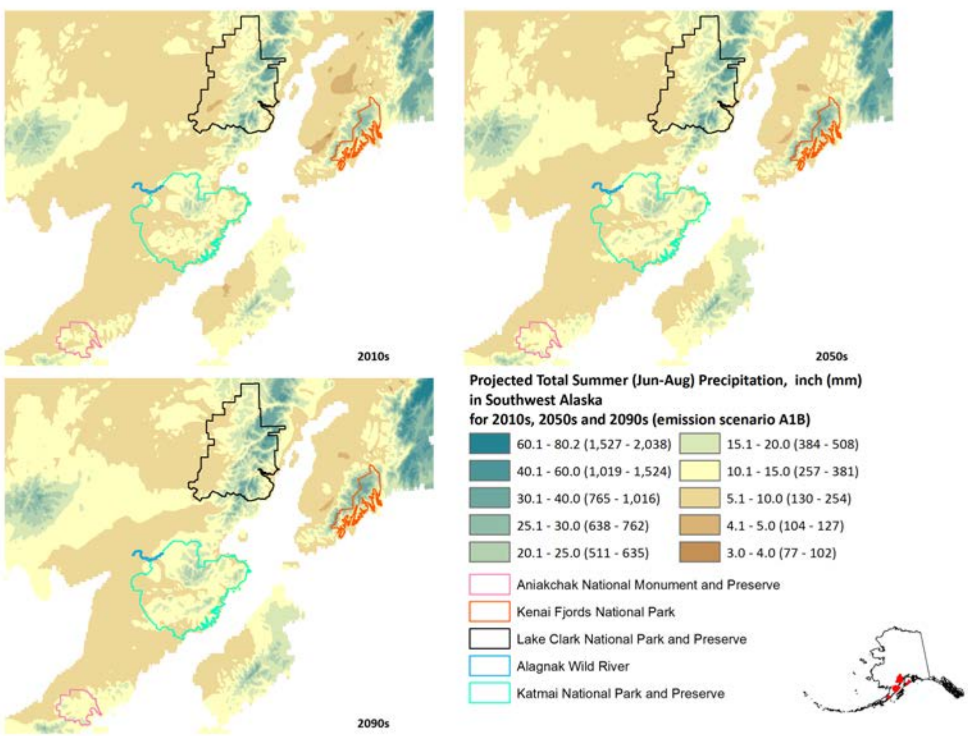
The set of maps included in this appendix were produced by SNAP. All maps represent projected data averaged across five downscaled GCMs and additionally averaged across decades (the 2010s, 2050s, and 2090s), in order to represent long-term trends. For a full description of SNAPs methods, see www.snap.uaf.edu.

Maps included in this set include seasonal maps (three-month averages) for precipitation, as well as several temperature-linked maps, including projections for date of freeze, date of thaw, length of summer season, and ground temperature at once meter depth.

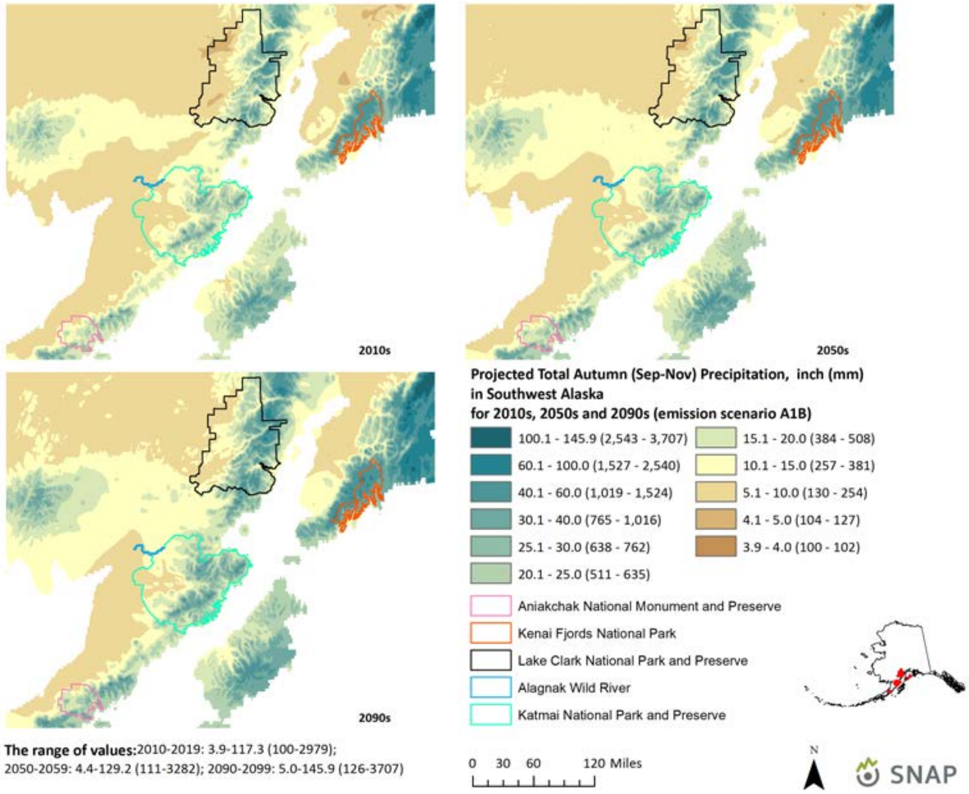
These maps show all Arctic Network Parks. They rely on a midrange (A1B) emissions scenario, as defined by the IPCC. For maps of individual parks, as well as maps depicting the more severe A2 climate change scenario, see http://www.snap.uaf.edu/webshared/NPS-CCSP/2011_Southwest_Alaska

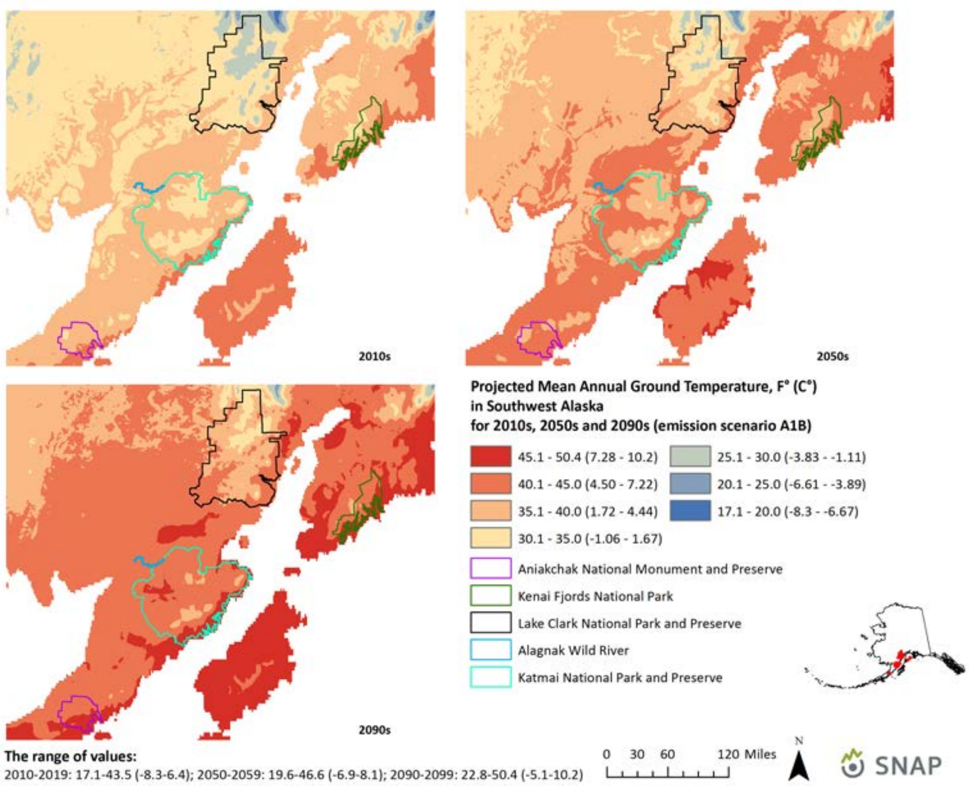


The range of values: 2010-2019: 1.5-81.0 (37-2058); 2050-2059: 1.6-87.2 (41-2216); 2090-2099: 1.8-96.7 (46-2455)



The range of values: 2010-2019: 3.0-67.8 (77-1723); 2050-2059: 3.5-76.5 (88-1942); 2090-2099: 53.6-80.2 (91-2038)


2010s
2050s
2090s
Projected Total Autumn (Sep-Nov) Precipitation, inch (mm)
in Southwest Alaska
for 2010s, 2050s and 2090s (emission scenario A1B)
100.1 - 145.9 (2,543 - 3,707)
60.1 - 100.0 (1,527 - 2,540)
40.1 - 60.0 (1,019 - 1,524)
30.1 - 40.0 (765 - 1,016)
25.1 - 30.0 (638 - 762)
20.1 - 25.0 (511 - 635)
15.1 - 20.0 (384 - 508)
10.1 - 15.0 (257 - 381)
5.1 - 10.0 (130 - 254)
4.1 - 5.0 (104 - 127)
3.9 - 4.0 (100 - 102)
Aniakchak National Monument and Preserve
Kenai Fjords National Park
Lake Clark National Park and Preserve
Alagnak Wild River
Katmai National Park and Preserve
The range of values: 2010-2019: 3.9-117.3 (100-2979);
2050-2059: 4.4-129.2 (111-3282); 2090-2099: 5.0-145.9 (126-3707)
0 30 60 120 Miles
N
SNAP


2010s
2050s
2090s
Projected Mean Annual Ground Temperature, F° (C°)
in Southwest Alaska
for 2010s, 2050s and 2090s (emission scenario A1B)
45.1 - 50.4 (7.28 - 10.2)
40.1 - 45.0 (4.50 - 7.22)
35.1 - 40.0 (1.72 - 4.44)
30.1 - 35.0 (-1.06 - 1.67)
25.1 - 30.0 (-3.83 - -1.11)
20.1 - 25.0 (-6.61 - -3.89)
17.1 - 20.0 (-8.3 - -6.67)
Aniakchak National Monument and Preserve
Kenai Fjords National Park
Lake Clark National Park and Preserve
Alagnak Wild River
Katmai National Park and Preserve
The range of values:
2010-2019: 17.1-43.5 (-8.3-6.4); 2050-2059: 19.6-46.6 (-6.9-8.1); 2090-2099: 22.8-50.4 (-5.1-10.2)
0 30 60 120 Miles
N
SNAP

Appendix F: Climate Drivers Table

Southwestern Park Units Climate Drivers						
Climate Variable	**General Change**	**Specific Change by 2050**	**Specific Change by 2100**	**Patterns of Change**	**Confidence**	**Source**
Temperature	Increase	+2°C ±1.5°C	+4°C ±2°	More pronounced in north and in autumn-winter	>95% of increase	IPCC (2007) and SNAP/UAF
Rain and snow (precip-itation)	Increased snowfall during winter, but shorter snow season	Winter snowfall	Winter snowfall	Increased % of precipitation that falls as rain. Mean winter temps above freezing for large areas.	High uncertainty in timing of snowmelt	AMAP/ SWIPA (Snow, Water, Ice, Permafrost in the Arctic, 2011); SNAP/UAF
Freeze-up date	Later in autumn, or not at all	5-10 days	10-20 days	Large increase in areas that rarely freeze, particularly along coastlines	>90%	SNAP/UAF
Length of ice-free season for rivers, lakes	Increase	7-10 days	14-21 days	Largest change near coasts where sea ice retreats or does not form	>90%	IPCC (2007); SNAP/UAF
River and stream temp-eratures	Increase	1-3°C	2-4°C	Consistent with earlier breakup or lack of ice formation, and higher summer temperatures	>90%	Kyle and Brabets (2001)
Length of growing season	Increase	10-20 days	20-40 days	Largest near coasts	>90%	IPCC (2007); SNAP (2011)
Sea level	Increase	3-24 inches	7-72 inches	Large uncertainties, especially at upper end of range	>90% chance of increase	IPCC (2007)

Southwestern Park Units Climate Drivers						
Climate Variable	**General Change**	**Specific Change by 2050**	**Specific Change by 2100**	**Patterns of Change**	**Confidence**	**Source**
Water availablility (soil moisture during growing season, as measured by precip minus potential ET)	Decrease	decrease of 0-20+%	decrease of 10-40+%	Most profound changes in areas where sub-freezing temperatures have historically limited PET. Much uncertainty regarding role of winter water storage and spring runoff	>90%; varies by region	SNAP (2011) and The Wilderness Society
Relative Humidity	Little change	0% ±10% increase or decrease	0%±15% increase or decrease	Absolute humidity increases	50% = *about as likely as not*	SNAP (2011)
Wind Speed	Increase		4% ±8%	More pronounced in winter and spring	>90% chance of increase	Abatzoglou and Brown (2011)
Pacific Decadal Oscillation (PDO)	Atmospheric circulation anomalies affect Alaska's climate	Unknown	Unknown	Major effect on Alaskan temperatures in cold season	High degree of natural variation	Hartmann and Wendler (2005)
Extreme Events: Temp-erature	More warm events Fewer cold events	3-6 times more warm events; 1/5-1/3 of present cold events	5-8.5 times more warm events; 1/12-1/8 of present cold events	Increase in frequency and length of extreme hot events (summer); Decrease in extreme cold events (winter)	Modeled and observed >95% *likely*	Abatzoglou and Brown (2011); Timlin and Walsh, 2007)
Extreme Events: Precipitation	Decrease/ Increase	change of -20% to +50%	change of -20% to +50%	Increase in frequency and contribution especially in winter. Decreases in spring.	Modeled and observed *Uncertain*	Abatzoglou and Brown (2011)
Extreme Events: Storms	Increase	Increase in frequency and intensity	Increase in frequency and intensity		>66% *Likely*	Field et al. (2007) IPCC Working Group 2 AR41

Climate Drivers Table Citations

Abatzoglou, J.T., and T.J. Brown. 2011. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology* 32 (5): 772-780.

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Appendix G: Ranked Climate Effects Table

The table below outlines some of the possible effects of climate change in Northwest Alaska. These effects are drawn from model data, expert observations, and the existing literature, and were one of the primary references during upcoming workshop. Prior to the workshop, participants were invited to take some time to read through this table and fill it out, indicating the level of importance (high, medium, or low) they would assign to each of these impacts, based on their own knowledge and experience. Workshop participants were also invited to use the comments section to clarify responses and/or indicate which parks/regions would be impacted.

Sector	Subsector	Potential Effects to Resources, Operations, and People	Affected Arctic Alaska Parks					Notes
			KEFJ	LACL	KATM	ANIA	ALAG	
Atmosphere	Greenhouse gases	**Shrub expansion into tundra, new vegetation in deglaciated areas, and increased woody vegetation overall sequesters carbon.**	H	H	MHH	LMM	MMM	Bud: Shrub expansion due to deglaciation is important for KEFJ, LACL, but less so for KATM (although somewhat) and ANIA. Troy: we do have a lot of shrub expansion throughout our unit. More extensive in KATM, but we have a lot of ash blows (?), especially in ANIA
	Air temperature	**Air temperature increases** at an average rate of 1°F (0.56°C) per decade for national parks in Alaska. Warming is especially pronounced for the northernmost parks and during the historically coldest times of the year.	MH	M	MHH	LHH	MHH	Jeff-- High for KEFJ. Bud: an increasing probability for these parks… less so for ANIA
		Average annual temperatures shift from below freezing to above freezing in several parks (BELA, DENA, YUCH), changing the freeze/thaw balance.	ML	M	MHH	LMM	MMM	
	Precipitation	**Average annual precipitation increases in all NPS areas in Alaska** through the mid- to late-21st Century. Relative proportions of moisture deposited as snow, ice or rain change as temperature increases.	H	H	M/HH MM	MHM M	M/HH MM	
		Many areas will experience drying conditions despite increased precipitation, due to higher temperature and increased rates of evapotranspiration.	MH	H	MMM	LLL	MLL	
		More freezing rain events affect foraging success and survival of wildlife, travel safety, and utility transmission.	H	H	MHLL	MHLL	MHLL	
		Avalanche hazards increase in some areas with rising precipitation and rising winter temperatures.	H	H	MLL	LLL	LLL	
	Stormy weather	**Lightning and lightning-ignited fires continue to increase.**	LM	M	MMM	LLL	MLL	Bud: lightning, low, except for northern part of LACL. Jeff:(?)--Here in seward, have seen winter storm events that are larger than previously observed.
		Storm and wave impacts	ML	M	MLL	MLL	LLL	
	Air quality	**More smoke from longer and more intense fire** seasons results in seasonal and locally-severe smoke events, with respiratory and other associated health risks to populations.	M	M	LMM	LLL	LMM	Bud: Smoke from longer and more intense fire seasons in more northern parts of these parks
Cryosphere	Ice/Snow	**Snow and ice season is shorter with later onset of freeze-up and snowfalls and earlier spring snowmelt and ice breakup in Alaska.**	H	H	MHH	MHH	M MM	Jeff: Ice and snow: increased frequency of midwinter thaws should be mentioned here. Increased mid-winter thaws
		Most glaciers diminish as warming continues.	H	H	HHH	LLL	LLL	Bud: Glaciers diminishing—high, except for ANIA and KATM. Jeff: glacial outburst and glacial dam bursts—definitely yes at KEFJ. Daniel/Troy: we don't have a lot of glacier mass, but we do have very tiny hanging glacier, also have glaciers in KATM: our biggest thing is that the way this is phrased ('impact to the park"), we were looking at impacts of change
		Glacial outwash (silt, sand, gravel) accumulates as glaciers melt, affecting aquatic productivity in both positive and negative ways and forming deposits that can complicate shallow water navigation.	H	H	MLL	LLL	LLL	
		Glacial lakes and glacially dammed lakes fail with increasing but still unpredictable frequency, putting park staff, residents, and visitors at risk of flash floods and debris flows.	H	H	MLL	LLL	LLL	
		Undiscovered cultural resources are exposed as perennial snow and ice patches melt and recede.	LM	H	LMM	LMM	LLL	A bit in LACL, but more in Wrangells
Hydrosphere		**Falling global phytoplankton concentration could reduce ocean productivity and CO_2 sequestration.** Phytoplankton has declined at a average rate of ~1% of the global average per year over the last century. These fluctuations are strongly correlated with climate indices and sea surface temperature.	MH	M	MLL	LLL	LLL	
		Freshwater influx from thawing glaciers dilutes marine waters, lowering salinity, calcium saturation, and pH, and stressing sensitive zooplankton, corals, mollusk s and other species in some areas.	M/H	L	L/MLL	LLL	LLL	
		Toxic marine algae and shellfish poisoning affects humans and marine mammals (e.g., PSP, ASP). Outbreaks are attributed to seasonal changes in coastal water temperature, nutrient enrichment, salinity, and ballast water discharge.	H	H	HLL	HLL	LLL	
		Ocean acidification affects plankton and benthic calcifying fauna (e.g., bivalves and echinoderms) in the Arctic more strongly than at lower latitudes, affecting food sources of fish, marine mammals such as walrus and gray whales, plankton feeding birds, and potentially the composition of the ecosystem.	H	M/H	M/HM M	MMM	LLL	high for all of us in the long term
		Ocean acidification reduces sound absorption. Based on current projections of future pH values for the oceans, a decrease in sound absorption of 40% is expected by mid-century.	MH	L	MLL	LLL	LLL	
	Estuarine	**Coastal erosion and sea level rise increase the frequency of saltwater flooding in some coastal areas**, infiltrating freshwater coastal lagoons, marshes, and groundwater with salt.	M	M	MLL	MLL	LLL	Bud: LACL, KEFJ, KATM, ANIA, but not as big as in the arctic regions (coastal erosion and sea level rise).. Jeff: medium or low for shallow water areas to convert to terrestrial ecosystems
	Freshwater	**Stream flows from by melting glaciers increase and then decrease over time.** As glaciers are diminished in extent, the quantity of water they store is also greatly reduced. Even if annual precipitation remains constant, seasonal flows are likely to change substantially.	H	H	M/HHH	LLL	LLL	Troy: seasonal stream flows from melting glaciers: high impact to KATM. One of the major impacts he foresees is that we may never have mid summer water levels high enough to operate the vessel that serves Brooks Camp.
	Groundwater	**Ground water supplies that depend on seasonal glacial recharge become less predictable.**	MH	M	L/MLL	LLL	LLL	Jeff: for KEFJ, issue is confounded by uncertainty of whether this is related to subsidence/tectonics, or glacial issues (ground water recharge).

		Large and small tsunamis could result from collapse of unstable slopes in fjords (e.g., glacial moraine and sediment deposits, both above and below water). Earthquakes have previously triggered slope collapse and tsunami events in Alaska.	H	L	MLL	LLL	LLL	Bud: KEFJ definitely has potential of large/small tsunamis.
	Soil	**Soil moisture declines** due to rising soil temperature, increased evapotranspiration, thawing permafrost, and natural drainage.	L	M	LLL	LMM	LLL	
	Rock and gravel	**Demand for rubble and rock increases**, as it is required for repairs and new construction, roads, and community relocation.	MH	L	MLL	LLL	LLL	
Biosphere	General	**Ecological "tipping points" are likely to result in rapid change**, when conditions exceed physical or physiological thresholds (e.g., thaw, drought, water temperature).	H		MM	LL	LL	Jeff: PDO and its ability to exacerbate or dampen impact of climate change fit in this general biosphere category. Troy: KATM is at center of this w/ permafrost. We view conversion of permafrost to non permafrost as contributing to major change. Bob: black spruce is often found on permafrost.
	Vegetation	**Increased growing season length.** Modeling predicts that the mean number of frost free days for the Boreal and Arctic bioregion will increase between 20 and 40 days by the end of the century.	MH	M	MMM	MMM	MMM M	
		Large-scale landcover changes occur over periods of years to decades. Some terrestrial vegetation models suggest potential for large-scale conversion of low tundra to shrubs, then to conifers, and from conifers to deciduous forests, or perhaps to grass. Other models indicate increasing lichen, decreased sedges, and increases to deciduous and evergreen shrubs.	HL	H	HHH	M	MLL	Bud: would think some veg change issues, particularly in LACL, and maybe KATM and ANIA.
		Vegetation expands into deglaciated coastal areas, but less markedly into higher elevation areas.	H	M	LLL	LLL	LLL	Troy: we don't have a lot of these ranked very high because of reduced set of species.
		Tree species and vegetation classes shift as species typical of lower altitudes and latitudes expand into higher areas.	H	H	MMM	MMM	LMM	
		Mountain and arctic ecosystems could change substantially within 50 years, and conditions become unsuited for some native species. **Some rare species could become endangered and endangered plants species may go extinct as conditions change.**	H	H	MMM	MLL	LLL	Bud: mountain ecosystems and rare species-some concern for this expressed in the mountains of LACL
		Drought stress affects boreal forests as evapotranspiration increases with warmer/drier summers leading to reduced tree growth, reduced carbon sequestration, and increased disturbance from fires and insect outbreaks.	LH	MH	LMM	LLL	LLL	
		Atypical outbreaks of forest pests and plant diseases occur more widely, increasing fire hazards and hastening decline of native and familiar species.	H	H	H/MHH	LLL	MLL	Bud: We're seeing this in LACL, KEFJ, and KATM, but less so in ANIA.
		Invasive exotic species and native species from other areas expand into parks. It becomes easier for invasive species that are already adapted to such conditions, to survive, reproduce and expand into available habitat as native species become increasingly stressed by changing conditions such as rising temperature and declining soil moisture.	MH	M	MMM	LLL	LLL	
		Black spruce may expand or contract, expanding under warming conditions coupled with increasing fire interval – or contracting as underlying permafrost soils thaw and fire frequency increases.	L	M	MMM	LLL	MLL	
		Mature forests and "old growth" decline, as a result of changing soil moisture, drought, insects, disease, and fire.	H	H	MLL	LLL	LLL	
	Fire	**Fire increases in boreal and tundra ecosystems.** Model simulations show a warming climate leads to slightly more fires and much larger fires, as well as expansion of forest into previously treeless tundra. Flammability increases rapidly in direct response to climate warming and more gradually in response to climate-induced vegetation changes.	MHM	H	MHHH	LHM M	MHM M	Daniel Noon: first two points have potential. Fire for them is exception rather than regular event. Transition to fire would have a big impact. Bud: lots of fires in northern area of LACL.
		Wildland fire hazards increase, affecting communities and isolated property owners.	LM	M	MMM	LLL	MMM	
		Fire-related landcover and soil changes include vegetation population shifts, major permafrost thawing, soil decomposition, and surface subsidence.	L	M	MMM	LLL	MLL	
	Wildlife - General	**Changes to the terrestrial and aquatic species compositions in parks and refuges occur as ranges shift**, contract, or expand. Rare species and/or communities may become further at risk, and additional species could become rare. Some early-succession species will benefit from changes.	MH	M	LLL	LLL	LLL	Troy: ranked these somewhat low at present for first two points. Don't really have them on their borders. Most of their dominant species are fairly resilient to the things we know are happening. Sees trend of predator issues. Not sure if this is climate related. Thinks this is more contingent on politics than it is any specific biological factor.
		Parks and refuges may not be able to meet their mandate of protecting current species within their boundaries, or in the case of some refuges, the species for whose habitat protection they were designed. While some wildlife may be able to move northward or to higher elevations to escape some effects of climate change, federal boundaries are static.	HHL	MH	MHLL	MHLL	LHLL	Jeff: for KEFJ, given our enabling legislation, we will be very challenged in meeting the mandate by some of the changes we're seeing now. Both re: mandate and visitor experience.
		Changes in terrestrial and marine wildlife distributions affect visitor experiences and subsistence throughout the region.	H	M	MLL	MLL	MLL	
		Some species suffer severe losses. An analysis of potential climate change impacts on mammalian species in U.S. national parks indicates that on average about 8% of current mammalian species diversity may be lost. The greatest losses across all parks occurred in rodent species (44%), bats (22%), and carnivores (19%).	M/H	H	M/HLL	MLL	M LL	If salmon populations collapse, then huge changes in species populations will occur
		Animals and plants will expand into landscapes vacated by glacial ice and utilize new alpine lakes after ice is gone	H	H	MLL	LLL	LLL	
		Predator-prey relationships may change in unexpected ways.	H	H	HLL	MLL	MLL	
		Migratory routes and destinations will change for some species (e.g., wetlands, open tundra, snow patches).	LH	L	LLL	LLL	LLL	
	Wildlife - Birds	**Arctic and alpine breeding birds' breeding habitats will be reduced** or eliminated as trees and shrubs encroach on areas currently occupied by tundra. 72% of Arctic and alpine birds are considered moderately or highly vulnerable to the impacts of climate change.	ML	M	MMM	LMM	LMM	

		Kittlitz's murrelet populations continue to decline as glacial retreat results in the loss of important nesting and foraging habitats.	H	M	M/LLL	LLL	LLL	high, but not sure it's related strictly to glacial retreat.
		Millions of geese could lose almost half of their breeding habitat due to a predicted change in vegetation in the Arctic from tundra to taiga and boreal forest.	HL	H	HLL	HLL	HLL	
		Waterfowl shifts occur as coastal ponds become more salty in some areas.	LH	MH	LHLL	LHLL	LHLL	
		Productivity of nesting shorebirds may increase if they are able to change their migration and nesting schedules to coincide with the time when the most insects are available.	LH	L	LLL	LLL	LLL	
		Coastal seabirds such as the arctic Ivory Gull, Aleutian Tern, and Kittlitz's Murrelet show medium or high vulnerability to climate change due to their low reproductive potential and their reliance on marine food webs that are also threatened by climate change.	H	M	MMM	MMM	LLL	Bud: coastal seabirds, substantial issue for all parks (John Morris agrees)
		The population cycles of birds and their prey, such as spruce budworm, will be decoupled in some Boreal areas due to warming temperatures. Populations could continue to move northward with continued climate warming.	H	H	HMM	HMM	HMM	
	Wildlife - Marine Mammals	**Harbor seals may move or decline**, spending more time in the water, or using terrestrial haul outs as floating ice declines. Population recovery could be affected.	H	L	LLL	LLL	LLL	Jeff: Harbor seal-KEFJ, yes, definitely
		Increased ambient sound affects marine mammals. Reduction in sound absorption and increased human vessel traffic due to receding sea ice and tidewater glaciers may affect marine mammals that rely on echolocation for communication and prey location.	H	M	MLL	MLL	LLL	
	Wildlife – Caribou/Reindeer	**Caribou and reindeer health may be affected** by changes in temperature and precipitation patterns, increases in insects and pests known to harass caribou and reductions of succulent forage.	L	M	MLL	MMM	MLL	Bud: yes for KEFJ. Troy: ANIA more of a caribou area than KATM. Caribou success is in two camps-one thinks it's lichen, one thinks it's green up.
		Caribou may suffer heavy losses, if vegetation glazes over following rain-on-snow events, preventing successful feeding during cold weather.	L	H	HLL	HLL	HLL	
	Wildlife - Moose	**Predicted shifts in forest community could result in less suitable habitat for caribou, but potentially increased habitat for moose** in Yukon Flats National Wildlife Refuge and similar habitats.	L	M	MLL	MLL	MLL	
		Climate change could decouple timing and synchrony of birth, hindering moose calf survival.	MH	M	MLL	MLL	MLL	
	Wildlife – Small mammals	**Reduced snow cover reduces survival of voles** and other subnivian species, due to increased predation and cold stresses, with changes in small and large mammal predator-prey relationships.	M	M	MLL	LLL	LLL	
	Fisheries	**Commercial fisheries shift.** Changes in ocean community organization in the Bering Sea caused by warming climate and associated loss of sea ice alter availability of snow crab and other fisheries resources.	HL	H	HLL	HLL	HLL	Jeff: we should consider sport fishing here as well. Fish diseases agreed to be not very far from any of the parks
		Ocean acidification affects fisheries. Pteropods and crustaceans foods of salmon may decline with ocean acidification.	H	H	HMM	HMM	HMM	Dan: more likely to become an issue for use. Bud: important for all the major parks.
		New stream habitats become available for colonization by fish and wildlife as glaciers decline.	H	H	L/MLL	LLL	LLL	
		Fish diseases such as *Ichthyophonus* increase with rising water temperatures. Models indicate that temperature increase in streams in south-central Alaska will be around 3°C, a change that could increase disease in fish.	H	H	HHLL	HHLL	HHLL	Troy: didn't rank these very high, partly because to get to the point where water is unsuitable for salmon, there has to be almost no surface water flowing, or you have to see a complete change in temp.. not just 3 degrees c, but we're talking temps vastly different cycled from day to day. There's a whole series of things that would have to happen to make that come up. There's a pretty broad range. It's usually more extreme… deforestation, road building, etc is what usually changes this. Doesn't think what we're talking about here will quite get it there.
		Some existing salmon waters may become unsuitable for migration, spawning and incubation.	H	H	HLL	MLL	MLL	
	Invertebrates	**Ice worm populations decline** locally as glacier habitats melt.	H	H	MLL	LLL	LLLL	
		Marine intertidal environments change and may become more susceptible to exotic marine species, including green crabs.	H	M	HLL	MLL	LLL	
		Exotic pests, diseases and their vectors expand into Alaska from warmer areas, and endemic pests expand as host species are stressed by climate change (e.g., bark beetles, budworms, ticks, lice, West Nile virus, Lyme disease, hantavirus, HP avian influenza, **plague, vespid [yellowjacket spp.] outbreaks, black flies, mosquito swarms, bott flies, etc.)**.	H	H	HMM	MMM	HMM	Bud: pests, diseases, high for all but ANIA. Jeff: yellowjackets
	Subsistence, Fishing, and Hunting	**Intensified management expands.** Some local residents and management agencies may advocate managing for new species that have the potential to replace diminished subsistence hunting, trapping, and fishing opportunities, and for intensified management of native species.	HM	H	HHLL	HHLL	H HLL	Especially for fish/salmon. Troy: ranked as low, bc it's already happening (intensified management could expand). Nancy Swanton—agrees w/ Troy, thinks it will continue to be an issue. Bud: thinks we will have serious intensified management of fisheries.
		Altered migration patterns make hunting more challenging. Migration patterns of terrestrial animals are predicted to change as temperatures, precipitation patterns, and vegetation availability change.	L	H	HLL	MLL	MLL	Don Calloway: marine subsistence becoming more challenging-LACL, KATM, ANIA… high
		Community resources available for subsistence activities decline as increased storm surges, and permafrost erosion compound effects of change to relative sea level, impacting infrastructure in Native Alaskan communities, in some cases requiring relocation of entire communities.	L	H	HLL	HLL	HLL	Bob: this is more about communities that are experiencing major climate change related issues and this. So maybe not so applicable in SWAN.
Other Human Uses and Values	Wilderness	**Large-scale physical and biological changes across broad landscapes** affect abundance and condition of wilderness-associated resources (glaciers, tundra, boreal forest, wildlife, scenic vistas, river flows, access routes, etc.)	H	H	HLL	MLL	MLL	

		The scientific community becomes increasingly interested in wilderness sites for a variety of inventories, monitoring and research projects, some of which involve highly technical instruments, mechanized access, and long-term installations.	H	H	HHH	MMM	MLL	Jeff: on feisty scientists-maybe not so much an emergence of feisty scientists, but perhaps instead a greater role for environmental compliance.
		The changing biophysical landscape, and increased human activity to research, monitor, and respond to threats associated with climate change affect key wilderness values such as naturalness, wild-untamed areas without permanent facilities opportunities for solitude, etc.	H	H	HM	HLL	HLL	
	Tourism	**Alaska's tourism season lengthens** with increasing temperatures and more snow-free days. Some visitor activities increase, while others (e.g., snow sports) may decline.	H	M	ML	L	ML	Bud: Glacier Bay phenomenon-are we seeing this in SWAN parks? (longer tourism season). Daniel/Troy: didn't rank this as particularly high; we think the foreseeable kinds of tourism here are fishing and wildlife viewing. Can't think of kinds of tourism that would be likely to expand. KEFJ: Jeff-15% increase in visitation last year. But on the road system, close to Anchorage. So much of their visitation is related to Anchorage, whereas other parks are 'destination visitors", i.e. lower 48.
		Landscape-level changes affect visitor experiences as iconic scenery changes, and access for subsistence, hiking, boating, etc. changes with vegetation, soil, and water	H	H	MLL	LLL	LLL	
		Visitor use patterns shift as tour operators seek to provide visitors with more opportunities to experience increasingly uncommon glacier scenery. Cruise ships and day tour operators may shift some itineraries away from the parks they've traditionally visited, or seek more opportunities to shift itineraries deeper into the parks. Land based operators may press to bring groups further into the park through aircraft, airboats, snowmobile tours, off road vehicles (ORVs), and road extensions.	H	L	LLL	LLL	LLL	
		Visitor demand for new interpretive/education media products, publications and services that address changing climate will increase, putting pressure on existing programs and staffing as a result.	H	MH	MHLL	LHLL	LHLL	
	Other Hazards	**Safety hazards develop, expand or are recognized in relation to climate change,** such as thin ice, erratic flooding, changing fire and smoke hazards, slope failures (mudslides, landslides, tsunami hazards), and expansion of more disease organisms (fish, wildlife, and human) and their vectors into Alaska.	H	M	HLL	LLL	MLL	Jeff: KEFJ-having to adapt operations to be more prepared to close road, manage visitors, direct to other places, etc. Already seeing this.
	Customary and Traditional Knowledge	**The predictive uses of traditional ecological knowledge will change**, as unprecedented changes develop for weather, freeze/thaw conditions, plants, animals, fire, etc.	LH	H	ML	ML	ML	Timing of salmon runs may change due to water temp's and flows. Daniel Noon/Troy: Not particularly high because main things that are relevant to peoples' experience out here are moose and caribou; this is always cycling anyway (every 40-60 yrs). Don Calloway—hears this more about western and northern Alaska. Lots of oral traditions there about what happens in starvation times.
	Resource and Economic Development	**Natural resource development and economic activities expand in Alaska** with increasing global demand for energy and resources to supply rising global population.	LHM	MH	MHHH	MHM	M HM M	Possible oil and gas in Bristol Bay region.
		Developmental pressures increase as direct or indirect effects of reduced snow and ice cover. These include expanded global and regional transportation systems and their associated infrastructure (e.g. opening of the Northwest Passage due to reduced sea ice, permanent roads to replace ice roads), increased demand for natural resource development (construction materials – especially gravel and rock, energy and minerals for infrastructure repair, replacement, and expansion), shifting agricultural production zones, community resettlement and other population shifts.	HM	H	HLL	HLL	HLL	
		Infrastructure development expands along Alaska's coasts and Interior to provide needed services, facilities, and transportation systems for other expanded activities.	LM	MH	LHLL	LHLL	LLL	Bud: LACL-higher bc of proposed mining. Troy: listed high for KATM, medium ANIA, etc because: 1) Pebble effect would be felt more in KATM. Airborne effects would be big bc of prevailing winds and 2) Every presidential cycle there is a change re: whether will there be oil and gas development initiatives. Bob: demand for gravel can be related to climate change, etc…. at first these things don't look related to climate change, but they are at closer look. Complex issue. Bob: friend in oil industry said we have to put in fuel and energy price increase as a result of carbon mitigation. Troy: we scored as a high effect in terms of our capability to simply manage the park.
		Damage to roads, buildings, and other infrastructure increases due largely to permafrost thaw (but also from storms, floods, and landslides) adding 10% to 20% by 2080.	H	M	MLL	LLL	LLL	
		Relocating indigenous communities represents a large social burden, not just financial cost for governments, but also impacts the communities themselves, potentially resulting in loss of integral cultural elements such as access to traditional use areas for subsistence activities, loss of history and sense of intact community, and potential loss of social networks and extended kin support. Significant increases in social pathologies such as alcoholism and domestic violence may be anticipated. In addition, tremendous stresses will be placed on traditional means of conflict resolution. In addition multiple strains will be placed on local governance and delivery of services. Finally, state and federal governments will have huge additional burdens placed on them as they try to provide relief from the impacts of climate change (flooding, destruction of infrastructure, high demands placed on social services and so forth). Response to climate change will require enormous pressures for integrated and efficient bureaucratic structures.	L	HM	MMLL	MML L	MMLL	
		Fuel and energy prices increase substantially as carbon mitigation measures are implemented (sequestration, carbon caps, offsets, etc.). Costs of transporting fuels to remote locations by barge, ice roads, aircraft, etc. also becomes more challenging and costly.	M	H	HHH	HMM	HMM	

Appendix H: Narratives

As noted in the body of this report, creatively framed narratives were an important outcome of the intensive group brainstorming efforts that went into this CCSP workshop. The following imaginative narratives were created to synthesize these climate change scenarios and to bring them to life in a manner intended to engage diverse audiences.

Narrative 1: A phone conversation between Danny and his grandfather

The following narrative was developed by the Coastal group based on the "PB & Jelly Fish" scenario (with a major increase in ocean acidification, not much change in storms) nested in the "Riots and Revolution?" quadrant (high societal concern and less integrated institutions) of the socio-political matrix (Figure 10).

--Hey Grandpa! How's it going?

--Oh, hi Danny. I miss you! How's life in Anchorage?

--Pretty good… I miss being able to go fishing with you, though -- even if we usually got nothing but jellyfish. Mom and Dad are just happy they have jobs again. I guess people still need interpretive rangers and port workers here.

--It was different twenty years ago, Danny. The fishing… well, you wouldn't believe how good the salmon fishing used to be. There were tons of mussels, and crabs, oysters, clams… you name it. Lots of visitors used to come to see the animals that fed on those fish, too.

--Yeah, that's what you always tell me. Mom and Dad say they used to see bears all the time, and tons of birds, and seals and otters and stuff. How come no one did anything about it when all those animals started to disappear?

--Well… it's hard to explain. We knew it was happening, but it was pretty tough to get the people with the power to do anything about it. They just weren't organized. There was a lot of arguing between the Council, and the Parks people, and the Fish and Wildlife people – all of those government folks. Some of them wanted to help, but they had no funding, and no plan. In the village, folks got depressed when they couldn't go fishing any more, and they felt like they just couldn't maintain their way of life.

--What about you, Grandpa? You're not depressed, are you? You should have moved to Anchorage with us!

--No, no, Danny. I'll stay here. I can't be a fisherman anymore, but there are still a few caribou worth hunting, and there might be a fish farm starting up. Maybe I could work there. Of maybe I can get an interview with that new oil and gas exploration company that is supposed to be moving into town soon. If the government isn't going to help us, we just have to help ourselves, I guess.

Narrative 2: A text chat between Anna and her boyfriend

The following narrative was developed by the Coastal group based on the "Acid Wash" scenario (with a major increase in ocean acidification, not much change in storms) nested in the "Big Problems, Big Solutions" quadrant (high societal concern and more integrated institutions) of the socio-political matrix (Figure 10).

Background:

This world in 2030: Steadily declining benthic community has led to loss of charismatic iconic megafauna and a drastic food web shift. Similar to a boom/bust economy, the bottom has dropped out of the fisheries industries as well as tourism. Small towns dependent on these resources, including subsistence communities, are facing major economic challenges. Frequent pummeling from intense storms has wreaked havoc on infrastructure. Concerned communities are coming together with institutions in a concentrated effort to creatively problem-solve the enormous issues they are facing.

Major impacts: Absent and altered fish communities create a ripple effect from subsistence users to birds and mammals. Increased storm surges impact productivity of waterfowl and cause dramatic coastal erosion. Density dependent diseases (prevalence and/or severity of outbreaks), pose greater risks to species survival. Access to roads and trails becomes difficult.

Issues facing management: Subsistence communities asking for introduction of surrogate species and/or increased harvest of remaining species. Agencies are no longer able to meet their mandate of protecting certain species so they are facing a re-working of mission. Utilizing available funding becomes a problem of rapid prioritization and implementation. Interagency plus robust public/private sector integration in the form of a problem-solving task-force aka “ecosystem cooperative.” Media and public “support” proves to be overwhelming at times. Increased pressure for natural resource development and activities to replace those lost… managers have to address user conflicts. Marine spatial planning becomes a necessity.

Narrative 3: The 20th annual meeting of the Southwest Alaska Collaborative Planning Team

The following is the first of two narratives developed by the Coastal group based on the "Acid Wash" scenario (with a major increase in ocean acidification, not much change in storms) nested in the "Big Problems, Big Solutions" quadrant (high societal concern and more integrated institutions) of the socio-political matrix (Figure 10).

Michael: Good morning, and welcome everyone, to the twentieth annual meeting of the Southwest Alaska Collaborative Planning Team. Just to remind you, today we have the special privilege of having not only many interested Alaskans and several members of the press covering the event, but also two members of our state legislature toggled in via multi-media holo-screenplex to hear our needs and concerns -- welcome, Nace Ayer and Cash Baggs -- and our very own Alaska State Legislator, Newt Eymes.

As most of you know, my name is Michael Shepherd. I'm honored to be hosting this event. I've been part of this process from the start, and in the past 20 years with the Park Service I've really earned all these gray hairs. We've seen a lot of changes in two decades, as we've struggled to adjust to the acidification of our coastal waters and the heavy rain and storms that have been pummeling our coastline, and although we've put in a lot of work during that time, there's still a lot to be done. With that, let's have a quick round of introductions. Let us know who you are, and just a few sentences about why you're joining us here today. If we could start with our honored guests?

Bud: I'm Representative Newt Eymes, and I'm happy to report that I'm working on a bill that would help coastal communities all over the US, and particularly here in Alaska. I'd like to know how Congress can help aid your communities in the shift away from salmon fisheries -- which I know are steeply declining -- as the basis for both your subsistence economies and your cash economies. We're working to help you create new sources of jobs and revenue such as your wind farm – which I hear has been cranking out the power -- and your new hydro plants. We're also hoping to help out in your new agricultural sector (I sure do love a good rhubarb pie).

Chuck: Nace Ayer here. I'm working for you guys down here in Juneau, and let me tell you, those of us in the legislature aren't going to want to hear a lot of sob stories and funding requests. All I hear from your area is complaints: "The salmon are declining, the shellfish are dying off, our historic sites have washed out, the glaciers aren't where they used to be, we have flooding and erosion and the park visitors aren't coming anymore." You guys have been doing a lot of planning and a lot of science-y research-y stuff for twenty years, working with those university folks, the co-management people, the Feds, and even the greenies. We want to know where it's gotten you.

Fritz: Hi there, glad to be toggled in. I'm Cash Baggs. If I could beg to differ with my colleague Nace, I've already been hearing good things about your progress – for example, the green energy initiative in which the Park Service shares all the newest conservation innovations with neighboring communities, and has hooked six villages into the zero-carbon grid. I think there are plenty of projects that the folks down here in Juneau would be interested in, during our upcoming budget cycle.

Michael: Thank you. And now let's hear from our team members. We have a few here in the room, and others toggled in. Perhaps you could each let us know a bit about what working groups and projects you've been involved in, and what you're hoping to see accomplished in the coming year?

Brooke: Thanks Michael. I'm Annie Molls, director of the Charismatic Megafauna Tour Company. Well, we've had some tough times with all the rainy weather, and we've had to cancel our Cute Critters tour – there just aren't frequent enough viewings of sea otters and seals to keep the visitors happy. But the new moveable floating dock that NPS put in is great – totally stormproof. It means that we can still get our boats out for our ocean tours. We're planning a new one called See Jellyfish Before You Die. We could really use some help from the agency folks in helping bolster that with your education and interpretation programs. We'd also looking forward to the report from the interagency monitoring team and the researchers from UA about what species are coming in, and what is likely to show up in the next few years, so we can gear our new tours towards those species.

Bill: Good morning. I'm Bill Ding, from NPS. I've been working on the new infrastructure developments at the Park – the moveable glacier kiosks, the floating dock, the foldable signs. I want to hear how those are working out for our visitors and for our partners in the tourism industry. We've got some ideas for ways to keep our bridges and roads from washing out, but we may need some funding to make that happen, so I'm glad to have our representatives toggled on. [Even you, Nace Ayer]

Sue: My name is Olive Ryteer, and I'm from the village of Pertinent. We've appreciated the help we've been getting from the new green energy plan, and the cooperative management agreement is really helping, but we still feel like our way of life is slipping away from us. The salmon fishing has been terrible for years now, and the caribou hunting is no good either. Folks are getting depressed, and that leads to all kinds of troubles. We're worried that if more folks move away, we may lose our school. We'd like to see more help finding us jobs, and more information on new ways to maintain our subsistence lifestyle.

Anna: Hi there. I'm Anna Collagist, from the University of Alaska. I've been part of the interagency monitoring team. With a gaggle of grad students slaving away in partnership with the folks from NPS, USFWS, and NOAA, we've been doing near-shore and offshore surveys of fish, shellfish, and bird populations, as well as assessing ocean pH and availability of food sources at all trophic levels. I'll be presenting some results that I think will be interesting to you, Annie. It looks like a major trophic shift is going on, and if you can point out some new species as well as some old species to your visitors, you could create a brand new Watch Climate Change As it Happens tour.

Nancy: Hi, I'm Raina Snow from the University of Alaska. I've been working with all my agency, business, and non-profit colleagues from the Climate Working Group to improve our climate modeling techniques, and to try to get a handle on what we can expect from the PDO, ENSO, and all the other acronyms.

Michael: Thank you, planning team. Well, it sounds like we have our work cut out for us, so let's get going on today's work session!

Narrative 4: "Low-grade Fever"

The following is a second narrative developed by the Coastal group based on the "Acid Wash" scenario (low magnitude change in ocean acidity, precipitation, temperature, and storms) nested in the "Is Anyone Out There?" quadrant (low societal concern and less integrated institutions) of the socio-political matrix (Figure 10).

Ocean acidification and increased precipitation and storm activity are primary drivers. Temperature continues to rise at a rate of approximately +2 °C over the next half century. A cool-phase (-) PDO is in effect until approximately 2030, at which time a shift to warmer, drier (+PDO) conditions is expected. The increase in mean annual temperature has been ameliorated by the cool-phase (-) PDO.

Summer and winter temperatures have been ≤ average over the past 20 years. Precipitation has been highly variable, with a few years of above-average snowfall and other years characterized by cold, dry conditions. Rates of glacial recession have decreased (e.g., at the termini), but thinning continues. Relatively low rates of change (temperature) and high variability (precipitation) result in barely perceptible climatic changes in southwest AK; i.e., climate conditions seem to be relatively stable.

Public perceptions of climate change are as follows: (1) Changes are slight enough to be perceived by the public as benign or even positive; (2) there is low media coverage of climate change, at least in southwest AK, due to lack of dramatic environmental changes, and this contributes to public complacency. Given the lack of change, those who question climate change gain credibility. There is little public pressure on politicians to deal with climate change issues in SW Alaska, and there have been no climate-related emergencies. Conditions remain stable, familiar.

Because of this perceived lack of change, climate change funding has dried up, at least for southern AK. There is still concern within the agencies about the effects of climate, particularly following the imminent shift in PDO (- to +); however, convincing the public that climate effects may be serious has become increasingly difficult. Large increases in temperature may be evident at higher latitudes, in contrast to the more subtle changes occurring in southwest AK, and thus may divert political and economic support away from SW AK. Meanwhile, the US carbon footprint (GHGs) has increased, although there has been some progress in clean/alternative energy, including increased reliance on natural gas. An aging population has put increasing pressure on the economy, and the national debt, health care, social security and other funding priorities have superseded climate change in terms of importance in the public view. Agency programs, including climate change funding, have been cut.

Major impacts on the bioregion include increased shrub cover; increased biomass, including woody biomass, and increased C uptake and sequestration. There are potential increases in drought stress in upland vegetation, including forests, as well as continued insect damage and/or forest dieback. However, ecosystem changes have been incremental, and mostly related to succession. A cool-phase PDO may result in reduced salmon runs, but potentially increased productivity in shellfish (shrimp/crab). Moose may benefit from increased shrub cover (willow cover), whereas caribou habitat will decline. With increased warming and lower snowpack depths at low elevations, deer may expand into new habitat. Sea lion and harbor seal populations, which may have bottomed out by 2010-2020 may see a slow recovery going into 2030. While fisheries resources diminish elsewhere in the world, the AK fishery (SW Alaska) becomes ever more valuable.

Management issues are driven in part by public perception. Convincing the public of the likelihood of sudden warming associated with a shift to warm-phase (+) PDO remains difficult. Agencies are faced with a lack of funding to educate public and/or adapt to or mitigate change. Agency mandates make rapid response to climate-related issues unlikely/difficult, and there is little impetus for a change in agency structure. Pressures from external communities are relatively low, but still some predator control issues remain. A variable environment (e.g., variable snowpack & freeze dates) results in an uncertain regulatory climate. Shifts in the timing of hunting season are needed annually, and yet there is resistance on the part of the leadership (agency) to remain responsive. The baseline that agencies rely on to set hunting seasons is highly variable, all over the map. Some interagency coordination exists at the landscape level (LCCs), although NPS will have some of the last habitat that will support species that are losing out to climate. As a result, NPS will be asked/expected to act as a biodiversity reserve. Biological stresses (e.g., drought stress, forest dieback, increasing fuel loads) and pressure from land managers and clients to mitigate these stresses will drive management decisions. Competition for resources continues among subsistence, sport, and commercial harvest users.

Other areas of AK may have changed more than southwest; focus on climate change may be on Arctic/Interior, and SW AK may be lost in the shadows. As a result, some resources previously allocated to climate change adaptation/mitigation in SW Alaska may be reallocated to the Arctic/Interior. These factors lead to a shift in priorities at the regional and national levels, and eroding budgets (no budget increases).

Narrative 5: “The Doctor’s Slide Show”

The following narrative was developed by the Coastal group based on “Is there a doctor in the house?” nested scenario. This is the “Low Grade Fever” scenario (low magnitude change in ocean acidity, precipitation, temperature, and storms) nested in the “Is Anyone Out There?” quadrant (low societal concern and less integrated institutions) of the socio-political matrix (Figure 10).

Dr. Deunough Harm, a retired physician, adjusts the focus on the image of the massive brown bear he photographed in Katmai last summer. It takes up the entire screen. He is addressing a group of his friends and colleagues, most of them who have spent their careers in the biological sciences, at an informal gathering in his home in Annapolis, MD. He spent two weeks traveling in southwest Alaska last August, fitting in a glacier tour (KEFJ), a bear-viewing trip to Brooks Camp (KATM), and a trout-fishing trip in LACL. He visited southwest Alaska because he views it as one of the few relatively intact, biologically diverse ecosystems remaining in 2030, and he avoided a visit to Denali and other Interior and Arctic locations in Alaska because fires and smoke make these places miserable and unhealthy. The message he heard repeatedly from park interpreters, however, was one of impending, and potentially very significant, environmental change. Here is an excerpt from his travelogue:

> *'We went on one of those glacier tours, and the glaciers were spectacular. We didn't see many calving glaciers, apparently because most of the tidewater glaciers have receded onto land in the last several decades. The park rangers talked a lot about climate change, but when you see the size of these glaciers with your own eyes, it's hard to believe the bleak predictions. In fact, the ranger admitted that one of the glaciers we saw had advanced some in the last couple of years. I didn't really understand why a glacier could be increasing in size if the world's in climate change crisis. '*
>
> *'We ate seafood, mostly salmon, almost every night, but it was more expensive than I'd expected. I thought being this close to the source would make it cheaper, but I guess that wild fish is expensive, no matter where you go. It was a lot better than the farmed stuff we eat here, and we were on vacation, after all.'*
>
> *'Speaking of fish, the bears didn't seem to be having any problems, although the ranger at Brooks Camp said that there were fewer bears now than when the salmon runs were really big. I was glad that we reserved our bear viewing trip ahead of time. I saw people getting turned away, since many of the tours were sold out. We flew to a beach in Katmai from Homer and watched bears digging for clams in the mudflats. Our guide said that if the ocean continues to acidify, the bears and other wildlife may have trouble finding clams in the future. Our pilot was a native guy who said he had moved his family to Homer because it was too expensive to live in the village anymore.'*
>
> *'If the park rangers and guide are right, I suggest that everyone visit Alaska soon. They say the kind of big changes we're already seeing on the eastern seaboard, like the breakup of Assateague Island into Assateague Archipelago, will be hitting Alaska soon due to a shift in the PDO.'*

His friend, Dr. C. N. Salmon, a retired fisheries biologist from Seattle, leaned forward. 'Are you talking about the Pacific Decadal Oscillation? We used to see strong salmon runs in warm-PDO years in Alaska. Nobody really knows what causes the PDO, but it tends to run on 20 to 30 year cycles. If they're expecting a shift from cool- to warm-phase PDO conditions, that change alone could really strengthen the already low-level warming that everyone else is dealing with. I would expect that the glaciers in southern Alaska will start receding rapidly again!'

(From a societal impacts perspective, recognition of PDO is important because it shows that "normal" climate conditions can vary over time periods comparable to the length of a human's career or generation.)

Narrative 6: An Ecologist's 30-Year Perspective

The following narrative was developed by the Riverine group based on the "Smokey" scenario (warm phase of the PDO, more thaw days, and less variation in precipitation) nested in the "Wheel-spinning" quadrant (low societal concern and more integrated institutions) of the socio-political matrix (Figure 12).

The day started off like so many in the past, checking the weather and prepping equipment. The winds were finally favorable for a day on the lake. As we motored outside of Hardenburg Bay, a smoky haze obscured the mountain tops to the west and a fourth fire of the season. I wondered if I'd ever see the mountain tops before field season ended. As we boated up towards the head of Lake Clark I looked south at Tanalian Mountain and noted the brown patches appeared larger this summer compared to last year. I recall my first trips to Lake Clark and observing a green jungle of alder dominating the lower mountains. Now stem rust, a new disease to Alaskan flora, is wiping out large patches of alder. "At least that green wave stopped spreading up the mountain side," I remarked to my crew mate.

Down low next to the lake the birch displayed a hint of autumn already. We were a good two months away from peak autumn colors but the signs of drought stress were obvious.

After a half hour boat ride we reached our first sampling site at the head of the lake. The upper lake is unusually quiet these days. I remarked how years ago the sound of rushing water would drown out one's thoughts as waterfalls cascaded off the mountains. But with the glaciers gone up top, the waterfalls are a mere trickle of their former self. Another slurry bomber passed high overhead. As we started our sampling sequence I lowered a Secchi disc over the side of the boat to check water clarity. "Ten meters" I called out. "Definitely not the turbid waters I remember earlier in my career," I thought. The Tlikakila River, once the primary source of glacial water flowing into Lake Clark, now runs crystal clear and the upper lake resembles the deep blue waters of Kijik Lake. Taking away a watershed's glaciers is like putting a tourniquet on the river. Greatly reduced flows and sediment loads down this Wild River have reduced a once braided network of constantly shifting river channels into a single canal wadeable throughout most of summer. The once vast river delta that was such an obstacle for boaters in my younger days is now stabilized and overgrown by the forest of 15' spruce and birch.

Not long into our second sampling site the day's first boat load of anglers passed by making their way to the Tlikakila. The clear stable waters now support a popular rainbow trout fishery. No one in their right mind would have fished that river twenty years ago. After completing our sampling we decided to make our way up to the old river delta and take a quick count of the sockeye salmon staging along the lakeshore. As we strolled down the beach schools of sockeye stirred about, most fish were crimson red with a few blush fish mixed in. In 2007 I visited my first fish camp just down river from Nondalton. Back then the sockeye run was peaking in the Newhalen River around July 20th. But from the looks of these fish most have been here at least a month already. Now four guide boats were beached just up the shoreline. Lake Clark—a rainbow trout destination, it was starting to look like some of the more popular Katmai fisheries of yesteryear. I recall when guides departed Port Alsworth via float plane early each morning, transporting clients to fish the rainbow trout waters around Lake Iliamna. Now they sleep in and take a boat ride up-lake. We stopped and talked with one of the guides. I wanted to know if he had spotted any sockeye spawning activity upriver. "We're a week or two early," he remarked. The greatly diminished flows and clear waters of the Tlikakila River sure made it easier for bears to fish. It used to be the Tlikakila River held the latest spawning population of sockeye salmon in Bristol Bay with peak spawning activity occurring in October, sometimes into November, after the glaciers stopped melting and the river cleared up. It was the best area to find a heavy concentration of brown bears late into the fall as they took advantage of a reliable food source just before hibernation. But now the Tlikakila sockeye are just like any other population in the area, spawning in early August even late July in a hot year, and the bears are forced to forage for berries in autumn as most sockeye are decaying when the heavy frosts hit in late September.

As we made our way back to headquarters the smoky haze dropped in low over Port Alsworth; given the wind direction I was certain another fire had popped up following last night's storm. State fire crews and Park officials were hosting a public meeting that night to lay out the Park's plan for the summer fire season. Regardless of the plan I was pretty sure I knew what the public response would be—no more smoke. Guess I can't blame them, why live in a place like this if you can't see the mountains? Despite the reality of the situation that this summer's fire season was becoming the norm, the public remained indifferent or unwilling to adapt. Biologist tried to put a positive spin on the situation: "Just think of the moose habitat this will create in ten years." But that rationale fell on deaf ears. Many long-time residents wanted to bring back the good ol' days when the Mulchatna caribou herd wandered through the park. But the Mulchatna herd resides mostly north of Bethel these days in the drying Y-K Delta area. I doubted Lake Clark would ever see caribou again as most of the park's tundra was shifting to a boreal forest ecosystem. Even in my short time in the park, the sockeye runs have undergone many changes. But, they still return every year, at least for now. When the salmon stop returning the people will take notice. I hope we're ready to deal with that possibility when the time comes. As I started pondering that scenario I couldn't help but count down my days to retirement.

Narrative 7: Troy Hamon at KATM

The following narrative was developed by the Riverine group based on the "Tiny Ice Age" scenario (cold phase of the PDO, fewer thaw days, and high variation in precipitation) nested in the "Is Anyone Out There?" quadrant (competing local concerns and less coordinated institutions) of the socio-political matrix (Figure 12).

Bear activity in southwest Alaska is still noteworthy in the year 2030, a remarkable piece of stability in the middle of a world that seems to be losing its grip on normal. The southwest coast of Alaska has been subject to a series of cooler and wetter years that defy the worldwide climate shift that has manifested itself through the loss of barrier islands on the Atlantic Coast of the nation, as well as a prolonged drought in the desert southwest. The apparent anomaly, due to local effects of a cooling phase in the Pacific Decadal Oscillation, has largely escaped notice because so many other things are going so wrong.

There are challenges here that are not getting a lot of attention. Bears are still easily seen along the salmon spawning grounds that consist of rivers connecting large lakes. But the tributary streams have been nearly abandoned, as their increasing frequency of floods and high water events have decimated many of those salmon spawning areas and made them difficult to fish. The ocean returns of salmon are down as well, but the persistent effort to market wild salmon against the farmed salmon industry has lost ground, and there is less market available, so commercial fishing effort has declined in tandem with the lower run sizes, and most fish processing facilities are barely hanging on. The stability of glaciers in this region, when most of the world has been reporting widespread loss of glaciers, is noteworthy, and there are even some glaciers that are growing. Wildlife populations have been hit hard by the deep snow conditions accompanied by especially cold winters, but access to wildlife for local subsistence hunters has been improved by the ease of overland travel in the winters. The rising costs of fuel and the migration of rural residents to urban centers has minimized the demand for subsistence resources, however, and the reductions in wildlife have not been especially problematic for the agency.

Local agency representatives find they are challenged to make local citizens and their home offices understand the sheer magnitude of change that likely awaits. When the cold phase of the PDO comes to an end, a transition to a warmer phase will likely result in a near catastrophic rearrangement of local ecosystems and physiography. Preparing the agency and the public has been the focus of a new education initiative, and the intention is to tag informational bulletins and twitter-based responses to climate pieces that mention local variability, oscillations, or ocean climate phases in order to keep the message of impending changes in the public eye.

Narrative 8: Letter to Senator Will Goforth, July 2030

The following narrative was developed by the Riverine group based on the "Freeze-Dried" scenario (cold phase of the PDO, fewer thaw days, and less variation in precipitation) nested in the "Riots and Revolution" quadrant (high societal concern and less integrated institutions) of the socio-political matrix (Figure 12).

An open letter to Senator Will Goforth, by the Peninsula Alaska Mayors' Council. Published by the Alaska Daily News, July 2030.

Dear Senator Goforth,

We, the undersigned, appreciate your many years of wise public service and support for Alaska's coastal communities. We are writing today to ask your help again in dealing with a crisis for which government agencies seem unable or unwilling to help our communities. You are well aware of the importance of community, place, and subsistence to rural Alaskans. While most of the people in our communities still live a subsistence lifestyle, it has become harder to subsist, and harder to maintain a viable community. After more than a decade of continually diminishing stream flows and sharply declining salmon returns, many local fishers have been forced to sell their salmon permits, their livelihood and their family legacy to out-of-state businesses. When our fish processing plant closed, more people left to seek wage work elsewhere. We were devastated when enrollment dropped below the stated minimum enrollment, and we fear that since the school closed, there will soon be few younger people and families left in the community. With the prohibitively higher costs of fuel and electricity, we are thankful that some residents still have good paying jobs in government and community services, although the number of such positions has also declined with falling tax revenue. A few residents have also found jobs with new construction, wind farms, and mining operations on nearby state and corporation lands, but too many good jobs seem to be filled by Outsiders. The federal and state agencies have compounded the challenges faced by our communities. For example, with the loss of our salmon resource, we have increasingly looked to hunters to provide for our aging residents. However, the decades-long drought, coupled with a history of water resources mismanagement, deforestation by wildland fires and mining impacts, and steadily increasing federal predator protection, has made it increasingly necessary for hunters to travel long distances to find harvestable wildlife. Agency regulators don’t seem to appreciate that the changed landscape and unrealistic hunting seasons make access boat, foot, and snow machine unreliable. Now, those same agencies are working against our hunters, by denying use of ORVs to access to herds on government lands. Senator, we need the agencies to work with our public, not against us, and we desperately more good jobs in our rural communities before all of our young families move away to hub communities and urban areas. Today, we are asking for your sponsorship for the “Salmon for our Children” bill, a program to fund construction and operation of an expanded network of government-funded community salmon hatcheries. We also ask for your support of a local-hire mandate, provisions for securing any necessary water rights from adjacent federal lands, and reasonable community access to federal lands by ORV in this bill.

Respectfully,
The Members of the Peninsula Mayors Council

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 181/125272, 186/125272, 188/125272, 127/125272, 193/125272, July 2014

National Park Service
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