National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Resource Stewardship Objectives and Actions for Climate Change-Sensitive Cultural and Natural Resources in Wrangell-St. Elias National Park and Preserve

Outputs from January–February 2022 Climate Change Adaptation Strategy Development

Natural Resource Report NPS/WRST/NRR—2024/2614











ON THIS PAGE
Rainstorm in the Wrangell Mountains.
Credit: NPS/Neal Herbert

ON THE COVER
Kennecott machine shop and concentration mill (top left), hikers on a glacier (top right), Copper River (bottom left), salmon drying rack (bottom right).
Credit: NPS/Matthew Yarbrough (top left), NPS/Neal Herbert (top right, bottom left), NPS/Barbara Cellarius (bottom right)

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January 2024

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Executive Summary

This report presents climate change-informed resource stewardship strategies for diverse Wrangell-St. Elias National Park and Preserve natural and cultural resources. The strategies were developed in early 2022 by park staff and other subject-matter experts in a scenario-based climate change adaptation planning process. Strategy development was facilitated by National Park Service (NPS) climate change adaptation specialists. Strategies address critical climate change implications for park resources identified in an immediately preceding (fall-2021) climate-resource scenario development process. The overall, nearly-year-long scenario- and strategy-development process was entirely virtual due to the COVID-19 pandemic. Although this circumstance was constraining in some ways, it also provided many benefits, including lower barriers to participant entry, smoother pacing, more opportunities to incorporate personal reflection and individual work, and more points in the process where facilitators could intervene to support participants or make changes. Absence of travel costs, plus organization of the process into a larger number of smaller steps than in the past, allowed the 11 participating park resource management staff to include a large pool of several dozen federal, tribal, state, academic, and private-sector partners. Climate change adaptation strategies are most likely to foster climate change-informed resource stewardship when they support a specific planning process. In this case, that process was the 2021–2023 development of the Wrangell-St. Elias National Park and Preserve Resource Stewardship Strategy. A Resource Stewardship Strategy is a dynamic planning tool that parks use to set goals for natural and cultural resource stewardship, identify activities to achieve and maintain desired conditions, and track progress.

Acknowledgments

We thank the participants for their contributions, insights, and tremendous energy in working with climate-resource scenarios to develop a broad set of climate change-informed resource management goals and actions. This project was also supported by in-kind contributions from the National Park Service Climate Change Response Program, the U.S. Geological Survey North Central Climate Adaptation Science Center, and the Alaska Climate Adaptation Science Center. We also thank M. Miller, J. Reynolds, and J. Littell for thoughtful input on design and execution of this phase of the scenario planning process, and G. Knowlton and K. Thomas for assistance in preparing this report. Finally, we acknowledge and thank reviewers of this report, including M. Miller, M. Loso, J. Reynolds, D. Harmon, P. Hosten, J. Lawler, W. Carr, B. Miller, T. Olliff, A. Pocewicz, D. Schirokauer, N. van Wilgen-Bredenkamp, and N. Latysh, as well as J. Reynolds for managing the peer review process.



Donoho Peak (center), with Kennicott Glacier to the left and Root Glacier in the foreground to the right. NPS photo by Neal Herbert.

Introduction

This report presents climate change adaptation strategies developed in early 2022 by staff from Wrangell-St. Elias National Park and Preserve (WRST; also referred to as "the park"), with the help of several dozen additional subject-matter experts (SMEs). *Climate change adaptation* is:

> *An intentional management response to observed climate changes or plausible future changes that involves identifying, preparing for (e.g., developing strategy and specific actions), and responding to (e.g., implementing actions) those changes. The desired outcome from the management response is to retain current conditions, recover from climate variations (perhaps to an altered state), or adjust to changing conditions that may include major transformation in practices or state. Adaptation may seek to 'moderate harm or exploit beneficial opportunities' (IPCC 2014).* (NPS 2021).

This report defines an *adaptation strategy* as one or more climate-informed management objectives with associated actions (sometimes organized under sub-objectives). In this context, "action" can also include making an informed decision to take no action (particularly where such a decision represents a break from a history of intervention). Climate change adaptation strategies are most likely to foster climate change-informed resource stewardship when they support a specific planning process (Miller et al. 2022). In this case, that process was the 2021–2023 development of the WRST Resource Stewardship Strategy (RSS). An RSS is a dynamic planning tool that parks use to set goals for natural and cultural resource stewardship, identify activities to achieve and maintain desired conditions, and track progress. A park's RSS is intended to inform near-term decisions and actions (i.e., over the next decade or so) and to be updated periodically, so it focuses not on all resources but instead on a subset of park-determined priority resources.

The WRST RSS necessitated that we modify the National Park Service (NPS) adaptation process (Figure 1; NPS 2021) into a facilitated, participatory,[1] scenario-based climate change adaptation planning process (Runyon et al. 2020; Miller et al. 2022; Schuurman, Miller, et al. 2022) embedded within RSS development (Figure 2). Adaptation strategies developed through this process (Figure 3) address critical climate change implications[2] identified by park staff and SMEs for a broad spectrum

[1] A list of participants in WRST climate change adaptation strategy development is provided in Appendix 1, and a list of strategy-development facilitators is provided in Appendix 2.

[2] Although this report uses the term "implications" in a manner synonymous with "vulnerabilities" (i.e., the integration of resource climate change sensitivities, exposure, and adaptive capacity), "implications" fits better with the manager-focused work described here, for both process-specific and general reasons. First, it is the term that NPS planners use to characterize potential resource response to anthropogenic threats, and thus fosters integration with other NPS planning processes not concerned with climate change. Second, its neutrality helps participants readily imagine both negative and positive resource change. Third, its more intuitive distinction (compared with

of WRST resources and management foci during late-2021 climate-resource scenario development. These adaptation strategies are one of the bases of the RSS.

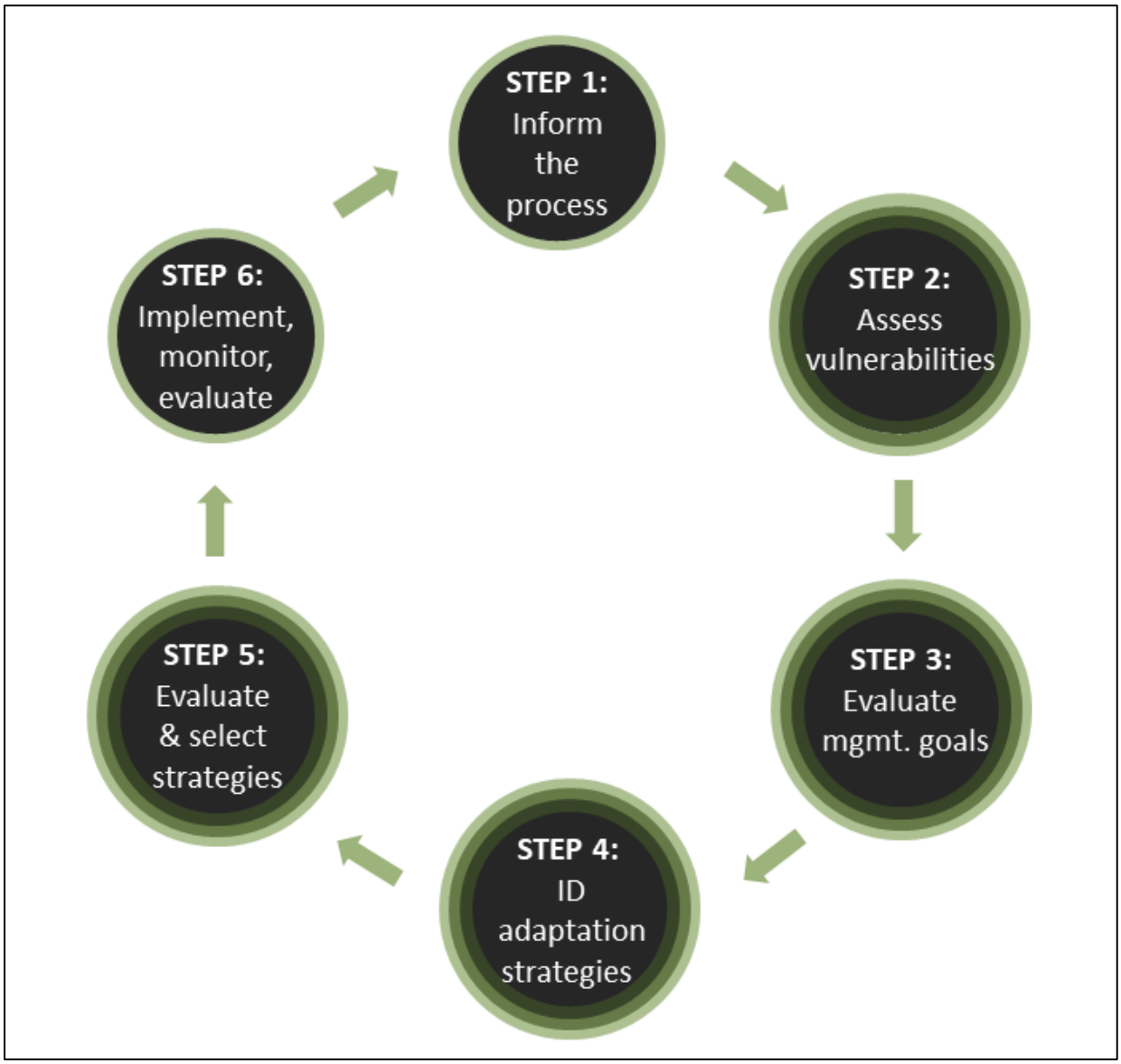


Figure 1. Generalized representation of the NPS climate change adaptation process. Concentric rings around Steps 2–5 represent consideration of multiple climate-resource scenarios (NPS 2021). Figure prepared by K. Thomas.

"vulnerabilities") from the term "sensitivities"—a term used prominently at the outset of the scenario planning process—helps participants avoid confusion between two important steps in the process.

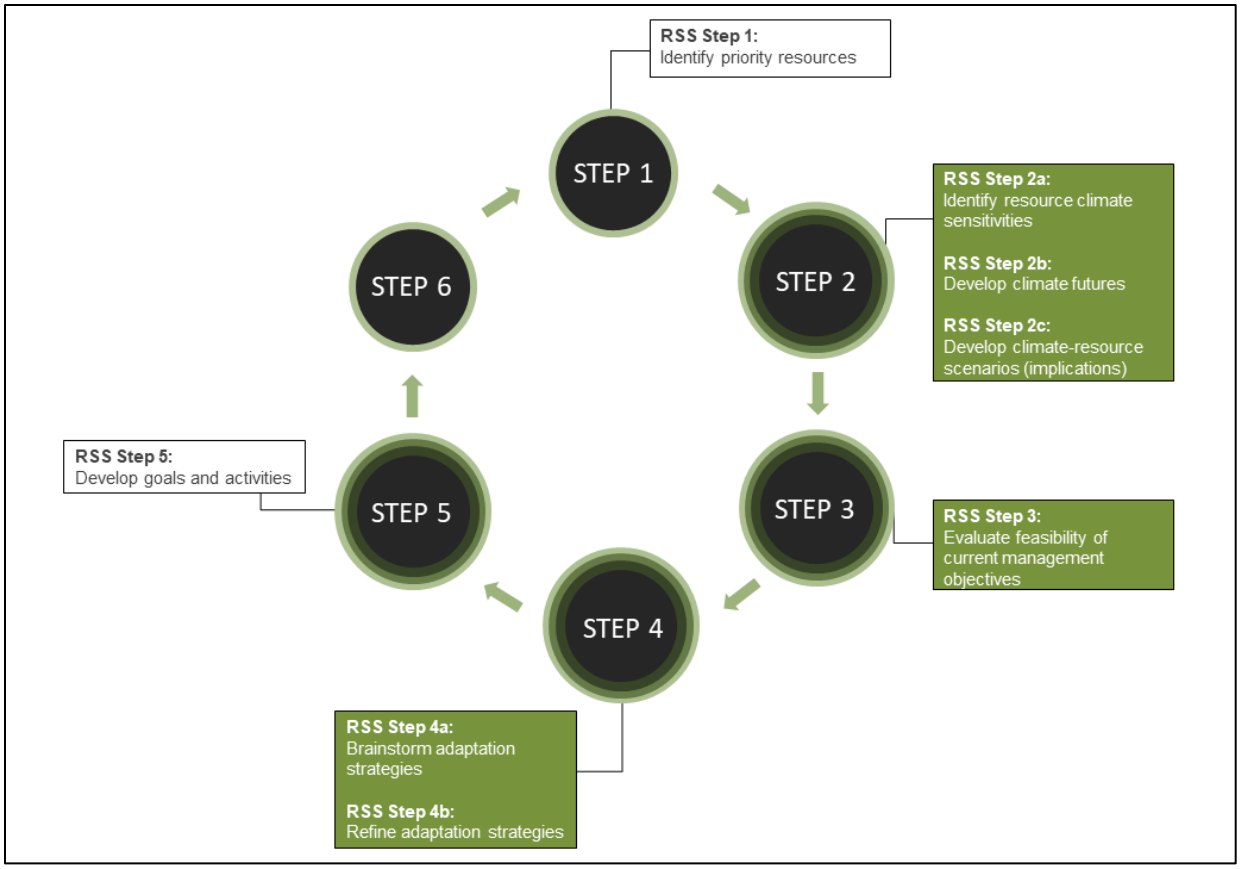


Figure 2. The WRST RSS development process (boxes), mapped to corresponding general NPS climate change adaptation steps (circles; Figure 1). Initial and final steps of the RSS process (white boxes) were conducted by the NPS Denver Service Center planning team and intermediate steps (green boxes) were led by the climate change team[3]. Adaptation strategy development (Step 4)—the focus of this report—shows the two strategy-development sub-steps for the park, each of which involved a workshop and post-workshop participant work. In this report, an adaptation strategy for a particular resource includes one or more climate-informed management objectives with associated actions (sometimes organized under sub-objectives; see Figure 3).

[3] The climate change team included scientists and adaptation specialists from the NPS Climate Change Response Program (CCRP) and the U.S. Geological Survey (USGS) North Central Climate Adaptation Science Center (NC CASC) for all climate change team-led steps, and from the USGS Alaska Climate Adaptation Science Center (AK CASC) for Steps 2 and 3.

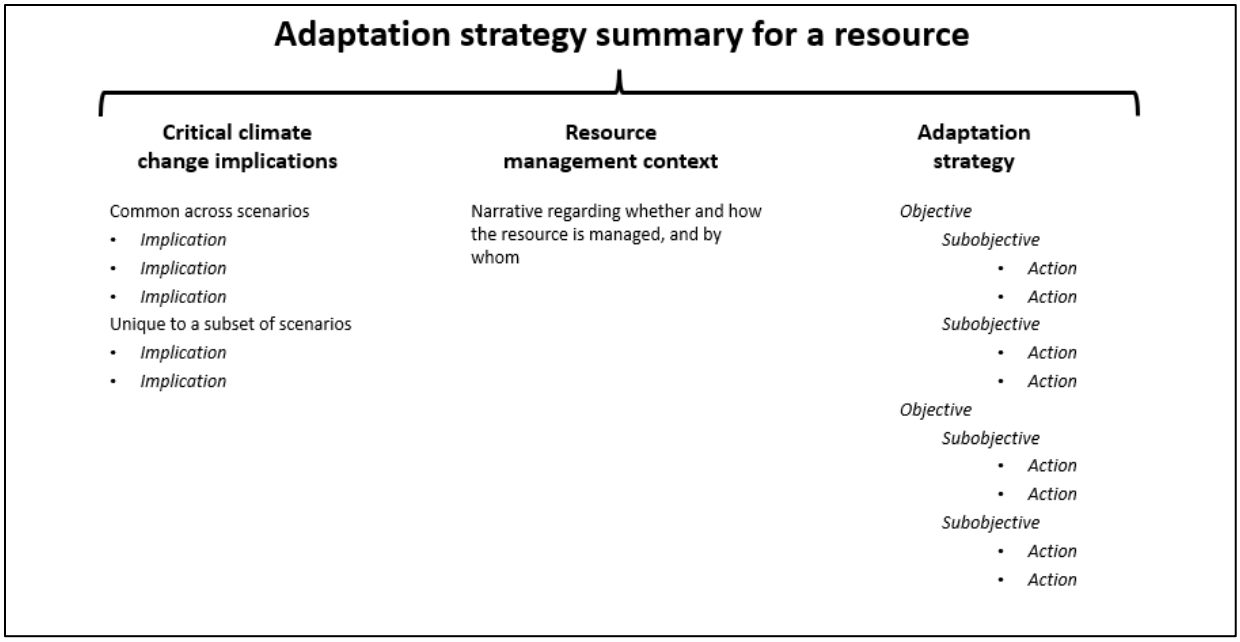


Figure 3. Components of a climate change adaptation strategy summary. A climate change adaptation strategy addresses critical implications identified during climate-resource scenario development (see Figure 4), within the context of how and by whom the resource is directly managed or monitored. This report provides an adaptation strategy summary for each resource.

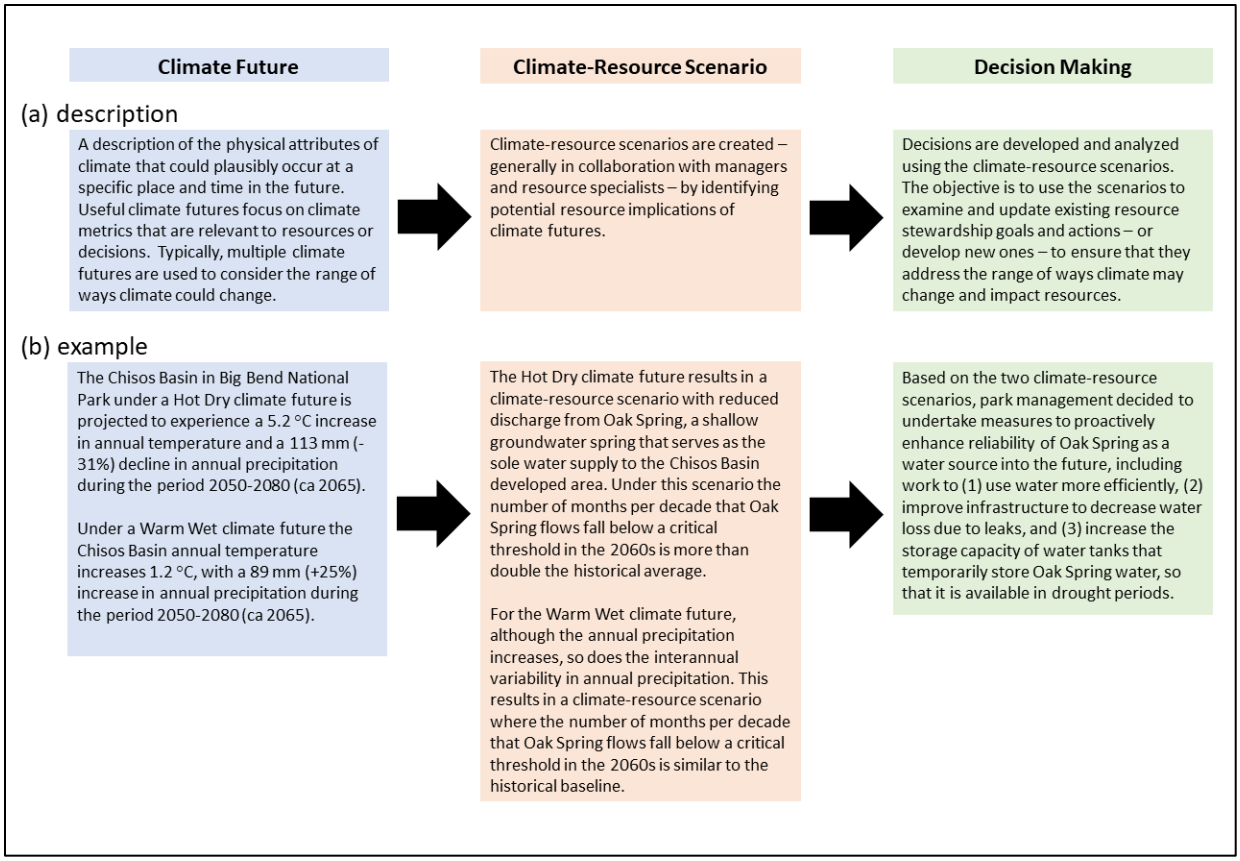


Figure 4. The roles of climate futures and climate-resource scenarios in supporting climate change adaptation. (a) After focal resources have been identified (Step 1 in the NPS adaptation process; Figure 2), the adaptation planning process continues by developing resource-relevant climate futures and building them out into climate-resource scenarios based on scenario-specific resource implications (Step 2), then evaluating feasibility of current management objectives across the scenarios (Step 3) and, ultimately, developing adaptation strategies to inform decision making (Steps 4 and 5). (b) The WRST RSS development process was ongoing at the time of this report's publication, but the Big Bend National Park water development decision process presented here illustrates the full progression of these steps (Lawrence and Runyon 2019; figure adapted from Lawrence et al. 2021). For more details on using scenario-based climate change adaptation to inform resource stewardship, see Runyon et al. 2020 and Miller et al. 2022.

The WRST climate-resource scenarios and the scenario development process are described in detail in a companion report entitled *Climate-Resource Scenarios to Inform Climate Change Adaptation in Wrangell-St. Elias National Park and Preserve* (Runyon et al. 2024). Use of scenario-based climate change adaptation to support natural and cultural resource stewardship in the NPS is abundantly illustrated on the NPS scenario planning showcase website as well (NPS 2023). Climate-resource scenarios based on plausible climate futures[4] (Runyon et al. 2020; Lawrence et al. 2021) can help

[4] Climate futures are "descriptions of the physical attributes of plausible future climates that could occur at a specific place and time" (Lawrence et al. 2021). Climate models produced by institutions around the world provide

managers identify and plan around change in resource conditions, as illustrated in Figure 4. Diverse complementary and alternative approaches exist for scenario-based resource stewardship and climate change adaptation (Rowland et al. 2014; Star et al. 2016), each with distinct strengths. More academic approaches structured around social science research and evaluation, for example, can help improve methods and expand theoretical underpinnings; such structured decision making can be an important complement where decision making is more dispersed and competing views exist regarding the value and uses of resources (Martin et al. 2009)[5]. For a busy park like WRST where staff resources are stretched, costs and benefits must always be balanced and the simple, pragmatic approach pursued here was a good fit. The adaptation strategy development process used here is flexible and can also address implications identified via non-scenario-based approaches.

For each resource, this report presents an *adaptation strategy summary* that includes the strategy along with the following information that participants used to develop it (as illustrated in Figure 3):

1) the critical climate change implications, drawn from the WRST climate change scenario report (Runyon et al. 2024) and
2) the park resource management team's characterization of the resource's management context (i.e., whether and by whom the resource is or could be managed).

Critical implications are organized in the text as they were in the worksheets: those associated with all scenarios are presented first (e.g., "Glacier area will continue to decrease through mid-century, with most loss at lowest elevations and associated safety issues"), followed by those associated with a specific subset of scenarios (e.g., "In addition to high-water impacts on fish wheel-based harvest, low water also potentially reduces fish wheel effectiveness in some sites (scenario 2)"). All implications presented here are critical and warrant a management response, but this "two-track" presentation maintains clarity regarding which implications are likely to occur because they are associated with all scenarios, and which may only occur in a subset but are highly consequential. Both types require anticipatory adaptation but potentially call for differing strategies. In a few cases, participants made changes to critical implications at this stage for clarity or completeness, and therefore the park's implications as presented in this report are the most current.

For each resource, participants (park staff and other SMEs) used the critical implications and the management context information for that resource—along with their characterizations of how non-climate resource stressors might be affected by climate change (Runyon et al. 2024 Appendix 5)—to develop actions that the park can take to address ongoing and plausible future impacts. For wildlife

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differing—yet plausible—projections of future climate. A set of divergent climate futures drawn from these projections can therefore describe a broad range of plausible conditions and support information needs of decision makers, including understanding a spectrum of potential resource responses to climate change, developing strategies robust to that range, and avoiding highly consequential surprises.

[5] Miller et al. (2023) have recently proposed a new generalized framework – Scenario-Based Decision Analysis– that integrates scenario planning and structured decision making for resource management under climate change.

and aquatics, participants had time to go further by annotating and prioritizing among their proposed actions; those priorities are documented here with the caveat that they serve as a *within-resource* designation and not as a tool for prioritizing actions *across resources*. Criteria for priority determination were decided by participants and included degree of climate change vulnerability, opportunity for management intervention, and need to sequence actions. At this point in the process, substantial overlap between sets of adaptation actions for similar resources can prompt participants to lump categories together. In the case of wildlife and aquatics, for example, although each salmon and bear species was treated separately during climate-resource scenario development, participants in adaptation strategy development chose to work at the level of "all salmon" and "all bears" because adaptation strategies for species within each group overlapped almost completely.

An important aspect of taking action is being clear about the underlying intention in responding to the climate change-driven environmental trajectory. Participants found the resist-accept-direct (RAD) framework (Schuurman et al. 2020; Schuurman, Cole, et al. 2022) useful in helping communicate the intention of a number of actions related to natural resources and environmental trajectories. The RAD framework is a simple tool that covers the entire decision space for stewarding ecosystems experiencing strong human-driven climate impacts and facing the potential for rapid, irreversible ecological change. Simply put, a steward may **resist** the trajectory by intervening to maintain or restore current or recent ecosystem conditions, **accept** the trajectory and allow the ecosystem to change autonomously, or **direct** the trajectory towards preferred new ecosystem conditions and dynamics. The framework helps managers make informed, purposeful choices, and provides a straightforward approach to support resource collaboration across disciplines and at larger scales across jurisdictions (see the NPS CCRP RAD framework web page [https://www.nps.gov/subjects/climatechange/resistacceptdirect.htm] for additional information).

For non-living cultural resources (e.g., archeological sites, historic structures), climate change generally brings greater likelihood of degradation rather than transformation. Given this difference, the utility of applying the RAD framework to such cultural resources is still being explored. In the WRST process, participants instead applied the analogous but more experimental protect-adapt-relocate-mitigate (PARM) framework, where adaptation options could be characterized as addressing threats by (1) reducing resource exposure (protect); (2) reducing resource sensitivity (adapt); (3) removing the resource from its environmental context and accepting diminished integrity (relocate); or (4) acknowledging imminent destruction of the resource and then mitigating loss of information about it (mitigate). This experimental cultural resource model was explored here with the intent to not only use language and concepts more familiar to cultural heritage managers, but also to emphasize cultural resource management objectives and regulatory compliance requirements. The PARM framework has since evolved further but maintains similar objectives (Wright and Hylton 2022).

The work highlighted in this report—the culmination of a nearly-year-long participatory scenario-based climate change adaptation process (see Figure 5 for process details and timeline[6]), conducted entirely virtually because of the COVID-19 pandemic—was facilitated by a team of scientists and climate change adaptation specialists from the NPS Climate Change Response Program (CCRP) and the U.S. Geological Survey (USGS) North Central Climate Adaptation Science Center (NC CASC). Although this circumstance was constraining in some ways, the virtual process also provided many benefits including lower barriers to participant entry, smoother pacing, more opportunities to incorporate personal reflection and individual work, and more points in the process where facilitators could intervene to support participants or make changes. Absence of travel costs and organization of the process into a larger number of smaller steps than in the past allowed the 11 participating park resource management staff to include a large pool of partners: 46 non-WRST SMEs from the Bureau of Land Management, National Oceanic and Atmospheric Administration, U.S. Forest Service (Anchorage), USGS Alaska Climate Adaptation Science Center, Ahtna Intertribal Resource Commission, Alaska Department of Fish and Game, Prince William Sound Science Center, University of Alaska–Fairbanks, 2100 Consulting Public Benefit Corporation, NPS Alaska Region Office, NPS Central Alaska Inventory and Monitoring Network, NPS Southeast Alaska Inventory and Monitoring Network, Glacier Bay National Park and Preserve, Kenai Fjords National Park, Yukon-Charley Rivers National Preserve, and Gates of the Arctic National Park and Preserve.

[6] See also Miller et al. 2022, Schuurman et al. 2022, and Runyon et al. 2020 for additional information about the evolving NPS participatory climate change scenario planning process.

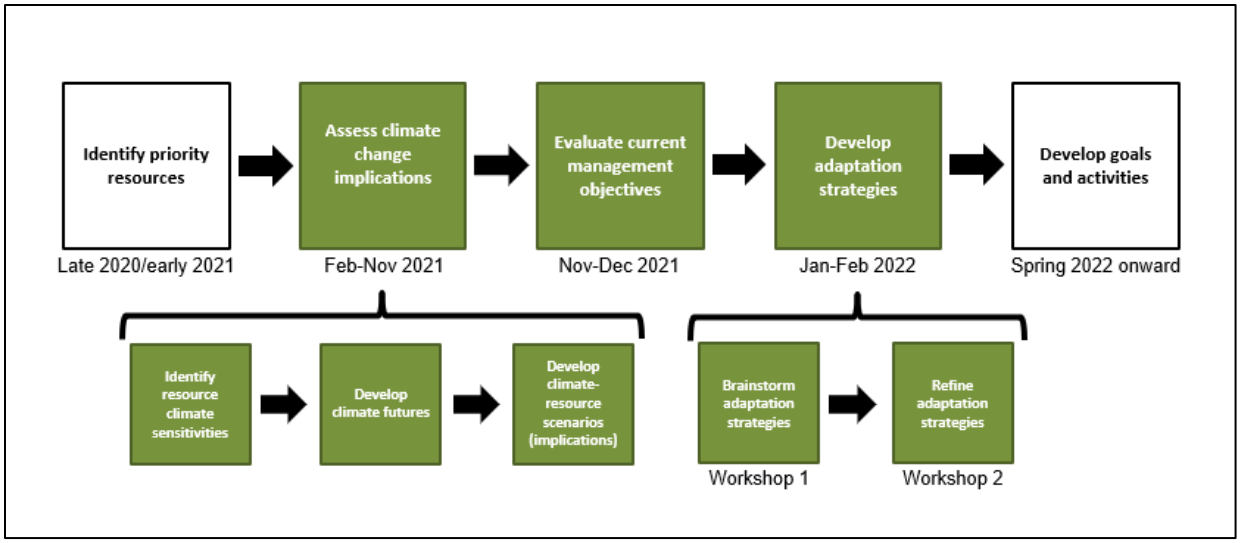


Figure 5. WRST RSS development timeline. Initial and final steps (outer white boxes) were conducted by the NPS Denver Service Center planning team and intermediate climate change scenario-planning steps (inner green boxes) were led by the climate change team. Adaptation strategy development—the focus of this report—is split out below the main timeline to show the two strategy-development sub-steps for the park, each of which involved a workshop and post-workshop participant work.[7] An adaptation strategy for a resource in this report includes one or more climate-informed management objectives with associated actions (sometimes organized under sub-objectives; see Figure 3). Appendix 1 provides a list of participants in the scenario- and adaptation strategy-development processes.

Adaptation strategies and characterizations of resource management context are presented as drafted and approved by the participants, to avoid any accidental loss of meaning arising from editing; language and structure therefore vary, to some degree, across resources.

Sequence of resource types

Information in this report is organized by resource (e.g., moose) grouped into resource types (e.g., wildlife). The vast region encompassed by the park is a complex social-ecological system that humans have inhabited for many millennia and where Alaska Native communities and other rural residents continue to engage in extensive subsistence harvest of diverse resources. Within the preserve portion of WRST specifically, sport hunting is also permitted. The order in which resource

[7] Note that the step between climate change implications assessment and adaptation strategy development—i.e., evaluation of current management objectives in light of climate-resource scenario implications (Step 3 in the adaptation cycle)—often involves a structured, "wind tunneling" approach (see van der Merwe 2008) in which the feasibility of current management goals and the efficacy of current or currently preferred activities are evaluated against the climate-resource scenarios. This step allows participants to distinguish activities or goals that need updating (to address plausible climate change implications) from those that do not, and therefore helps narrow and focus the rest of the adaptation strategy development process.

types are organized reflects this reality. The document begins with hydrological systems,[8] which are dominated by abiotic responses to climate. It then addresses the park's diverse vegetation systems, setting the biophysical stage for thinking about how the park's many other high-priority resources may be impacted not only directly by changes in climate but also by other changes in these fundamental aspects of the ecosystem. Next, the document addresses what participants called "human systems": ways that humans use, move through, and gain access to various parts of the park's vast landscape and resources. The document then moves into addressing wildlife and fish (labeled as "aquatics"), recognizing that the NPS may have common objectives for wildlife and aquatics: natural and healthy populations and subsistence-harvest opportunities. These two objectives are identified and addressed together for each resource. The document then concludes summarization of participant work by addressing cultural resources and wilderness.

Participants used numerous acronyms in developing and refining climate-informed resource management strategies, and the important acronyms—i.e., established abbreviations of names of key places, organizations, and tools—are retained in this report's resource-specific summarizations; the meaning of each is clarified in Appendix 3.

Resource-specific adaptation strategy summaries

As described above, adaptation strategy summaries for all resources follow the same format: critical climate change implications, the management context, and finally context-appropriate strategies that address the critical implications. Further, each strategy's actions are organized under categories of monitoring, research, or management,[9] with each action indicated by a solid black bullet, creating the following general structure:

Critical Implications

Critical implications that are common across scenarios:

- [Implications common across scenarios listed here]

Critical implications that are not common across scenarios:

- [Implications unique to a subset of scenarios listed here]

Management Considerations

[Description of resource management context here]

[8] This category includes cryospheric processes—i.e., processes characteristic of the frozen-water part of the Earth system—which are significant park features and ecosystem drivers and are strongly affected by climate change.

[9] Although taking management action now is important where sufficient information exists, changes in monitoring to detect potential future climate change impacts or support for new research to resolve critical uncertainties are often also important to inform future management decisions.

Adaptation Strategy

Objectives

Manage, research, and monitor [the resource] in a climate change-informed way

Sub-objectives

- [Sub-objectives listed here]

Monitoring actions

- [Monitoring actions listed here]

Research actions

- [Research actions listed here]

Management actions

- [Management actions listed here]

Some actions include important annotations (sub-bulleted and indicated by the prefix "**NOTE:**"), and high-priority actions for wildlife and aquatic resources include the prefix "**HIGH-PRIORITY:**".



Kennicott Glacier is one of the most heavily visited glaciers in Alaska, because of its proximity to roads and human communities. The glacier's volume loss and terminus retreat are representative of ongoing changes in thousands of less accessible glaciers in and around Wrangell-St. Elias National Park and Preserve. The park's glaciers have lost over 5% of their area during the past half-century, revealing deglaciated terrain that includes proglacial lakes, bedrock and glacial till, changing river channels, unstable slopes susceptible to landsliding, habitat for colonization by successional vegetation, and new migration routes for animals and routes for human travel (Loso and Larsen 2020). NPS photo by Jacob Frank.

Hydrological Systems

Glaciers

Critical Implications

Critical implications that are common across scenarios:

- Glacier area will continue to decrease through mid-century, with most loss at lowest elevations and associated safety issues
- Tidewater and lake-terminating glaciers will experience more variable and generally more rapid change
- Glacier-melt and runoff will increase through next decade, but rate of runoff post-2030 uncertain (scenario-dependent)

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Glaciers are not directly managed but are monitored to a limited extent by the NPS Central Alaska Inventory and Monitoring Network (CAKN) and by NPS Southeast Alaska Inventory and Monitoring Network (SEAN) and are frequently investigated through research conducted by external partners with authorization via NPS research permit, sometimes in collaboration with the NPS and supported by NPS project funding. This resource is a driver of other managed resources.

Adaptation Strategy

Objectives

Manage, research, and monitor glaciers in a climate change-informed way

Monitoring actions

- Monitor (including through remote sensing) the rate of change in volume and extent of glaciers
- Monitor (including through remote sensing) rate and extent of tidewater (e.g., Hubbard, Malaspina, and Yahtse) and lake-terminating (e.g., Kennicott, Tana) glacier change
    - Monitor production of icebergs by calving glaciers (marine mammals, marine traffic, marine recreation users)
    - Identify locations where glacier retreat has led (or will lead to) debutressing of slopes and landslide-generated tsunamis. Map landslide susceptibility of slopes near retreating tidewater glaciers.
- Monitor mid- and high-elevation precipitation rates to constrain currently very high uncertainty and potentially improve climate modeling and projections (to reduce future uncertainty)

Research actions

- Research rate of change in volume and extent of glacial change to anticipate effects of glacier change on park resources, visitors, infrastructure by monitoring and forecasting glacier change
    - Project when popular glacier viewing areas will not be accessible by visitors and identify which park trails (or other infrastructure) will need to be changed to adapt to glacial changes or to accommodate visitor use pattern changes
    - Identify park infrastructure that may be affected by tidewater glacier change (as seen in Glacier Bay National Park and Preserve's [GLBA's] Dry Bay)
    - Identify expected changes in user behavior as glacial lakes, glacial rivers, and other water bodies (especially accessible ones) change
    - Plan for potential impacts of enhanced cruise ship traffic at tidewater glaciers in the park as accessibility of these and other tidewater glaciers (including those outside WRST) diminish/change.
- Retain flexibility to study and monitor unique or consequential changes in a focused way appropriate to the anticipated impacts
- Document past glacier change and locations of pertinent glacial deposits

Management actions

- Communicate nature, change, and consequences of decreasing glacier volume to internal/external stakeholders and visitors
    - Timing and volume of melt
    - Provide structured documentation of effects
    - Past glacier change and locations of pertinent glacial deposits
- Identify park infrastructure and visitor travel routes that may be affected by land-terminating and tidewater glacier change (analogous to what is occurring at Dry Bay in GLBA)
- Identify management/regulatory strategies pertinent to changes in user behavior as water bodies change
- Revisit process for developing monitoring protocols that are forward-looking and can shift to study and monitor unique or consequential changes in a focused way appropriate to the anticipated impacts (e.g., 'threshold monitoring', as opposed to 'effectiveness monitoring' or 'surveillance monitoring')



Hubbard Glacier, North America's largest tidewater glacier, starts at Mt. Logan in the Yukon Territory of Canada and ends over 75 miles away in Wrangell-St. Elias National Park & Preserve. The ice calving into the sea along the glacier's six-mile-wide face fell as snow several centuries ago. NPS photo.

Glacial Rivers

Critical Implications

Critical implications that are common across scenarios:

- Increasing runoff, particularly in spring with variable peaks
- Declining navigable river ice
- Declining bank stability from erosion and extreme events

Critical implications that are not common across scenarios:

- Disappearing navigable river ice and accessibility of park via river ice may disappear
- Clear side-channel habitat blown-out by spring freshet
- Lateral erosion from mid- and late-season flood events
- Magnitude of runoff increases

Management Considerations

Rivers are not directly managed (i.e., controlled), but are monitored to a limited extent by the USGS, the National Oceanic and Atmospheric Administration (NOAA), and/or other partners, sometimes in

collaboration with the NPS supported by project funding; this resource is a driver of directly managed resources.

Adaptation Strategy

Objectives

Manage, research, and monitor glacial rivers in a climate change-informed way

Monitoring actions

- Add stream gauges to understand changing river dynamics (this information is critical for many resources in this adaptation exercise and is currently limited by a low number of stream gauges)
    - **NOTE:** Discussion deemed 'a lot of work to maintain and expensive, but important and worth advocating for'
- Groundwater monitoring to better understand surface water changes
    - Areas where and why winter base-flow is increasing
    - Near Kennicott River gauge
    - At Chitina [Copper River] gauge
- Monitor impacts of extreme events and erosion on bank stability
- Monitor impacts that large spring freshets have on habitat

Research actions

- Research specific impacts interactions of temperature changes from glacial melt and increasing air temperatures will have on runoff timing and peaks (likely to increasingly occupy remnant channels in proglacial zone, challenging access routes, potentially harming water quality in community water supply (Clear Creek), and threatening developments and infrastructure)
- Study hydrologic changes due to enhanced flows from Kennicott River and work collaboratively with Department of Transportation and community to identify mitigation strategies
- Research to understand effects of increasing glacial river discharge and frequency, magnitude of high-flow events on salmon migration/passage and/or fish condition
- Research related to changing water temperatures and water volume effects on salmon migration and spawning habitat

Management actions

- Communicate nature, change, and consequences of increasing runoff from glacial melt to internal/external stakeholders and visitors
    - Timing and volume of high flows/runoff
    - Provide structured documentation of effects (more structured than current documentation)

    - Communicate past runoff for interpretation, infrastructure, geohazards and associated safety issues
- Accept changes to historical conditions of navigable river ice, communicate changing travel hazards, and encourage consideration of alternate travel methods and timing
- Anticipate future needs outside historical precedent and investigate using freshwater for other purposes (e.g., storage for fire suppression)



The Tebay River and associated wetlands. NPS photo by Jacob Frank.

Non-Glacial Rivers and Streams

Critical Implications

Critical implications that are common across scenarios:

- Increasing length of ice-free season

Critical implications that are not common across scenarios:

- Increasing stream discharge and frequency and magnitude of high-flow events
- Channel instability or disruption

Management Considerations

Non-glacial streams are not directly managed, but monitored to limited extent by CAKN and SEAN and may be investigated through research conducted by external partners with authorization via NPS research permit; this resource is a driver of managed resources

Adaptation Strategy

Objectives

Manage, research, and monitor non-glacial rivers and streams in a climate change-informed way

Monitoring actions

- Add stream gauges to understand changing river dynamics (this information is critical for many resources in this adaptation exercise and is currently limited by a low number of stream gauges)
    - Identify criteria and prioritize locations for additional stream gauges
- Identify criteria and prioritize locations to monitor impacts of extreme events and erosion on bank stability
- Identify criteria and prioritize locations to monitor impacts of thawing permafrost on bank stability, turbidity, etc.
- Monitoring near placer mining operations: changes in flow regime at Gold Hill (for example) could lead to expansion/contraction of feasible mining season or technology, with associated potential impacts on water quality and other resource concerns
- Monitor change in National Creek and other streams in Kennecott area for declines in available water

Research actions

- Research activities to understand interactions between precipitation change and air temperature changes and effects on stream temperatures
- Understand the degree to which increased infiltration into groundwater from permafrost thaw leads to increased baseflow and warmer water entering streams to create winter refugia (and cooler water entering streams to create summer refugia)
- Research related to changing water temperatures and water volume effects on salmon migration and spawning habitat

Management actions

- Accept changes to historical conditions of navigable river ice, communicate changing travel hazards, and encourage consideration of alternate travel methods and timing
- Plan management activities associated with Nabesna Road flooding and access
- Plan management activities associated with potential for insufficient National Creek flows (e.g., Drilling wells at Kennecott Mines National Historic Landmark, trucking water)



Lake in the Donoho Basin. NPS photo by Jacob Frank.

Lakes

Critical Implications

Critical implications that are common across scenarios:

- Outburst floods and ongoing and increasing hazards
- Changing shape, size, and volume of lakes
- Reduced habitation for cold-tolerant species
- Forming of new scour lakes

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Lakes are not directly managed, but monitored to limited extent by CAKN and may be investigated through research conducted by external partners with authorization via NPS research permit; this resource is a driver of managed resources.

Adaptation Strategy

Objectives

Manage, research, and monitor lakes in a climate change-informed way

Monitoring actions

- Monitor changing lake levels (especially in relation to salmon spawning)
- Monitor changes in extents and locations of glacier-dammed and proglacial lakes, and their implications for hazards to visitors and infrastructure

Research actions

- Research changing lake levels and temperature (especially in relation to salmon spawning)
    - Develop criteria for prioritizing and selecting which lakes to monitor
    - Engage with partners to monitor and research changing lake levels
        - **NOTE:** First, develop criteria for prioritizing and selecting which lakes to monitor, and especially consider in relation to salmon spawning (contributed by Mark Miller)
    - Determine salmon impacts
- Research on cold-tolerant species habitat change

Management actions

- Develop criteria for prioritizing and selecting which lakes to monitor, and especially consider in relation to salmon spawning
- Identify management/regulatory strategies pertinent to changes in recreation user behavior in proglacial lakes
- Communicate nature, change, and consequences of outburst floods internal/external stakeholders and visitors
    - Timing and volume of melt
    - Provide structured documentation of effects
    - Past glacier change and locations of pertinent glacial deposits



A small wetland along the Nabesna Road, with the Mentasta Mountains in the distance. Wetlands in the park, which cover several million acres, are dominated by sedges and mosses with grasses, forbs, and scattered shrubs. Wetland plants and wetland-associated trees in this photo include woollyfruit sedge (*Carex lasiocarpa*), bog blueberry (*Vaccinium uliginosum*), balsam poplar (*Populus balsamifera*), and black spruce (*Picea mariana*). NPS photo by Heidi Kristenson.

Wetlands

Critical Implications

Critical implications that are common across scenarios:

- Wetland habitat degradation due to trail migration (overall wetlands in WRST may increase)
- Reduced ice integrity in permafrost dominated wetlands

Critical implications that are not common across scenarios:

- Expansion of riverine wetlands
- Non-riverine and subsurface ice-perched wetlands lost

Management Considerations

Not directly managed, but monitored to limited extent by CAKN and may be investigated through research conducted by external partners with authorization via NPS research permit; this resource is a driver of managed resources.

Adaptation Strategy

Objectives

Manage, research, and monitor wetlands in a climate change-informed way

Monitoring actions

- Monitor riverine change including response to warming and increasing groundwater (from glacial melt) effects on habitat
- Monitor habitat changes due to habitat degradation and trail migration
    - Identify priority locations and variables to consider
    - Consider partnering with other agencies (e.g., U.S. Fish and Wildlife Service) with similar habitat monitoring needs
- Continue monitoring permafrost active layer depths at select locations
- Monitoring of spatial variability in trail conditions in relation to off-road vehicle (ORV) use

Research actions

- Find wetlands research partner that can identify research needs
- Use Light Detection and Ranging (LiDAR) and other remote sensing data to better monitor wetlands and do landscape analysis on trail systems (resist, accept, direct)
    - Partner with CAKN and SEAN—doing this in limited way already

Management actions

- Proactively manage trail system to anticipate consequences of permafrost degradation / thermokarst that will increase wetland extent
    - Identify locations where trail system may need to be managed differently
- Accept ice integrity reduction in permafrost dominated wetlands and communicate travel condition hazards
- Management actions related to mass movement hazards associated with permafrost thaw

Vegetation

Coastal Forests

Critical Implications

Critical implications that are common across scenarios:

- [no critical implications in this category]

Critical implications that are not common across scenarios:

- Upslope expansion
- Increased rot and disease
- Increased erosion from disturbances (wildfires, flooding, avalanches, landslides)
- Ecological transformation and emergence of novel vegetation communities
- Potential loss of unique non-forest habitats (fens and fen-related species, orchids, ferns, etc.)

Management Considerations

Not directly managed, but resource is monitored to limited extent by U.S. Forest Service (USFS) forest inventory and analysis program, and may be investigated through research conducted by external partners with authorization via NPS research permit.

Adaptation Strategy

Objectives

Manage, research, and monitor coastal forests in a climate change-informed way

Alt. Objective: Maintain vegetation composition, structure, dynamics, and spatial configuration of coastal forests

Monitoring actions

- Monitor landscape level changes over time and consider further actions as/where needed. Monitoring activities could include:
    - Upslope expansion of populations
        - Partner with U.S. Forest Service (USFS) monitoring program (Forest Inventory and Analysis [FIA], Forest Health Monitoring [FHM], etc.)
    - Unique non-forest habitats (fen and fen-related species, orchids, ferns, etc.)
    - Emergence and spread of new (and potentially invasive) plant species
        - Partner with USFS monitoring program (FIA, FHM, etc.)
    - Arrival and spread of pest infestations and disease
        - Partner with USFS monitoring program (FIA, FHM, etc.)
    - Tree rot (esp. around places of high recreational use) to determine potential risk
    - Phenological shifts (longer growing seasons, etc.)
    - Changes in frequency of disturbances

    - Changes in wildfire regimes, severity, etc.
    - Extreme change to drought (due to being historically wet areas)
    - Threshold events of coastal forest conversion to deciduous species, grasses
        - Partner with USFS monitoring programs (FIA, FHM, etc.)
- Use remote sensing technologies and inventorying methods (WorldView2, Planet Labs public Earth imaging, etc.), integrated with ground-based monitoring conducted by CAKN and others
- Maintain continuing support for installation and repeat sampling of CAKN visitation vegetation-monitoring plots and integration with CAKN landscape-level research and monitoring activities (core element of thoughtful core monitoring)
    - Complete establishment of baseline plots

Research actions

- Inventory and develop digital maps of:
    - Rare and endemic species
- Conduct research activities, triggered by threshold conversion events, to identify bottlenecks limiting forest regeneration to consider if there are activities that could be taken to extend 'lifetime' of habitat
- Identify threshold conversion events to deciduous species, grasses, or warmer climate trees
    - Work with partners (e.g., Southeast Alaska Inventory and Monitoring Network [SEAN], CAKN)
    - Potential for novel vegetation colonization in periglacial / newly deglaciated coastal areas
- Investigate if lack of forest regeneration is due to dispersal or seed limitation of local native species

Management actions

- Increase vegetation staffing
    - Prioritize hiring a vegetation ecologist
- Hold critical conversations about resist, accept, direct regarding coastal forest ecological transformation to deciduous species and grasses
    - Accept transformation to deciduous grassy landscape
    - Hold intentional discussions around the feasibility of planting/reseeding /supplementation
        - Seed in native, rare, and endemic plants, especially after large disturbance events
- Establish fire management plan that includes mechanical thinning, prescribed fires, and suppression
- Collect native, rare, and endemic seeds and develop a storage system
- If rare and endemic plant locations are mapped, limit visitation or other destructive activities in those locations

- Apply for ‘insect and disease suppression’ funding
- Remove rotted trees (esp. around places of high recreational use)



Subalpine forest in the Donoho Basin. National Creek Rock Glacier spills off Porphyry Mountain in the background. NPS photo by Jacob Frank.

Subalpine Shrublands and Woodlands

Critical Implications

Critical implications that are common across scenarios:

- Overall and upslope expansion of distributions
- Implications for wildlife (upland areas, more willow, moose; north section of WRST with alpine lichens utilized by caribou, potential loss due to shrubification
    - Note: The USGS Wildlife Potential Habitat Forecasting Project (WiLDCAST) identifies wildlife implications of shrubification

Critical implications that are not common across scenarios:

- Increased erosion from disturbances (wildfires, flooding, avalanches, landslides) with possible post-disturbance regeneration
- Possible establishment of and competition from invasive species

Management Considerations

Not directly managed, but resource is monitored to limited extent by CAKN and potentially by the USFS FIA program, and is sometimes investigated through research conducted by external partners with authorization via NPS research permit.

Adaptation Strategy

Objectives

Manage, research, and monitor subalpine shrublands and woodlands in a climate change-informed way

Alt. Objective: Maintain vegetation composition, structure, dynamics, and spatial configuration of subalpine shrublands and woodlands

Monitoring actions

- Monitor landscape level changes over time and consider further actions as/where needed. Monitoring activities could include:
    - Upslope expansion of populations and changing species dominance
        - Partner with USFS monitoring program (FIA, FHM, etc.)
    - Emergence, spread of, and increased competition with invasive plant species
    - Rates of loss of lichen species important to wildlife
    - Phenological shifts (longer growing seasons, etc.) and mismatch with wildlife
    - Changes in frequency of disturbances
- Use remote sensing technologies and inventorying methods (WorldView2, Planet Labs public Earth imaging, etc.), integrated with ground-based monitoring conducted by CAKN and others
- Maintain continuing support for installation and repeat sampling of CAKN vegetation monitoring plots and integration with CAKN landscape-level research and monitoring activities (core element of thoughtful core monitoring)
    - Complete establishment of baseline plots
- Revisit plots from 2010 Carl Creek project (permanent markers from fire-effects program) to assess changes over time
    - Plots located between shrub line and alpine

Research actions

- Inventory and develop digital maps of:
    - Rare and endemic species
    - Lichen populations (important for wildlife)
- Conduct research activities, triggered by threshold conversion events, to identify bottlenecks limiting shrubland regeneration to consider if there are activities that could be taken to extend 'lifetime' of habitat
- Investigate if lack of habitat regeneration is due to dispersal or seed limitation of local native species

Management actions

- Increase vegetation staffing
    - Prioritize hiring a vegetation ecologist
- Hold critical conversations about resist, accept, direct regarding changing subalpine shrubland and woodland populations
    - Accept changes
    - Hold intentional discussions around the feasibility of planting/reseeding /supplementation
        - Seed in native, rare, and endemic plants, especially after large disturbance events

        - Seed in lichen for wildlife to compensate for loss from shrubification
    - Explore possibility of controlling shrubification via:
        - Thinning and reducing shrubs along trail systems (e.g., ridgeline trail off McCarthy Road)
        - Prescribed burning (e.g., 2010 Carl Creek fire-effects program)
        - Introduced wildlife species (e.g., reindeer)
- Collect native, rare, and endemic seeds and develop a storage system
- If rare and endemic plant locations are mapped, limit visitation or other destructive activities in those locations



Boreal forest south of McCarthy with the Nizina River in distance. NPS photo by Neal Herbert.

Boreal Forests

Critical Implications

Critical implications that are common across scenarios:

- [no critical implications in this category]

Critical implications that are not common across scenarios:

- Increased rot and disease

- Upslope expansion
- Conversion to deciduous species or grasses
- Changes to fire regimes and increased fuel loads

Management Considerations

Managed to limited extent through implementation of fuel-reduction treatments and through enforcement of regulations and issuance of permits pertaining to noncommercial harvest of standing timber. Permitting for standing timber is mostly restricted to house log permits. Subsistence firewood harvest of standing dead is covered under a regulation that does not require a permit. Resource is monitored to limited extent by CAKN, NPS fire program, and USFS forest inventory and analysis program, and is sometimes investigated through research conducted by external partners with authorization via NPS research permit. A statewide fire management strategy identifies what regions will have fires suppressed or not, thus has large impact on WRST fire management actions/activities. Large swaths of lands have recently been changed to management strategy of 'modified fire management option' that includes more suppression (e.g., Ahtna lands being managed for carbon sequestration).

Adaptation Strategy

Objectives

Manage, research, and monitor boreal forests in a climate change-informed way

Alt. Objective: Maintain vegetation composition, structure, dynamics, and spatial configuration of boreal forests

Monitoring actions

- Monitor landscape level changes over time and consider further actions as/where needed. Monitoring activities could include:
    - Upslope expansion of populations and changing species dominance
    - Increased competition among all plant species
    - Emergence, spread of, and increased competition with invasive plant species
    - Arrival and spread of pest infestations and disease
    - Tree rot (esp. around places of high recreational use) to determine potential risk
    - Phenological shifts (longer growing seasons, etc.)
    - Changes in frequency of disturbances
        - **NOTE:** Look into structure-from-motion lessons learned from Denali National Park and Preserve (DENA) and lessons learned from Burned Area Emergency Response regarding effective mitigation actions around erosion control
    - Fire activity to determine regime changes
    - Threshold conversion events to deciduous species, grasses, or warmer climate trees
        - Work with partners (e.g., CAKN)

- Use remote sensing technologies and inventorying methods (WorldView2, Planet Labs public Earth imaging, etc.), integrated with ground-based monitoring conducted by CAKN and others
- Maintain continuing support for installation and repeat sampling of CAKN vegetation monitoring plots and integration with CAKN landscape-level research and monitoring activities (core element of thoughtful core monitoring)
    - Complete establishment of baseline plots

Research actions

- Inventory and develop digital maps of:
    - Rare and endemic species
- Conduct research activities, triggered by threshold conversion events, to identify bottlenecks limiting forest regeneration to consider if there are activities that could be taken to extend 'lifetime' of habitat
- Identify threshold conversion events to deciduous species, grasses, or warmer climate trees
    - Work with partners (e.g., the NPS Arctic Inventory and Monitoring Network [ARCN], CAKN)
- Investigate if lack of forest regeneration is due to dispersal or seed limitation of local native species

Management actions

- Increase vegetation staffing
    - Prioritize hiring a vegetation ecologist
- Hold critical conversations about resist, accept, direct regarding boreal forest ecological transformation to deciduous species, grasses, or warmer climate trees
    - Accept transformation to deciduous landscape
    - Adapt to having lodgepole pine
        - Understand lodgepole fire regime
        - Adopt new fire management strategies
    - Under special circumstances, if a habitat will be lost or converted to highly unfavorable circumstances, consider supplementing habitat with native species (e.g., at severe post-burn locations)
    - Hold intentional discussions around the feasibility of planting/reseeding /supplementation
        - Seed in native, rare, and endemic plants, especially after large disturbance events
- Establish fire management plan that includes mechanical thinning, prescribed fires, and suppression
    - Identify site-specific fire risk mitigation measures
- Collect native, rare, and endemic seeds and develop a storage system

- If rare and endemic plant locations are mapped, limit visitation or other destructive activities in those locations
- Apply for 'insect and disease suppression' funding
- Remove rotted trees or beetle killed hazard trees (esp. around places of high recreational use)



Hikers in the alpine tundra. NPS photo by Jacob Frank.

Alpine Tundra

Critical Implications

Critical implications that are common across scenarios:

- Reduction from shrubification and boreal forest encroachment
- Reduction and/or extirpation of rare plant species

Critical implications that are not common across scenarios:

- Conversion to drier plant communities
- Erosion from increased slides and slumps due to thermokarst

Management Considerations

Not directly managed, but resource is monitored to limited extent by Central Alaska vegetation inventory and monitoring program and potentially by USFS forest inventory and analysis program,

and is sometimes investigated through research conducted by external partners with authorization via NPS research permit.

Adaptation Strategy

Objectives

Manage, research, and monitor alpine tundra in a climate change-informed way

Alt. Objective: Maintain vegetation composition, structure, dynamics, and spatial configuration of alpine tundra

Monitoring actions

- Monitor landscape level changes over time and consider further actions as/where needed. Monitoring activities could include a focus on:
    - Increased shrubification and forest encroachment
    - Rates of loss of lichen species important to wildlife
    - Rates of loss of rare and endemic plants
    - Phenological shifts (longer growing seasons, etc.) and mismatch with wildlife
    - Changes in frequency of disturbances
    - Threshold conversion events to drier alpine tundra community
        - **NOTE:** Drier conditions tend to lead to more abundant lichen communities (takes over scree/talus habitats)
- Use remote sensing technologies and inventorying methods (WorldView2, Planet Labs public Earth imaging, etc.), integrated with ground-based monitoring conducted by CAKN and others
- Maintain continuing support for installation and repeat sampling of CAKN vegetation monitoring plots and integration with CAKN landscape-level research and monitoring activities (core element of thoughtful core monitoring)
    - Complete establishment of baseline plots
    - Consider installing Global Observation Research Initiative in Alpine Environments (GLORIA) plots
- Revisit plots from 2010 Carl Creek project (permanent markers from fire-effects program) to assess changes over time
    - Plots located between shrub line and alpine

Research actions

- Inventory and develop digital maps of:
    - Rare and endemic species
    - Lichen populations (important for wildlife)

- Conduct research activities, triggered by threshold conversion events, to identify bottlenecks limiting tundra regeneration to consider if there are activities that could be taken to extend 'lifetime' of habitat
- Identify threshold conversion events to drier alpine tundra community
    - **NOTE:** Drier conditions tend to lead to more abundant lichen communities (takes over scree/talus habitats)
- Investigate if lack of habitat regeneration is due to dispersal or seed limitation of local native species

Management actions

- Increase vegetation staffing
    - Prioritize hiring a vegetation ecologist
- Hold critical conversations about resist, accept, direct regarding loss of alpine tundra
    - Accept loss of alpine tundra and associated species
    - Hold intentional discussions around the feasibility of planting/reseeding /supplementation
        - Seed in native, rare, and endemic plants, especially after large disturbance events
        - Seed in lichen for wildlife to compensate for loss from shrubification
- Collect native, rare, and endemic seeds and develop a storage system
- If rare and endemic plant locations are mapped, limit visitation or other destructive activities in those locations

Berries

Critical Implications

Critical implications that are common across scenarios:

- Upward shift in distributions of berry-producing species, recognizing limitations by soil type and tradeoffs between temperature and precipitation
- Loss of tundra berry-producing species
- Phenological mismatch of harvest times and changing access for berry-producing species
- Phenological mismatch of pollinators & berry-producing plants

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Berry production is not monitored per se, but the distribution and abundance of key berry-producing species are monitored to a limited extent by Central Alaska vegetation inventory and monitoring program, and additional monitoring or scientific research may be conducted by NPS or external partners, potentially authorized by NPS research permit (contingent on location and authority), and possibly in collaboration with the NPS by project funding. Levels and adequacy of subsistence

harvest may be investigated through community harvest surveys and/or research conducted by external partners and/or the NPS, potentially supported by NPS project funding. Access may be managed through enforcement of regulations, contingent on particular circumstances and authority.

Adaptation Strategy

Objectives

Manage, research, and monitor berries and berry harvest in a climate change-informed way

Alt. Objective: Maintain vegetation composition, structure, dynamics, and spatial configuration of berries and berry harvest

Monitoring actions

- Monitor landscape level changes over time and consider further actions as/where needed. Monitoring activities could include:
    - Changes in abundance, composition, distribution, and production of berry-producing species, in particular tundra species
        - **NOTE:** There has been some research on this funded by former Landscape Conservation Cooperatives and AK CASC, but the study focused on Yukon-Kuskokwim Delta /central Interior (contact Jeremy Littell, USGS, for details)
    - Upslope expansion of populations
    - Potentially increased competition by local and new invasive plant species
    - Phenological shifts and mismatches regarding harvest and pollinators
    - Changing access to harvest (e.g., newly open/closed trails and waterways)
- Use remote sensing technologies and inventorying methods (WorldView2, Planet Labs public Earth imaging, etc.), integrated with ground-based monitoring conducted by CAKN and others
- Maintain continuing support for installation and repeat sampling of CAKN visitation vegetation-monitoring plots and integration with CAKN landscape-level research and monitoring activities (core element of thoughtful core monitoring)
    - Complete establishment of baseline plots

Research actions

- Fires can be beneficial for berry production and to slow shrubification—do experimental testing or observational studies to better understand the type/degree/intensity of fire that benefits berry production
- Conduct pollinator surveys to identify mismatches with berry-producing species

Management actions

- Hold critical conversations about resist, accept, direct regarding changing distributions and loss of berry-producing species

    - Accept changes in the distribution and productivity of tundra berry-producing species, and consider implications for priority wildlife and subsistence users, including implications for adaptive changes in locations, timing, or means of access by subsistence users
    - Manually remove shrubs to reduce competition with berry-producing species
    - Hold intentional discussions around the feasibility of planting/reseeding /supplementation
        - Plant berry-producing species in heavily used subsistence areas
- Ensure that questions about patterns in berry harvest are incorporated in community harvest surveys



Hiking and backpacking are important ways to experience this rugged and remote park. NPS photo by Jacob Frank.

Human Systems

Recreating/Backcountry Use

Critical Implications

Critical implications that are common across scenarios:

- Mountaineering shifting to earlier-season—earlier staffing needs
- Enhanced melt-season river flows causing increased drowning risk for travelers

Critical implications that are not common across scenarios:

- Increasing mountaineering incidents as routes change and past information becomes less reliable
- Intensified need for trails
- More concentrated visitor use
- Variable early and late-season risks associated with river crossing

Management Considerations

May be managed through regulations and issuance of permits, contingent on potential nexus with State of Alaska authority.

Adaptation Strategy

Objectives

Manage, research, and monitor recreating and backcountry use in a climate change-informed way

Actions

- Establish a larger backcountry planning effort
- Shift staffing to earlier season
- Communicate hazards of mountaineering to users (historical mountaineering routes will become less reliable)
    - Develop staff capacity in mountaineering area
        - Improve park involvement in mountaineering patrols to acquaint park staff with conditions in various locations
        - Offer safety briefings for backcountry users (have better controls, both in terms of monitoring data and understanding who is in backcountry)
    - Increase search and rescue (SAR) staffing
- Communicate hazards of river crossings to users (increased waterways and flows)
    - Adopt signage warning users to avoid hazardous areas
    - With changing river levels / growth of pro-glacial lakes, scale of waterway usage can drastically change, and "difficulty" of access can no longer be a form of "regulation"; need to consider future ability to regulate access on navigable rivers

        - More river flow gauges, esp. areas w/ travel nexus
    - Increase SAR staffing
- Work with private/commercial groups to create forum for sharing backcountry conditions / information
- Hold critical conversations about what park wants to do about loss of trails/changing trail systems (resist, accept, direct, etc.). Options could include:
    - Maintain existing trails vs. creating of new trails
    - Recognize trails will become critical access for visitors/backcountry users, especially where brush thickens, choking off access between valleys and alpine areas
    - Consider broader spectrum of trails (more types of trails that require less maintenance but keep opportunities available, e.g., non-ORV trails)
    - Consider how much park must be beholden to past precedent on trails (where they are, what types they are, etc.)
    - Increase staffing for trail maintenance
    - Accept loss of trails, update maps/signage
    - Discuss trail needs with partners (potential Resource Stewardship Strategy [RSS] activity)
- Manage impacts to the limited number of portals due to increased concentration of visitors
    - Educate visitors about leave no trace
    - Increase number or extent of campsites



Taking off from a landing strip in the Bremner Historic Mining District. NPS photo by Jacob Frank.

Aviation Use

Critical Implications

Critical implications that are common across scenarios:

- Highly variable (temporally and spatially) snow and ice conditions make landing more challenging/hazardous
- Increased tourism/extraction and associated flying
- Longer summer season

Critical implications that are not common across scenarios:

- More fires disrupt summer flying season except for fire suppression/monitoring
- Increasing shrubification of landing sites (may lead to decline in fixed-wing aircraft landings, or decreased number of landing sites)
- Increased gravel bars rearranging existing airstrips (creating new ones or washing out existing ones)

Management Considerations

Overflights are not managed due to lack of NPS authority to regulate air space, but landings may be managed through enforcement of regulations and issuance of permits, contingent on potential nexus

with State of Alaska authority. Special use permits are issued for research/rescue helicopter landings. Very limited fixed wing aircraft permitting by park.

Adaptation Strategy

Objectives

Manage, research, and monitor aviation use in a climate change-informed way

Monitor Actions

- Gather information on temporal and spatial aircraft use (potentially through Automatic Dependent Surveillance–Broadcast)

Research Actions

- Map airstrips
    - **NOTE:** Park has pursued this and has decent maps, but it tends to get complicated quickly (with regard to the Department of the Interior's Office of Aircraft Services [OAS], fleet use, vendor use, user-conflicts, pilot skill variability). In short, this is something that the park already keeps track of and will continue to do so.

Management Actions

- Management decisions and actions from park leadership about the role the park plays in promoting/maintaining/supporting aircraft access
    - Create new process to create new airstrips (due to increased gravel bars). Without mechanism to replace, repair or make decisions about locations, there will be net loss of airstrips (with implications on solitude from use concentration)
    - More frequent maintenance of airstrips from shrubification
        - **NOTE:** Question of how aggressively want to market, institutionalize, and maintain particular airstrips versus recognizing that as landscape changes airstrips change
    - Be less heavy-handed in description of airstrips so pilots are encouraged to find other strips when shrubification overtakes existing airstrips
    - Consider process for allowing pilots to maintain existing airstrips or develop new airstrips (cutting down trees, moving dirt, etc.)
    - Be thoughtful in planning process about actions that harden an attachment to a particular landing zone for spring skiing/mountaineering and retain adaptability by remaining open to new landing zones
- Switch to more helicopter use for administrative use
- Switch to more float plane use and communicate with public that it is preferred due to shrubification

- Promote Federal Aviation Administration Aviation Weather Cameras[10]
- Use information about different airsheds, to inform users about where wildfire smoke is relative to where they want to fly
- Identify better ways to communicate wildfire conditions to keep the public safe and away from hazardous places
    - Aviation-specific venues
    - Investigate partnerships to help with info sharing
    - Encourage shifting visitation (take advantage of longer visitation seasons) away from fire season
- Plan ahead to recognize that FirePro helicopter may be less available for resource/law enforcement/maintenance project work (because of increased fire frequency), possibly requiring alternate aviation option.
- Obtain exclusive use helicopter or establish strong partnership with someone that has one
- Increase staffing capacity to accommodate shifting visitation (to avoid high fire season, or shifting mountaineering season)
- Investigate potential need for growth in lodging
- Add SAR capacity to accommodate increasing hazards related to more variable (temporally and spatially) snow and ice conditions

Snow Machine, ORV (Off-Road Vehicle), and Watercraft Use

Critical Implications

Critical implications that are common across scenarios:

- Changing snow machine/watercraft/ORV suitability/opportunities are likely (increasing or decreasing, dependent on scenario and seasonality)
- Expansion of jetboat/watercraft opportunities (although any expansion seems likely to be relatively small)
- New watercraft opportunities due to expansion of proglacial lakes

Critical implications that are not common across scenarios:

- Increasing risk of snow machine accidents (due to warmer shoulder-seasons, ice instability, worsening avalanche conditions)
- New watercraft hazards that vary spatially

[10] https://weathercams.faa.gov/

Management Considerations

Notes on snowmachine/ORV management: May be managed through enforcement of regulations, designation of trails that are open to recreational ORV use, and issuance of ORV permits—contingent on nexus with State of Alaska authority over rights-of-ways.

Notes on jetboat/watercraft management: May be managed to limited extent through enforcement of regulations and issuance of permits, contingent on nexus with State of Alaska authority over navigable waters or potential State authority over waters that may be determined navigable. Overall, not much done in terms of issuing permits for watercraft use.

Adaptation Strategy

Objectives

Manage, research, and monitor snow machine, off-road vehicle, and watercraft use in a climate change-informed way

Monitor Actions

- Assess capacity for future monitoring
- Monitor shifting avalanche windows
- Monitor and update watercraft portal information

Research Actions

- Conduct connectivity modeling or develop/collect more information on spatial extent of where snowmachine/watercraft/ORV can move (information gathering)
- Identify areas with more/less stable ice conditions for users, in connection with Dana Brown's river ice condition project (https://fresheyesonice.org/)
- Put in more river flow gauges to establish a baseline now to better monitor change, particularly in areas that have nexus with backcountry/travel uses; potentially provide public access to the real-time data
- Investigate how changing technologies will affect forms of movement (e.g., standup paddle boards [SUPs], advanced snowmachine technologies, amphibious ORVs, etc.), which will allow users to have more access

Management Actions

- Develop backcountry plan to prioritize management tools (if going to prioritize)
- Recognize changing snow machine/watercraft/ORV suitability and opportunities
    - Develop materials (online, signage, brochures, etc.) to communicate changing suitability and opportunities of use to direct users to appropriate transport
        - Announce snow conditions (have announcement of places with hazards or redirecting to places with best snow coverage)
    - Develop/investigate different trail construction techniques for ORV use

    - Adjust ORV permitting, contingent on nexus with State of Alaska authority over rights-of-ways
    - Potentially build bridges
        - Unlikely, but identify criteria for developing bridges/crossings (e.g., high use trail crossings, esp. with environmental benefit as well (e.g., anadromous stream crossings)
- Recognize increased hazards / risks of snow machine accidents
    - Offer pre-trip briefings for visitors (could consider mandating)
    - Develop materials to direct users to avalanche education opportunities
    - Increase SAR staffing during winter/spring
- Recognize increased hazards / risks of watercraft accidents that vary spatially
    - Adopt signage warning users to avoid hazardous areas
        - At portals or airstrips, post up-to-date info (if exists) or common hazards to look for
    - Offer pre-trip briefings for visitors (could consider mandating)
    - With changing river levels / growth of pro-glacial lakes, scale of waterway usage can drastically change, and "difficulty" of access can no longer be relied upon as a de facto way to limit access; need to consider future needs (if any) to regulate access on navigable rivers and lakes
        - More river flow gauges, esp. areas w/ travel nexus
    - Increase SAR staffing
- Transition to new (more automated) reporting system
    - **NOTE:** Commercial Use Authorization (CUA) holders provide annual use reports, however, it is imperfect for gathering monitoring data. Need to transition to new (more automated) reporting system. Have poor data on private users



Moose cow near park headquarters. Moose are an important subsistence resource in Wrangell-St. Elias and throughout much of Alaska. NPS photo.

Wildlife[11]

Moose

Critical Implications

Critical implications that are common across scenarios:

- Modest abundance increases or decreases are possible—depending on the relative influences of different climate change impacts
- Large declines in abundance and quality of the resource (meat and hide) if climate changed enough to allow establishment of a novel (to WRST moose) parasite or pathogen (e.g., winter tick in western Canada moves north, or deer introduce brain worm and/or liver fluke as seen in northern Minnesota)
- Harvest ease and opportunities decline due to high water at stream crossings

Critical implications that are not common across scenarios:

- Harvest opportunities and ease decline substantially due to soggy trails (scenarios 1 & 3) and widespread permafrost thawing and shrubification (scenario 3), but higher water levels make boat-based harvest easier
- Harvest opportunities and ease remain good due to dry trails (scenario 2), although (as in scenarios 1 and 3) stream crossings still become more difficult (due in scenario 2 to enhanced glacial melt)
- Increasing meat-care challenges due to a combination (in scenario 2 and especially scenario 3) of warming temperatures and declines in ease of ORV-based harvest leads to a shift in subsistence harvest 1) towards cooler end of season and 2) towards more road-, boat-, and aviation-based harvesting

Management Considerations

Biota: Moose are monitored to limited extent by the State of Alaska, NPS CAKN, and NPS WRST (separate from CAKN surveys), and may be subject to additional monitoring or scientific research conducted by the state of Alaska, NPS, or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), potentially in collaboration with the NPS supported by NPS project funding.

Sport / Subsistence harvest: The Superintendent has the authority to establish the harvest quota for the winter federal subsistence hunt of moose in Game Management Unit 11, in consultation with the Alaska Department of Fish and Game, and to close the season when the quota is reached. Harvest also may be affected indirectly through park recommendations concerning State and/or Federal regulations, and through enforcement of Federal subsistence regulations. Levels and adequacy of

[11] As noted above in the introduction, participants who worked on wildlife (and aquatics) resource types annotated and prioritized among their proposed actions for each resource; those priorities are documented here with the caveat that they serve as a within-resource designation and not a tool for prioritizing actions across resources.

subsistence harvest may be investigated through community harvest surveys and/or research conducted by external partners and/or the NPS, potentially supported by NPS project funding. Access may be managed through enforcement of regulations and potentially through issuance of permits, contingent on particular circumstances and authority. Permit issuance is based on meeting basic eligibility requirements and doesn't necessarily provide the park with an ability to affect harvest. Both state and federal permits or harvest tickets come with a requirement to submit a harvest report, which is a regular source of information about harvest and effort.

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage moose abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level moose populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional and park-level abundances and trends, including reviewing and updating monitoring methods, if necessary—for example, consider following the lead of Northwest-Alaska parks and switching from fall to spring population surveys in response to declining fall snow (recognizing the loss of data on bull:cow ratios through this method)—to ensure that they are robust to projected changes in climatic conditions and sensitive to important potential climate change effects on the species.
    - **NOTE:** In the context of increasingly later snow season onset, fall surveying is more and more difficult to do (because day length is too short by the time sufficient snow covers the ground); spring surveys produce a more accurate population number but do involve the compromise of not being very good for quantifying bull:cow ratios, so expectations would need adjustment
- Increase awareness of regional climate change-driven pest/pathogen dynamics and trends
- Increase park-level monitoring for climate change-driven changes in pest/pathogen dynamics and impacts (e.g., monitoring for winter tick, chronic wasting disease, etc.), including working with Alaska Department of Fish and Game and hunters to obtain/develop baseline and trend info
- Identify and monitor key elements of habitat if climate change-driven population changes are larger than anticipated

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's moose population

Research actions

- **HIGH PRIORITY:** Foster research (i.e., scenario-based climate change vulnerability assessment) to better understand the nature, likelihood, and population-level consequences of potential future climate change-driven changes in WRST moose pest/pathogen dynamics
- **HIGH PRIORITY:** Work with NPS and outside collaborators to assess recent wildfire history in relation to moose distributions and populations trends and interpret findings in the context of wildfire implications in WRST climate-resource scenarios and findings from ongoing wildfire-climate research
    - **NOTE:** New research at Yukon-Charley Rivers National Preserve finds an increasing trend in moose abundance linked to wildfire abundance
- Work with NPS and outside collaborators to assess and map snow and ice conditions in relation to moose distributions and population trends and interpret findings in the context of WRST climate futures

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST moose population

Management actions

- **HIGH PRIORITY:** Engage with the Federal Subsistence Board, the Alaska Board of Game, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees and — if pest/pathogen climate change vulnerability assessment and other research or regional trends suggest strong possibilities of major WRST population declines — conduct an inclusive process to identify preferred management responses (e.g., RESIST or ACCEPT the trend) and triggers for application and be prepared to recommend changes to harvest regulations
    - **NOTE:** Working towards adjustment of harvest regulations is a high priority if populations decline

Harvest management objective: Monitor, study, and manage moose harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in moose harvest access and ease

Monitoring actions

- Monitor changing harvest access (e.g., newly open/closed trails and waterways and impacts of permafrost thaw) and ease
    - **NOTE:** Means of access, in a general sense, is included in harvest reports

Research sub-objective: Better understand how climate change might affect moose harvest access and ease

Research actions

- **HIGH PRIORITY:** Support research to investigate how climate change, particularly warming temperatures, might influence WRST moose behavior (e.g., timing of rut) and movement patterns, to inform consideration of shifting the moose harvest season

Management sub-objective: Manage moose harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- **HIGH PRIORITY:** Prepare to manage a potential shift by subsistence harvesters and sport hunters towards more boat-, road-, and aviation-based harvest, if conditions become wetter and substantially warmer, by conducting a detailed assessment (learning lessons from any particularly extremely wet years) of how they would most likely respond to more difficult ORV-based access for moose harvest, followed by a WRST process to develop ready-to-use plans to influence or respond to changes in harvest-access choices that links in with broader plans to manage changing snow machine, ORV, watercraft, and aircraft access; this response should include understanding and addressing how such shifts might affect other WRST resources and values
- Evaluate planned investments in ORV trails to ensure that they are either designed to fulfill intended purposes under the range of projected changes in climate or else are scaled down such that they deliver positive return on investment even if climate change ultimately causes abandonment or substantial reconstruction
- Work with the Alaska Board of Game and Federal Subsistence Board to explore the option of shifting harvest season a few weeks later to reduce meat-care challenges if research supports this option
    - **NOTE:** A hunting season would presumably want to avoid the rut, and therefore better understanding whether the rutting season is likely to shift with warming is critical
- **RESIST** declines in stream crossing ease/safety via improved/increased infrastructure (bridges) in a very few key places
- **ACCEPT** declines in stream crossing ease/safety in most places and work with harvesters to enhance awareness and capacity to adapt to these access changes



Dall's Sheep on the Lakes Plateau, east of Jacksina Glacier. NPS photo by Jared Hughey.

Dall's Sheep

Critical Implications

Critical implications that are common across scenarios:

- Large declines in abundance are possible in mid- and late-21st century (although not assured; scientific uncertainties exist)

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Biota: Sheep are monitored to limited extent by the State of Alaska and NPS WRST (generally in partnership with one another), and may be subject to additional monitoring or scientific research conducted by the State, NPS, or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), and sometimes in collaboration with NPS supported by NPS project funding.

Sport / Subsistence harvest: Harvest may be affected indirectly through park recommendations concerning State and/or Federal regulations, and through enforcement of Federal subsistence harvest regulations. Levels and adequacy of subsistence harvest may be investigated through community harvest surveys and/or research conducted by external partners and/or the NPS, potentially supported by NPS project funding. Access may be managed through enforcement of regulations and potentially

through issuance of permits, contingent on particular circumstances and authority. Most sheep harvests—even by federally qualified subsistence users—are under state harvest tickets. There are only federal subsistence permits for hunts by people 60 years of age or older. And permit issuance is based on meeting eligibility requirements, so isn't necessarily a way that harvests can be impacted even indirectly. Harvest tickets and federal registration permits issued for sheep come with a reporting requirement which provides information on sheep harvests on an annual basis.

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage Dall's sheep abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level Dall's sheep populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional and park-level abundances and trends (because of potential implications for species persistence in the park, as well as subsistence harvest)—including integrating WRST Dall's sheep monitoring more strongly into the CAKN (and ARCN) Dall's sheep vital sign monitoring program—reviewing and updating monitoring methods, if necessary, to ensure that they are robust to projected changes in climatic conditions and sensitive to important potential climate change effects on the species
    - **NOTE:** Dall's sheep is a vital sign, but vital-sign monitoring has not yet been implemented in WRST (instead, WRST and the state work together to monitor [cyclical approach]). (It is important that the park and the Alaska Department of Fish and Game be on the same page with monitoring sheep and the methods used.) Sheep mobility and access to forage is a critical function that may be impacted and could be monitored. In addition, awareness of events/changes in the Dall's sheep in other parks—via integration with CAKN and ARCN vital signs monitoring—may be illuminating. Finally, awareness of regional trends is important due potential implications for changes in hunting pressure
- Increase park-level monitoring for climate change-driven changes in pest/pathogen dynamics and impacts

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's Dall's sheep population

Research actions

- **HIGH PRIORITY:** Support research (i.e., scenario-based climate change vulnerability assessment) to better understand WRST Dall's sheep climate change vulnerabilities, including modeling climate change-driven habitat losses and gains and assessing prospect (and impacts) climate change-driven changes in WRST Dall's sheep pest/pathogen dynamics

    - **NOTE:** Key information needs include effects on lamb and adult survival of changing spring snow conditions and icing decreased ability to forage in winter.

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST Dall's sheep population

Management actions

- **HIGH PRIORITY:** Engage with the Federal Subsistence Board, the Alaska Board of Game, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees and — if strong negative population trends are detected and/or research validates concerns about strong negative climate change implications — conduct an inclusive process to identify preferred management responses (e.g., RESIST or ACCEPT the trend) and triggers for application and be prepared to recommend changes to harvest regulations
    - **NOTE:** Detecting negative population trends, if they exist, is a very high priority because it would inform consideration of a management response

Harvest management objective: Monitor, study, and manage Dall's sheep harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in Dall's sheep harvest access and ease

Monitoring actions

- Monitor changing harvest access (e.g., newly open/closed trails and waterways and impacts of permafrost thaw) and ease

Research sub-objective: Better understand how climate change might affect Dall's sheep harvest access and ease

Research actions

- Support research to investigate how climate change, particularly warming temperatures, might influence Dall's sheep distribution and movement patterns

Management sub-objective: Manage Dall's sheep harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- Prepare to adapt management of Dall's sheep to a potential shift towards more boat-based harvest if conditions become wetter, which would change the spatial distribution of harvest
    - **NOTE:** Notes on potential increases in boat use for Dall's sheep harvest: 1) The NPS has regulatory control when hunters touch the shore (although it is unclear what specifically might be regulated with regard to boat use), 2) the degree to which this action would be

needed depends on the degree to which riverine access changes, and 3) largest change might be an increase in numbers of people using boats, rather than an increase in the spatial extent of boat use.



Mentasta caribou herd cow with radio collar. Biologists use radio collars to better understand caribou habitat use and seasonal movements in the park. NPS photo by Mason Reid.

Caribou

Critical Implications

Critical implications that are common across scenarios:

- Large changes in abundance are unlikely, but smaller changes may occur (declines possible in all scenarios; increases possible in a subset) (note that Kyle Joly has concerns that this characterization is overly optimistic, given declines in caribou across the range)
- Warming increases meat care challenges, particularly if access becomes more difficult
- Permafrost thaw constrains access in some areas
- Possible arrival of new pathogens or diseases brought by climate change-driven expansion of other ungulate species
- Possible shifts in animal movement patterns due to changing temperatures

Critical implications that are not common across scenarios:

- Harvest opportunities and ease decline substantially (scenarios 1 & 3), due to soggy trails, widespread permafrost thawing, and shrubification but higher water levels will make boat-based harvest easier

- Harvest opportunities and ease remain good due to dry trails (scenario 2)

Management Considerations

Biota: Caribou are monitored to limited extent by the State of Alaska (Nelchina herd) and by the NPS CAKN (Mentasta and Chisana herds, often in partnership with the State), and may be subject to additional monitoring or scientific research conducted by the State, the NPS, or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), potentially in collaboration with the NPS supported by NPS project funding. Another important partner for monitoring the Chisana herd is the Yukon Department of Environment. Tetlin National Wildlife Refuge also does some flights to monitor the caribou collars in the winter, specifically regarding the mixing of the Mentasta and Nelchina Herds during a winter hunt that occurs on refuge lands.

Sport / Subsistence harvest: The Superintendent has the authority to establish the harvest quota for the annual federal subsistence hunt of the Chisana caribou herd, consistent with the interagency cooperative management plan, and to close the season when the quota is reached. Harvest also may be affected indirectly through park recommendations concerning State and/or Federal regulations, and through enforcement of Federal subsistence regulations. Levels and adequacy of subsistence harvest may be investigated through community harvest surveys and/or research conducted by external partners and/or the NPS, potentially supported by NPS project funding. Access may be managed through enforcement of regulations and potentially through issuance of permits, contingent on particular circumstances and authority. Issuance of permits is generally based on meeting eligibility criteria, not on any kind of biological or conservation grounds, although in this specific case the park does have the authority to restrict the number of permits issued for the Chisana caribou herd. This is a relatively unusual authority. Both state and federal caribou permits come with a requirement to submit a harvest report, which is another regular source of information about harvest and effort (e.g., hunted but did not successfully harvest).

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage caribou abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level caribou populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional and park-level abundances and trends, including reviewing and updating WRST monitoring methods, if necessary, to ensure that they are robust to projected changes in climatic conditions and sensitive to important potential climate change effects on the species
    - **NOTE:** WRST caribou are a vital sign monitored through CAKN (WRST wildlife biologist conducts monitoring in collaboration with others as needed), but it is limited to mostly population estimation; funds have been lacking to do anything beyond that. The park does also collaborate with Alaska Department of Fish and Game to try to get the work done, and is increasing use of Global Positioning Systems (GPS) collars.

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's caribou population

Research actions

- **HIGH PRIORITY:** Collaborate with NPS and outside partners to better track and map snow and icing conditions and their impacts on caribou movements, distribution, health, and survivorship
- **HIGH PRIORITY:** Conduct research on predation, survival and habitat change impacts, increase use of GPS collars
    - **NOTE:** This is a particularly high priority (comment by David Payer)
- Use remote sensing to track alpine habitat change

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST caribou populations

Management actions

- Collaborate with U.S. and Canadian partners to conduct an inclusive process to identify preferred management responses (i.e., **RESIST** or **ACCEPT** the trend) and triggers for application and engage with the Federal Subsistence Board, the Alaska Board of Game, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees and be prepared to recommend changes to harvest regulations if needed in response to changes in resource abundance, resource distribution, harvest pressure, ease of access or opportunity, or other climate-related circumstances
    - **NOTE:** WRST caribou are collaboratively managed, with management of the Chisana herd being an international collaboration that includes the Yukon Department of Environment.

Harvest management objective: Monitor, study, and manage caribou harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in caribou harvest access and ease

Monitoring actions

- Monitor changing harvest access (e.g., newly open/closed trails and waterways and impacts of permafrost thaw)
- Identify changes in harvest methods and means

Research sub-objective: Better understand how climate change might affect caribou harvest access and ease

Research actions

- [no critical implications in this category]

Management sub-objective: Manage caribou harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- Collaborate with the relevant regulatory bodies to suggest changes to season dates to facilitate better harvest access/opportunity—for example, seasons later into the fall or a winter season
    - **NOTE:** For this resource, the list of relevant regulatory bodies includes the Federal Subsistence Board, the Alaska Board of Game, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees. Note that this action is closely related to a resource management sub-objective listed above on this sheet. Also, impacts to pregnant females might have been a concern for a previous proposal for a later season, given the small size of the Chisana herd. If a Unit-11 harvest targeting the Nelchina herd (which is a larger herd) were to be established, a late fall season might be the time the animals are in that unit
- If declines in ease of harvest become apparent, 1) consider limiting harvest (perhaps via changes in permitting) and work with partners to consider additional approaches (e.g., fire management) and 2) anticipate and proactively address public pressure to reduce wolf abundance in areas surrounding the park
    - **NOTE:** NPS management policies limit what can be done in this situation; actions to provide harvest opportunities would not include things like predator reduction, even though such things could be undertaken for other reasons (e.g., to prevent loss of the species from the park). Potentially one could set quotas more than doing something with permitting for harvest opportunities. But first way to limit harvest might be a shortened season.



The wolf is a top predator that influences the park's ungulate populations. NPS photo by Ken Conger.

Wolves

Critical Implications

Critical implications that are common across scenarios:

- Large abundance changes are unlikely, but abundances may shift in direction of changes in prey abundance
- Harvest ease declines due to shorter season when snowmachines or airplanes (ski-planes) can be used or a shorter season when fur is in prime condition, less stable ice on water crossings, and the need for increased trap check frequency
- A decline in extreme cold conditions (increasingly severe from scenario 1 through to scenario 3) reduces fur quality proportionately
- Trapping participation declines

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Biota: Wolves are monitored to limited extent by the State of Alaska, and may be subject to additional monitoring or scientific research conducted by the State, the NPS, or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), and sometimes in collaboration with the NPS supported by NPS project funding.

Hunting/trapping: Harvest may be affected indirectly through park recommendations concerning State and/or Federal regulations, and potentially through enforcement of Federal regulations. Access may be managed through enforcement of regulations, contingent on particular circumstances and authority. Harvests are monitored through a requirement that hides be sealed (reported and tagged) by the Alaska Department of Fish and Game.

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage wolf abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level wolf populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional and park-level abundances and trends, including implementing monitoring methods—and working with State partners—to ensure that they are robust to projected changes in climatic conditions and sensitive to important potential climate change effects on the species
    - **NOTE:** WRST has an interest in better awareness of status and trends in its wolf population, as indicated by previous efforts to survey the park's wolf population. However, WRST has had trouble with adverse conditions and therefore little information exists regarding size of the WRST wolf population; this lack of context would make detecting change in the population very difficult.

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's wolf population

Research actions

- **HIGH PRIORITY:** Monitor status of, and changes in, predator-prey relationships between wolves and focal terrestrial ungulates
- Monitor predator complex generally (e.g., wolves in relationship to coyotes and other predator species)

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST wolf population

Management actions

- Engage with the Federal Subsistence Board, the Alaska Board of Game, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees and be prepared to recommend changes to harvest regulations if needed in response to changes in resource abundance, resource distribution, harvest pressure, ease of access or opportunity, or other climate-related circumstances

Harvest management objective: Monitor, study, and manage wolf harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in wolf harvest access and ease

- **NOTE:** Airplanes cannot be used for harvest in the park (but regulations allow some individual exemptions), so there are some constraints but there is a process if other means of access can't happen.

Monitoring actions

- **HIGH PRIORITY:** Monitor wolf harvest patterns and trends through sealing records and community-based household surveys
    - **NOTE:** Hides/harvests are required by state to be sealed.
- Monitor changing harvest access (e.g., changes in snowmachine season and stability of ice on water crossings)

Research sub-objective: Better understand how climate change might affect wolf harvest access and ease

Research actions

- [none identified]

Management sub-objective: Manage wolf harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- [none identified]
    - **NOTE:** WRST does not focus on managing trapping, but if there were proposed changes in trapping regulations then park would review them and could propose changes. Wolves are both hunted and trapped.



Brown bears (pictured) and black bears are found throughout the park. NPS photo by L. Law.

Black and Brown Bears

Critical Implications

Critical implications that are common across scenarios:

- Large changes in abundance are unlikely, but smaller changes may occur

Critical implications that are not common across scenarios:

- Harvest opportunities and ease decline (scenarios 1 & 3), perhaps substantially (scenario 3), due to soggy trails (e.g., Nabesna Road ORV trails), widespread permafrost thawing, and shrubification
- Harvest opportunities and ease remain good due to dry trails (scenario 2), but permafrost thaw constrains access in some areas

Management Considerations

Biota: Bears are monitored to limited extent by the State of Alaska, and may be subject to additional monitoring or scientific research conducted by the State, the NPS, or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), and sometimes in collaboration with the NPS supported by NPS project funding.

Hunting/baiting: Harvest may be affected indirectly through park recommendations concerning State and/or Federal regulations, and potentially through enforcement of Federal regulations. Access may

be managed through enforcement of regulations, contingent on particular circumstances and authority. Harvests are monitored through reporting associated with permits/harvest tickets, sealing requirements, and sometimes both. (There might be a place where neither happens, but in most cases at least one of these reporting mechanisms exists.)

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage brown and black bear abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level brown and black bear populations and key climate-related threats

Monitoring actions

- Initiate an effort to develop awareness of abundances and trends that is robust to projected changes in climatic conditions and sensitive to important potential climate change effects on the species
    - **NOTE:** Most parks do not monitor bear abundances, so the best approach is likely to work with harvesters to infer trends in availability

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's brown and black bear population

Research actions

- [none identified]

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST brown and black bear populations

Management actions

- Engage with the Federal Subsistence Board, the Alaska Board of Game, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees and be prepared to recommend changes to harvest regulations if needed in response to changes in resource abundance, resource distribution, harvest pressure, ease of access or opportunity, or other climate-related circumstances

Harvest management objective: Monitor, study, and manage brown and black bear harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in brown and black bear harvest access and ease

Monitoring actions

- Monitor harvest patterns and trends through sealing records, harvest reports, and community-based household surveys.
    - **NOTE:** Hides/harvests are required by state to be "sealed" (reported and tagged by Alaska Dept of Fish and Game)
- Monitor changing harvest access (e.g., newly open/closed trails and waterways)

Research sub-objective: Better understand how climate change might affect brown and black bear harvest access and ease

Research actions

- [none identified]

Management sub-objective: Manage black bear harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- Improve understanding of occurrence of 'glacier bears' (black bears with lighter pelage) in WRST, focused on Icy Bay and Disenchantment Bay, because climate change-driven changes might afford more opportunities for harvest
    - **NOTE:** This is the only action in this report that is specific to one of the two bear species. The "glacier bear" morph is relatively rare where it occurs, as well as being the subject of sport hunting and potentially of illegal hunting in the park. WRST, however, is unsure whether the morph occurs in the park, so this is the first step



Harbor seals haul out (rest) on drifting icebergs derived from calving glaciers, as well as rocks, reefs, and beaches, when they are not traveling or foraging. NPS photo by M. Reid.

Harbor Seals

Critical Implications

Critical implications that are common across scenarios:

- The timing of the thinning and retreat of individual tidewater glaciers is uncertain. The overall outcome for now through mid-century will be a continuation of iceberg-generating tidewater ice on the WRST coastline, though possibly slightly less or slightly more than present
    - Mike Loso comment of 1 Feb 2022: the locus of iceberg production will vary by this chronology: GLBA proper wanes soonest, then Icy Bay. Disenchantment hangs in there longest of all the current tidewater glaciers on the outer coast, but then Malaspina turns tidewater (happening now) and it will be the "big daddy" of ice production into the most distant future we can possibly forecast
- Changes (positive or negative) in ice habitat will likely result in changes in abundance of seals in coastal WRST, including the possibility of shifts to terrestrial habitats or other glacial ice sites (to Prince William Sound or Glacier Bay or other areas), which may have population-level consequences.

- Across all scenarios, in addition to changes in ice habitat, bottom-up shifts in prey communities, due to marine heatwaves or other factors in the Gulf of Alaska or other nearby areas, will likely also play a key role in influencing distribution, abundance, condition, and reproductive rates of seals.

Critical implications that are not common across scenarios:

- Abundance—and therefore availability for harvest—increases or remains stable due to increases in ice habitat, and harvest opportunities also increase due to reduced boat travel distances (scenario 1)
- Abundance—and therefore availability for harvest—decreases due to decreases in ice habitat, and harvest opportunities also decrease due to increased boat travel distances and cruise ship-driven impacts to access (scenarios 2 and particularly 3)

Management Considerations

Biota: Harbor seals and other ecosystem variables are expected to be monitored in Disenchantment Bay and possibly to a limited extent elsewhere in WRST by NPS SEAN and NOAA-Marine Mammal Laboratory, and may be subject to additional monitoring or scientific research conducted by the State, NPS, or external partners, sometimes in collaboration with NPS supported by NPS project funding.

Subsistence harvest: Harbor seal harvests are limited to Alaska Natives and take place under the provisions of the Marine Mammal Protection Act. It does not appear there are any state regulations nor opportunities to comment on harvest regulations for this species. The state used to do regular harbor seal harvest surveys through a partnership with the Alaska Native Harbor Seal Commission and NOAA, but it seems the commission has been inactive since 2017 and the last survey was about a decade ago. Levels and adequacy of subsistence harvest may be investigated through periodic (about decadal) community harvest surveys and/or research conducted by external partners and/or NPS, potentially supported by NPS project funding.

Extended subject-matter expert discussion (during Adaptation workshop 1), involving Jamie Womble, Barbara Cellarius, John Jansen, and Scott Gende), transcribed from embedded comments in the workshop-1 worksheet

- Full text of Barbara's management discussion: Harbor seal harvests are limited to Alaska Natives and take place under the provisions of the Marine Mammal Protection Act. I don't believe there are any state regulations. And I have no recollection of opportunities to comment on harvest regulations for this species. I looked on the NOAA website and didn't easily find seal harvest regulations or any related Federal Register notices related to seal harvests in Alaska. The state used to do regular harbor seal harvest surveys through a partnership with the Alaska Native Harbor Seal Commission and NOAA, but best I can tell the commission has been inactive since 2017 and the last survey was about a decade ago. Harbor seal harvest are documented in periodic (once a decade if we are lucky) community harvest surveys in Yakutat and I suppose Cordova might have some limited harvest, I would have to look. Maybe Jamie or Scott know something about harvest rules, but I would have to

call NOAA or Yakutat to ask someone. I'd be inclined to just mention the monitoring through community harvest assessments and other projects and not talk about potentially making recommendations about the harvest regulations.

- John Jansen: unique species b/c subsistence harvest legally guaranteed. It would be unusual for NOAA to try to limit those subsistence rights (not a management tool that is on the table). Scott's concern below re: last-chance tourism is a real concern, and Icy Bay will almost certainly get targeted w/ decreasing tidewater glacier-viewing opportunities elsewhere. Just like at Disenchantment, ships will get better at operating in Icy Bay.
- Jamie: agree with Scott and John's comments; only way there would be changes to subsistence harvest would be if a stock were categorized as depleted; this is not the case now for any of the dozen-odd seal populations.
- Scott: when thinking outside the box re: management responses, with any access (e.g., cruise ships coming into Icy Bay), there's always a low-prob/high-consequence event of ship running aground, spilling/contamination of park lands, etc. Increasing importance of documenting where and how ships are proceeding (AIS receiver could allow park to get better handle re: ship behavior in the bay). John and Jamie have been involved in this kind of work. Park could also do more pre-spill baseline-setting surveys (lesson from Exxon Valdez) —important for many reasons. Final point: significant opportunities for collab with Yakutat tribe; John's research focus on cruise ship impacts responds to request from the tribe. So, harbor seals work enhances integration of tribal voices into understanding pop dynamics, processes, etc. and improves park-tribal relationships.
- Additional information from workshop-1 group discussion: 180 cruise ship visits/year; management concern and also a strong perception. This is not just disturbance to subsistence but also to the resource (seals) itself. Disenchantment Bay has been increasingly important as a cruise ship destination b/c of declining opportunities to visit tidewater glaciers in Alaska (which are receding and thinning). There's also a serious and sustained demand to see tidewater glaciers as part of last-chance tourism. So, there will be a continuing cruise ship market for this experience. Given demand and decreasing supply, Disenchantment Bay will be an increasing target for tourism; park has opportunity/need to decide what role it wants to play in influencing this.

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage harbor seal abundance in a climate change-informed way while considering potential for increases in vessel traffic and visitation

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level harbor seal populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional and park-level abundances, population trends, and distribution including reviewing and updating monitoring methods in collaboration with NPS and NOAA/National Marine Fisheries Service-Marine Mammal Laboratory, if necessary, to ensure that they are robust to projected changes in climatic conditions and sensitive to important potential climate change effects on the species
    - **NOTE:** More information about methods can be found in the following Womble-suggested references: Ver Hoef & Jansen 2014, Womble et al. 2020 & 2021, Jansen et al. 2006
- **HIGH PRIORITY:** Increase monitoring of Icy Bay for vessel-based tourism using Automatic Identification Systems (AISs); currently at low levels (and small ships) but anticipated to increase dramatically, especially with declining ice cover and better bottom mapping
    - **NOTE:** Quantitative data on vessel-based tourism is lacking and is urgently needed to establish a baseline.
- **HIGH PRIORITY:** Foster open communication and share results from monitoring and any management-related concerns among partners and stakeholders (NPS, NOAA-Marine Mammal Laboratory, and tribal entities)
- Implement aerial photographic surveys of ice habitat using analytical approaches and algorithms that have been developed and to semi-automate the quantification of ice availability in fjords and quantify changes in ice habitat over time
    - **NOTE:** Womble et al. are currently testing new algorithms for quantifying ice coverage in fjords (as seal habitat) with Jason Amundson at University of Alaska–Southeast and in collaboration with Mike Loso and Andy Bliss (NPS) to inform outer coast monitoring expansion. For more info regarding approaches and algorithms, see the following Womble-suggested references: McNabb et al. 2016, Womble et al. 2020 & 2021
- Collaborate with SEAN vital signs monitoring for marine environmental contaminants to modify the approach to allow for sampling to more appropriately monitor baseline environmental conditions in the event of an oil spill
    - **NOTE:** Similar sampling has occurred in Klondike Goldrush National Historical Park and GLBA, and the timing is good now (BEFORE the conclusion of the RSS) to influence design of contaminant sampling (alongside harbor seal and glacier monitoring) on the outer coast, given state of SEAN monitoring plan
- Systematic sampling of biota of polycyclic aromatic hydrocarbons or heavy metals; maintain awareness of legal changes such as recent passage of the Vessel Incidental Discharge Act (VIDA); what boats discharge (and are allowed to discharge) in state waters influences what ends up in biota along NPS coasts
- Partner with Yakutat Tlingit Tribe to collaborate with cruise industry to put NPS Interpretation staff on board ships entering Disenchantment or Icy Bay which can facilitate

monitoring and communication (other boats in the bay; usage, etc.); staff can access ships via Southeast Alaska Pilot's Association (SEAPA) Pilot boat based out of Yakutat airport (YAK)

- **NOTE:** GLBA represents an ongoing model of placing interpretation staff on cruise ships

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's harbor seal population

Research actions

Potential changes in ice habitat

- **HIGH PRIORITY:** Support research and monitoring (i.e., climate change vulnerability assessment) to investigate multiple uncertainties (see implications summary) regarding how climate and climate change impacts might influence harbor seals
- Collaborate with NPS Physical Scientists (WRST, SEAN) and academic partners (University of Alaska–Fairbanks, University of Alaska–Southeast, and others) to facilitate and develop monitoring and research to better understand mechanistic relationships between the calving dynamics of tidewater glaciers and the availability of ice habitat for harbor seals in fjords
- Collaborate with NPS Physical Scientists to monitor how ongoing and predicted changes at the Malaspina Glacier will influence harbor seal distribution
  - **NOTE:** This change will likely happen at a longer time scale (i.e., latter half of the century) but is worth focusing on given the ongoing research at Malaspina Glacier
- Develop analytical models to integrate glacier, ice, and seal data

Potential changes in vessel traffic and visitation

- **NOTE:** This whole research sub-category is a priority (as noted by Barbara Cellarius)
- Support research and monitoring efforts to integrate AIS data with harbor seal distribution, abundance, and ice data from aerial photographic surveys
- Complete analyses, publications, and share results from NPS/NOAA study in Disenchantment Bay that quantified the influence of cruise ships (proximity, speed, and distance) on the behavior and movement of harbor seal pups
- Install AIS receivers in Disenchantment and Icy Bays to quantify the spatial and temporal distribution of vessels, number and type of vessels, residence time of vessels, and shifts in vessel behavior
  - **NOTE:** Lots of AIS data can be archived so a plan for storage and analysis would need to be developed
- Develop robust data management standards, protocols, and analysis tools to address management-relevant questions that can be derived from AIS data
- Ensure results and ongoing efforts are shared with key stakeholders (Yakutat Tlingit Tribe, NOAA Office of Protected Resources-Alaska Region, NOAA-Marine Mammal Laboratory)

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST harbor seal population

Management actions

- **HIGH PRIORITY:** Ensure and facilitate open communication with key partners and stakeholders and tribal entities regarding the influence of climate-driven changes on ice habitat and seal distribution and abundance
    - **NOTE:** This action is particularly high priority (David Payer)
- Increase presence of park staff in Icy and Disenchantment Bay by facilitating visitation/access via field station, boats, etc.
- Maintain a base of operations at Yakutat to support monitoring, research, etc.
    - **NOTE:** Yakutat is a necessary base of operations for almost all of the activities described in this report
- Consider developing Icy Bay as a destination to guide visitation in terms of activities, access, etc. (i.e., be proactive, rather than reactive)

Harvest management objective: Monitor, study, and manage harbor seal harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in harbor seal harvest access and ease

Monitoring actions

- [none identified]

Research sub-objective: Better understand how climate change might affect harbor seal harvest access and ease

Research actions

- Collaborate with tribal partners to monitor changing harvest locations and ease of access (e.g., trends in boat travel distances from local communities in relation to changes in ice habitat)

Management sub-objective: Manage harbor seal harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- Engage with harbor seal subsistence users and stakeholders to increase awareness and strengthen relationships, in anticipation of a possible future need to help tribal and federal (NOAA) partners deal with a declining population.



Five species of salmon are found within the park: sockeye (pictured), Chinook, coho, pink, and chum. Salmon, particularly Chinook and sockeye, are the focus of subsistence harvest and a world-class sport fishery. NPS photo.

Aquatics[12]

All Salmon

Critical Implications

Critical implications that are common across scenarios:

- Resource availability (abundance) may change, perhaps dramatically, in terms of both greater temporal variability and strong trends (complex system—change likely but difficult to predict).
- Harvest opportunities shift in space as bank erosion on the Copper River (a result of increased glacial melt under all scenarios and increased precipitation under scenarios 2 and 3) causes loss of some fish wheel sites; impacts on subsistence harvest include additional time and effort needed to find suitable new locations for wheels, or a switch to less efficient (or more labor-intensive) dip-net harvesting, adding additional travel time to suitable sites and perhaps reduced overall harvest levels
- Warmer weather poses a challenge to the meat care of salmon (similar to meat-care challenges for harvested mammals) as does potentially warmer non-glacial water in the case of sockeye and non-glacial watershed-rearing coho and Chinook, and potentially a need to check fish wheels more frequently
- Warming of non-glacial tributary waters could significantly affect survival for sockeye and non-glacial watershed-rearing coho and Chinook

Critical implications that are not common across scenarios:

- In addition to high-water impacts on fish wheel-based harvest, low water also potentially reduces fish wheel effectiveness in some sites (scenario 2)
- Wetter conditions (scenarios 1 and 3) pose a challenge to preservation via drying racks (not the most common means of preservation)

Management Considerations

Biota: Salmon are monitored to limited extent by the State of Alaska and the Native Village of Eyak, and may be subject to additional monitoring or scientific research conducted by NPS or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), and sometimes in collaboration with the NPS supported by NPS project funding. Main species counted at NPS-run Tanada Creek Weir. We generally rely on the federal subsistence board and the State of Alaska to manage harvest opportunities for fish and wildlife, including closures. There is, however, a separate closure authority in 36 CFR 13.50 that gives the superintendent some

[12] As noted above in the introduction, participants who worked on the aquatics (and wildlife) resource types annotated and prioritized among their proposed actions for each resource; those priorities are documented here with the caveat that they serve as a within-resource designation and not a tool for prioritizing actions across resources.

authority to issue a closure for the purposes of resource protection. Consultation with the state is generally required for closures related to fish and wildlife.

Sport / Subsistence harvest: The Superintendent has delegated authority from the Federal Subsistence Board to issue emergency special actions affecting fisheries in Federal public waters within the Copper River Drainage when necessary to conserve healthy populations of fish or to ensure the continuation of subsistence uses of fish. Such actions may not exceed 60 days and cannot be extended. The delegation allows for opening or closing Federal subsistence fishing periods or areas provided under codified regulations. It also allows for specification of methods and means, permit requirements, and setting of harvest and possession limits for Federal subsistence fisheries. The delegation also allows for closing and re-opening of Federal public waters to non-subsistence fishing (i.e., fishing in State-managed fisheries). Harvest also may be affected indirectly through park recommendations concerning State and/or Federal regulations, and through enforcement of Federal subsistence regulations and emergency special actions. Levels and adequacy of subsistence harvest may be investigated through community harvest surveys and/or research conducted by external partners and/or NPS, potentially supported by NPS project funding. Access may be managed through enforcement of regulations, contingent on particular circumstances and authority. Federal subsistence, state subsistence and state personal use harvests of salmon are monitored through required harvest reports associated with permits. Monitoring of sport harvests is through end-of-season surveys.

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage salmon abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level salmon populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional-, watershed-, and park-level abundances and trends, including reviewing and updating monitoring methods, if necessary, to ensure that they are robust to projected changes in climatic and river conditions—and, for sockeye, lake conditions—and sensitive to important potential climate change effects on the species

- Increase monitoring and awareness of trends in body size
    - **NOTE:** Decreasing salmon body size has been documented in the Copper River and is consistent with trends in other salmon species elsewhere in Alaska returning to spawn. These changes may be attributable in part to the increasing occurrence and severity of marine heatwaves that are projected to intensify in the future. Declines in size are expected to result in declines in productivity, and analyses indicate a decline in productivity of Copper River king salmon, for example, beginning in the early 2000s.

The park is concerned about this trend and has shared their concern with the Alaska State Board of Fisheries

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's salmon population

Research actions

- Foster research (ideally in the form of scenario based vulnerability assessment) to better understand the nature and likelihood of potential future climate change-driven changes in abundance and condition of these species, integrating the influences of climate change effects on rearing habitat (e.g., reduced winter severity, increased beaver activity, and, for sockeye, substantially earlier ice-out), ocean conditions, the timing and duration of the glacial melt season, heat stress, heavy rain events, aquatic food webs, and disease/parasites, and also, for sockeye, drought/low water, and in- and out-migration being blocked by increased beaver activity

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST salmon population

Management actions

- Implement management strategies to account for potential climate change-driven changes in survival and abundance while seeking to maintain suitable escapements to address this change and ensure sustainable returns

- Engage with the Federal Subsistence Board, the Alaska Board of Fisheries, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, and Local Fish and Game Advisory Committees and be prepared to recommend changes to harvest regulations if needed in response to changes in resource abundance, resource distribution, harvest pressure, ease of access or opportunity, or other climate-related circumstances

Harvest management objective: Monitor, study, and manage salmon harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in salmon harvest access and ease

Monitoring actions

- Monitor trends in harvest methods (fish wheels versus dip nets versus rod and reel)
- Monitor climate change-driven changes in harvest access (e.g., changes in fish wheel location suitability)

Research sub-objective: Better understand how climate change might affect salmon harvest access and ease

Research actions

- Support research to better understand how both higher water levels (all scenarios) and periods of lower water levels (scenario 2) would influence fish wheel and dip net efficiency in general

Management sub-objective: Manage salmon harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- **HIGH PRIORITY:** Continue monitoring of harvests and consider integrating with new monitoring about whether subsistence needs are being met, potentially in partnership with Ahtna Intertribal Resource Commission or others
- Make preparations to respond to calls for greater park involvement in Copper River salmon management caused by increasing temporal variability in abundance, as well as potential trends in abundance and condition (e.g., work with partners to develop triggers for changes in resource management approach)
- Develop a communication strategy to maintain public awareness of changes and the NPS' proactive engagement in monitoring, research, and management activities that aim to ensure long-term sustainability of fish stocks and subsistence use
- Develop communication strategy to maintain public awareness of changes in harvest ease
- Encourage harvest methods and practices that address the challenge that warming air temperatures pose for meat care, such as frequent monitoring of fish wheels and the use of live boxes, being clear that doing so is advantageous because it 1) reduces loss (degradation) of the harvested resource and 2) maintains the ability to release undesired fish



Burbot (*Lota lota*) are the only freshwater gadoid (cod) in North America. This individual, captured, measured, and inspected for tag presence, is about to be released as part of a mark-recapture-based abundance study in Grizzly Lake. NPS photo by David Sarafin.

Freshwater Fishes

Critical Implications

Critical implications that are common across scenarios:

- Resource availability shifts and ease of harvest generally improves across the landscape—proportional to degree of warming—as contrasting (but largely positive) impacts of warming expand habitat (but increase thermocline depth, negatively impacting lake trout and burbot) and expand the ice-free period and increase dissolved oxygen, productivity, and winter survivorship
- Ice-fishing harvesting opportunities (i.e., safe and comfortable conditions) shift (contract) towards mid-winter and away from late spring, at a rate consistent with air temperature warming rates (i.e., much faster if scenario-3 warming rates occur)

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Biota: Non-salmon species are not systematically monitored, but may be inventoried periodically or subject to scientific research conducted by NPS or external partners, sometimes with authorization by NPS research permit (contingent on location and authority), and sometimes in collaboration with NPS supported by NPS project funding.

Sport / Subsistence harvest: The Superintendent has delegated authority from the Federal Subsistence Board to issue emergency special actions affecting fisheries in Federal public waters within the Copper River Drainage when necessary to conserve healthy populations of fish or to ensure the continuation of subsistence uses of fish. Such actions may not exceed 60 days and cannot be extended. The delegation allows for opening or closing Federal subsistence fishing periods or areas provided under codified regulations. It also allows for specification of methods and means, permit requirements, and setting of harvest and possession limits for Federal subsistence fisheries. The delegation also allows for closing and re-opening of Federal public waters to non-subsistence fishing (i.e., fishing in State-managed fisheries). Harvest also may be affected indirectly through park recommendations concerning State and/or Federal regulations, and through enforcement of Federal subsistence regulations and emergency special actions. Levels and adequacy of subsistence harvest may be investigated through community harvest surveys and/or research conducted by external partners and/or the NPS, potentially supported by NPS project funding. Access may be managed through enforcement of regulations and potentially through issuance of permits, contingent on particular circumstances and authority. Most freshwater fish are harvested under state sport regulations, which are monitored through an end of the year survey sent to people with sport fish licenses. For local communities, harvests would be captured in the periodic community harvest surveys.

Adaptation Strategy

Objectives

Population management objective: Monitor, study, and manage freshwater fish abundance in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of status and trends of regional and park-level freshwater fish populations and key climate-related threats

Monitoring actions

- **HIGH PRIORITY:** Maintain awareness of regional-, watershed-, and park-level population levels as well as changes in abundances and distributions, including reviewing and updating monitoring methods, if necessary, to ensure that they are robust to projected changes in climatic conditions and sensitive to important potential climate change effects on these species
    - **NOTE:** The park and partners have engaged in periodic studies that focus on freshwater fish, but the need now is to get more extensive and develop baselines in order to be able to detect and characterize change. Details: A limited group of population assessments are

currently conducted on various WRST lakes (by Sarafin). The state has also done burbot studies for abundance and recent work on WRST lake trout genetics, and there's a USGS study that intends to look at contaminants (e.g., mercury and lake trout)

Research sub-objective: Better understand how climate change-driven changes in the environment may impact the park's freshwater fish population

Research actions

- Encourage research (i.e., scenario-based climate change vulnerability assessment) to better understand how warming will expand beaver-created pond habitat and how such changes will affect species such as lake trout, burbot, whitefish, rainbow trout, Arctic grayling, Dolly Varden, and cutthroat trout
    - **NOTE:** Whitefish are an important subsistence species for some communities on the northern edge of the park
- Encourage research (i.e., scenario-based climate change vulnerability assessment) to better understand how warming may lead to loss of suitable habitat associated with permafrost thaw/ or loss of lake depth in smaller waters
- Encourage research (i.e., scenario-based climate change vulnerability assessment) to better understand how warming may influence contaminant levels in fish (e.g., mercury)

Management sub-objective: Prepare to work with stakeholders—if research or monitoring suggests the need—to determine whether and how to address climate change-driven changes in the WRST freshwater fish population

Management actions

- Engage with the Federal Subsistence Board, the Alaska Board of Fisheries, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, Local Fish and Game Advisory Committees, and (for the Yukon Northern region) the U.S. Fish and Wildlife Service, and be prepared to recommend changes to harvest regulations if needed in response to changes in resource abundance, resource distribution, harvest pressure, ease of access or opportunity, or other climate-related circumstances

Harvest management objective: Monitor, study, and manage freshwater fish harvest opportunities and ease in a climate change-informed way

Sub-objectives

Monitoring sub-objective: Be aware of climate change-driven changes in freshwater fish harvest access and ease

Monitoring actions

- Monitor harvest levels or participation relative to effects on abundance
    - **NOTE:** Monitoring this kind of harvest (which occurs through state-regulated fishing) would be best done by monitoring participation, which can be done with overflights

Research sub-objective: Better understand how climate change might affect freshwater fish harvest access and ease

Research actions

- [none identified]

Management sub-objective: Manage freshwater fish harvest so that it recognizes, mitigates, and—if necessary—accepts and adjusts to climate-driven changes in harvest access and ease

Management actions

- Manage shift (contraction) in seasonality of safe ice-fishing conditions by engaging with fishers to help them understand and adjust
- Prepare to work with the relevant regulatory bodies to manage a long-term trend of increased freshwater fish harvest interest or activity in WRST
    - **NOTE:** For this resource, the list of relevant regulatory bodies includes the Federal Subsistence Board, the Alaska Board of Fisheries, the Wrangell-St. Elias Subsistence Resource Commission, Federal Subsistence Regional Advisory Councils, Local Fish and Game Advisory Committees, and (for the Yukon Northern region) the U.S. Fish and Wildlife Service. Note that this action is closely related to an action listed above under the freshwater fish management sub-objective



Screened cache in the Bremner Historic Mining District. NPS photo by Jacob Frank.

Cultural Resources

Kennecott Mines National Historic Landmark District

Critical Implications

Critical implications that are common across scenarios:

- Integrity of structures reduced (location, setting, design, materials, workmanship, feeling, and association)
- Structures destroyed
- Integrity of context reduced (setting, feeling, and association)

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

The contributing structures and cultural landscape character defining features of the National Historic Landmark (NHL) are among the approximately 25% of WRST's cultural resources that have been identified for active management.

Adaptation Strategy

Objectives

Document, stabilize, and monitor prioritized structures and other character defining features of the cultural landscapes that comprise the Kennecott Mines NHL in a climate-informed way.

Sub-objectives

Documentation sub-objective: Update list of priority structures and character defining features of the cultural landscapes that make up the NHL.

Documentation actions

- Complete a cultural resource survey of the NHL and re-evaluate and update the inventory of contributing historic structures and character defining features.
- Update and / or undertake new cultural landscape assessments and studies of priority areas of the NHL (including the mill town, various mines, and cemetery).
    - **NOTE:** Identify cultural resources and character defining features that need be prioritized for documentation, stabilization, and monitoring. Coordinate with Cultural Landscape section.
- Digitally document prioritized historic structures and character defining features of NHL.
    - **NOTE:** Help inform stabilization measures and to create a record for mitigating the loss of integrity or loss complete loss of structure or feature. Consider using digital documentation to help update and/or prepare Historic American Buildings Survey/Historic American Engineering Record/Historic American Landscapes Survey (HABS/HAER/HALS) records.

Stabilization sub-objective: Develop consistent, efficient, and effective strategies for exterior and interior stabilization of historic structures.

Stabilization actions

- Prepare and implement consistent stabilization measures that address structural destabilization and water ingress at the roof, exterior walls, and foundations of historic structures.
    - **NOTE:** Stabilize prioritized historic structures, particularly those whose foundations, structural systems, and exterior envelopes have been compromised.

Risk Assessment sub-objective: Complete risk assessment to inform remediation plan for site contaminants that also incorporates climate impacts.

Risk Assessment actions

- Prepare and implement remediation plan for site contaminants.

Monitoring sub-objective: Improve communication strategies with NHL stakeholder groups on or near site.

Monitoring actions

- Develop and operationalize new monitoring protocols and processes with key stakeholders.
    - **NOTE:** Engage stakeholders to assist with monitoring and reporting on conditions especially during and after weather events.

Historic and Prehistoric Structures

Critical Implications

Critical implications that are common across scenarios:

- Integrity of structures reduced (location, setting, design, materials, workmanship, feeling, and association)
- Structures buried and/or destroyed
- Associated circulation patters obscured (visitor traffic and how it might change and how these changes interact with roads and access being impacted by erosion, etc.)
- Access to restricted or blocked structures

Critical implications that are not common across scenarios:

- Wildfire risk increase (Scenarios 2 and 3); high concern in some geographic areas—lower in high elevations and along the coast

Management Considerations

Active cultural resource management is currently designated for approximately 25% of WRST's historic structures.

Adaptation Strategy

Objectives

Improve access, document, and stabilize historic structures with a focus on recording, monitoring, and preserving identified character defining features.

Sub-objectives

Improved Access sub-objective: Improve access to historic structures to help facilitate documentation, stabilization, preservation, and monitoring.

Improved Access actions

- Prepare and implement a plan to enhance vegetation clearance that engages other park unit groups
    - **NOTE:** Work with existing stakeholders, like back country park rangers, to help inform and implement strategies for improving access.

Kennecott Operations Plan (KOP) sub-objective: Explore potential update and expansion of priorities articulated in the KOP (or other appropriate planning document) to accurately reflect range of historic structures current needs. including an updated list of prioritized historic structures for documentation, stabilization, and monitoring.

General Management Plan actions

- Update list of prioritized of historic structures for documentation, stabilization, and monitoring.
    - **NOTE:** Establish priorities for updating and expanding HABS/HAER/HALS records and identify funding needs to support documentation.

Inventory and Documentation sub-objective: Enhance existing inventories and documentation measures.

Digital Documentation actions

- Engage with regional representatives and others, such as the NPS Heritage Documentation Program and National Center for Preservation Technology and Training, using terrestrial LiDAR (laser scanning) and other 3D digital documentation techniques
    - **NOTE:** Consider using digital documentation data to update existing and create new HABS/HAER/HALS records.

Park Cabin Inventory and Documentation sub-objective: Prepare an achievable strategy and plan for establishing a baseline inventory and documentation for park cabins 50 years and older.

Park Cabin Inventory and Documentation actions

- Inventory and document park cabins 50 years and older.
    - Consider preparing determinations of eligibility to inform a cover nomination of park cabins on the National Register of Historic Places.

Data Collection Storage and Access sub-objective: Establish a process and protocols for cross-coordination, particularly at the region and park unit level, for the collection, storage, and access to data and records.

Data Collection, Storage, and Access actions

- Prepare a process and protocols for the cross-coordination of data collection, storage, and access.
    - **NOTE:** Engage stakeholders to help develop and implement a cross-coordination process.

Stabilization sub-objective: Develop consistent stabilization approaches for historic structures and other, non-building structures such as air strips, to address snow loads and other climate impacts.

Stabilization actions

- Stabilize prioritized historic structures and other non-building structural resources.
    - **NOTE:** Consider the stabilization of structural systems, roofs, exterior envelope, and foundations of historic structures.



A cabin in the Wrangell-St. Elias backcountry in the historic mining settlement of Chisana, which retains extensive evidence of early-20th-century mining. NPS photo.

Cultural Landscapes

Critical Implications

Critical implications that are common across scenarios:

- Site integrity reduced (includes resource burial, inundation, etc.)
- Degradation of historic structures and cultural landscape character defining features
- Structures and cultural landscape character defining features destroyed
- Viewsheds and associated character defining features impeded (vegetation, wildfires, landslides, avalanches, etc.)
- Associated circulation patterns obscured

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

31 cultural landscapes identified; different management prescriptions recommended for different cultural landscapes. Active cultural resource management is designated for approximately 25% of WRST's cultural resources.

Adaptation Strategy

Objectives

Document, monitor, and manage cultural landscapes in a climate change-informed way.

Sub-objectives

Documentation sub-objective: Undertake similar inventory and documentation actions discussed for other cultural resources utilizing digital technologies like rapid surveys, aerial and terrestrial LiDAR (laser scanning), etc. and prepare Historical Context Statements.

Documentation actions

- Use digital technologies and products to inventory and document cultural resources.
    - **NOTE:** Focus on resources beyond the mining cultural landscapes.
- Prepare a literature review to inform the development of Historical Context Statement(s).
    - **NOTE:** Include literature on ethnographical landscapes.

Condition Assessment Protocol sub-objective: Develop a process and protocols for undertaking condition assessment of the character defining features of cultural landscapes with a focus on non-mining resources.

Condition Assessment Protocol actions

- Formalize condition assessment processes and protocols.
    - Engage with various stakeholders at the regional and park level and outside, affiliated groups to utilize assessment protocols. Include condition assessment protocols for ethnographic landscapes.

Existing Cultural Landscapes Review sub-objective: Review and, if deemed appropriate, update the list of the 31 recognized cultural landscapes.

Existing Cultural Landscapes Review actions

- Assemble subject matter experts to review the list of existing cultural landscapes and consider expanding.
    - **NOTE:** Emphasize ethnographical landscapes not originally considered.

Monitoring Coordination sub-objective: Coordinate with backcountry rangers, other park staff, and outside affiliated groups to assist with monitoring efforts.

Monitoring Coordination actions

- Utilize existing staff and park affiliated groups to help advance monitoring.
    - **NOTE:** Determine approaches for vegetation clearance and maintaining access.
- Partner with Commercial Use Authorization holders as part of permitting to encourage increase stewardship across priority actions including, but not limited to, inventory, documentation, monitoring, and park access.
    - **NOTE:** Prepare simple instructions and protocols for partners on inventory, documentation, monitoring, park access, etc.

Museum Collections

Critical Implications

Critical implications that are common across scenarios:

- Degradation of museum collections
- Loss/destruction of museum collections
- Access to museum collections restricted or blocked
- Impacts from exposure to pollutants

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

General concerns with housing museum collections within historic structures, recommend considerations for other strategies.

Adaptation Strategy

Objectives

Protect and manage museum collections in a climate change-informed way.

Sub-objectives

Documentation, Assessment, and Prioritization sub-objective: Consider conducting a range of documentation strategies, assessments, and prioritization processes.

Documentation, Assessment, and Prioritization actions

- Document and conduct a conservation survey of collections threatened by a range of climate change impacts.
    - **NOTE:** Consider de-accessioning duplicates and manufactured materials and explore options for relocation.
- Conduct studies of potential pollutants such as asbestos and leaching at mine sites.
    - **NOTE:** Consider enclosures and other forms of abatement.
- Undertake geophysical and structural studies to understand the stability of the substrate, foundations, and systems of historic structures that house museum collections and other resources
    - **NOTE:** Closely monitor the conditions and stability of historic structures that house museum collections.
- Implement a study to determine whether the Kennecott museum collections housed on-site in historic structures in the Kennecott Mill Town should be relocated and prepare a phased plan for their relocation.
- Identify a time frame and establish a phased plan for relocation with prioritized collections moved first.
- Conduct region-wide vulnerability assessment of collection storage.
    - **NOTE:** Focus on Copper Center and Kennecott at WRST.

Management sub-objective: Consider a range of actions for enhancing current management practices and overall stewardship of museum collections.

Management actions

- Explore relocation of museum collections housed in historic structures in Kennecott.
    - Incorporate relocation of archaeological materials and other items for potential de-accessioning.
- Prepare emergency evacuation plans for Kennecott and other vulnerable areas housing museum collections.
    - **NOTE:** Address complex logistics in these areas.
- Identify most at-risk museum collections and prepare a plan for mitigating potential loss of integrity or resources.
    - **NOTE:** Consider the use of digital documentation techniques to create a record.
- Install fire suppression options at Kennecott.
    - **NOTE:** Reference report on Security and Life Safety and Fire Risk Assessment for Alaska Park Museum Facilities (2021) recommended “installing smoke detectors in Kennecott Collections Room.”
- Install cabinets to house museum collections at Kennecott.

- **NOTE:** Identify which museum collections items could be housed in cabinets versus relocated. Refer to relocation plan recommendation above.

- Coordinate museum collections monitoring with winter caretakers, private landowners, and local partners.
  - **NOTE:** Goal is to enhance monitoring during times of year when access is difficult.



Lithic scatter near the base of Mt. Sanford. More common than stone tools are the by-product of their manufacture, often called flakes or debitage. Each pin flag marks a single flake resulting from the crafting and sharpening of stone tools. These flakes indicate locally sourced tool stone was used for tool manufacture. NPS photo by Lee Reininghaus.

Archeological Resources

Critical Implications

Critical implications that are common across scenarios:

- Site integrity reduced (site/artifacts revealed, inundated, buried)
- Site and artifacts destroyed
- Impacts on unidentified sites and artifacts
- Human landscape use patterns change
- Impacts due to changing invasive species management

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Active cultural resource management is designated for approximately 25% of WRST's cultural resources. Given the size and wilderness nature of the park, many archeological sites within WRST's boundaries may be yet unidentified.

Adaptation Strategy

Objectives

Document, assess risk, and manage archaeological sites in a climate change-informed way.

Sub-objectives

Documentation sub-objective: Accelerate and conduct increased archeological resource inventory and surveys to better understand and anticipate climate change impacts.

Documentation actions

- Conduct aerial surveys and other rapid documentation methodologies (e.g., 3D LiDAR, photogrammetry) to efficiently collect minimum datasets.
    - **NOTE:** Help inform stabilization measures and to create a record for mitigating the loss of integrity or loss complete loss of site.
- Prioritize data acquisition areas to identify the most vulnerable resources and sites (e.g., areas expected to experience increased fire, riverine flooding, sea level rise).
- Review existing site and resource data to identify critical gaps where additional inventory is warranted.
    - **NOTE:** Identify cultural resources that need be prioritized for documentation, stabilization, and monitoring. Coordinate with Cultural Landscape section.

Research sub-objective: Improve understanding of archeological site climate vulnerabilities and feasible response options.

Risk Assessment actions

- Conduct archeology-specific, scenario-based climate vulnerability assessment.
    - **NOTE:** Conduct vulnerability research with intent to enable actionability to focus management responses and limited capacity/resources.
- Conduct research on archeological site adaptation and management strategies.
    - **NOTE:** Potential interest in pilot project for model application.

Management sub-objective: Establish management priorities and available partnerships and coordination opportunities.

Management actions

- Establish prioritization of sites and resources for management actions and funding requests.
    - **NOTE:** Develop potential criteria, correlate with higher regional vulnerabilities and other vulnerable resources.

- Coordinate with CCRP and other groups to identify sources of climate impacts to archaeological sites, incorporating existing models and frameworks.
- Explore partnership opportunities for effort enhancement and force multiplication.
    - **NOTE:** Consider development of citizen science programming/visitor cooperation to help monitor sites, document impacts and vulnerabilities via increased education and requests for information.
- Explore coordination opportunities with region and other park groups to track/manage archaeological site use patterns, access, invasive species management.
    - **NOTE:** Utilize larger initiatives to scale across parks to identify opportunities for learning across similar areas, while acknowledging individual characteristics of Alaskan parks.

Wilderness

Wilderness Character

Critical Implications

Critical implications that are common across scenarios:

- Degraded undeveloped quality from human activities (both public & park activities)
- Increased hazards to unconfined recreation
- Increased need to grapple with questions related to management interventions in Wilderness

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Managed through park visitor regulations.

Adaptation Strategy

Objectives

Manage, research, and monitor wilderness character in a climate change-informed way

Monitoring actions

- Monitor how Wilderness Character is changing alongside changing climate

Research actions

- Conduct a proactive strategic study of expected, climate-related growth in community populations, tourism, etc. to better be prepared for challenges stemming from them
- Investigate if and how Wilderness Character is changing alongside a changing climate
- Look into application of the resist-accept-direct (RAD) framework for Wilderness (review work of others doing this research, e.g., Aldo Leopold Wilderness Research Institute post-doc)

Management actions

- Have intentional discussions around Wilderness Character and what the park wants to do about it
- Review impacts of aviation, snowmachine, off-road vehicle, and watercraft use on Wilderness Character and consider alternative options
- Review and consider alternative options to use of monitoring instruments
- Consider soundscape implications for any NPS visitor infrastructure (see Natural Soundscape)



Solitude in a remote campsite in the Bremner Historic Mining District. NPS photo by Jacob Frank.

Solitude

Critical Implications

Critical implications that are common across scenarios:

- Decreased opportunities for solitude and remoteness

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

May be managed through enforcement of regulations and issuance of permits, contingent on specific circumstances and authorities.

Adaptation Strategy

Objectives

Manage, research, and monitor solitude in a climate change-informed way

Monitoring actions

- Monitor motorized transport as a metric for possible reduction in solitude

Research actions

- Conduct study of visitor perception of solitude

- Study helicopters, fixed wing aircraft, or other motorized use in support of increased research and monitoring
- Study what "solitude" even means in WRST
- Study visitor perceptions of current and desired conditions in backcountry areas
- Study thresholds related to human waste, crowding, trailing, campfire rings, etc.
  - Lots of social science has been conducted in the L48 (lower 48 states) that can be drawn upon
- Study acceptability of possible management actions

Management actions

- Review visitation and access routes
- Increase capacity for backcountry patrols
- Outreach to communities that use these facilities / kick off improved community engagement and discussion
  - E.g., What are the issues you are encountering? What would you like to see improved?
- Map areas of expected high traffic use and pro-actively identify areas of higher potential solitude
  - Use to manage access (public, commercial, administrative)
  - Use existing info on overflight analysis to monitor and report
- Review overflights
  - Review DENA's FACA (Federal Advisory Committee Act [1972]) group for oversight of overflight management
  - Explore possible incentives to provide to aviation community for providing data or improved communication and information sharing
  - FAA Safety branch—potential partnership to develop forum for bringing pilots together for 'aviation party' to promote a discussion of solitude and remoteness as park values potentially impacted by overflights and ways that the aviation community might work together with WRST to minimize such impacts through improved communication and mutual sharing of information
    - NOTE: See lessons learned from Talkeetna and Healy experiences ('Fly Friendly, Good Neighbor' best practices)
  - Ensure noise is part of broader discussions around safety, smoke, etc.
- Administrative use of aviation
  - Continue to use Helicopter Use Policy; explore possible revisions to it
  - Review Jane Swanson & Peter Newman papers (e.g., Swanson et al. 2002; Miller et al. 2018; Newman et al. 2018) on perceptions of helicopter use in Alaska

Natural Soundscape

Critical Implications

Critical implications that are common across scenarios:

- Degraded natural soundscapes from human activities
- Implications for wildlife—decreased alerting/detection/communication distance for animals

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Only managed through enforcement of regulations and issuance of permits, contingent on specific circumstances and authorities.

Adaptation Strategy

Objectives

Manage, research, and monitor natural soundscapes in a climate change-informed way

Monitoring actions

- [none identified]

Research actions

- Explore use of drones as alternative to larger aircraft
    - Research the effects of increased drone use (by administration and visitors) on natural soundscapes (e.g., drones are quieter but can get closer)
- Research the impacts of increasing/changing sound on wildlife species
    - Implications are dependent on taxa
    - Identify species that are more susceptible to noise
- Investigate soundscape implications of aviation, snowmachine, off-road vehicle, and watercraft use and explore alternative options
    - Consider collaborations
- Investigate soundscape implications of NPS visitor infrastructure and explore alternative options
    - Consider collaborations
- Develop a baseline soundscape across the park

Management actions

- Review and consider alternative options to aviation, snowmachine, off-road vehicle, and watercraft use
    - Consider collaborations
- Consider soundscape implications for any NPS visitor infrastructure

- Modify CUA and permit processes to consider effects on Natural Soundscapes & Solitude (e.g., define a threshold that qualifies as 'impairment', even if it won't be reached, to raise awareness and have intentional consideration about sound levels)
- Map known flight routes
    - Assess/monitor cumulative effects of transportation networks, including consideration of spatial patterns flown between portals and airstrips (could lead to consideration of potential constraints on approved flight patterns)
    - Look into how airstrips get put on public maps, to help influence location of use
        - **NOTE:** Katmai National Park and Preserve found hotspots due to overlap of transects that were separate from portals and airstrips
        - **NOTE:** Davyd Betchkal has flight GPS database
- Support stream gauging as an indicator of a major natural driver of changes in soundscapes
    - Review and potentially regulate recreational vehicle and construction use to impede negative sound impacts on wildlife species

Night Skies

Critical Implications

Critical implications that are common across scenarios:

- Decreased night sky viewing opportunities (due to changes in cloud cover or smoke from increases in wildfires)

Critical implications that are not common across scenarios:

- [no critical implications in this category]

Management Considerations

Only managed via limited regulation of lights in areas, and monitoring.

Adaptation Strategy

Objectives

Manage, research, and monitor night skies in a climate change-informed way

Monitoring actions

- Monitor changes in light levels

Research actions

- Work with the NPS Night Skies and Natural Sounds Division to do lighting inventory to identify baseline light levels

Management actions

- Increase education and outreach / interpretation about Night Skies, artificial light at night, etc.

    - Use ‘Park Service as a model society’—do our own actions to demonstrate actions people can take
- Proactively recognize the consideration of lighting design in all relevant facility projects, including retrofitted considerations
- Offer resources and information to groups wanting to reduce night lights

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Appendix 1. Participants

Listed here are participant names, affiliations, and the role each played in the climate change scenario or adaptation strategy development processes. These processes—each a sequential step in the overall Wrangell-St. Elias National Park and Preserve RSS development process (Figure 5)—included both group work (via remote-participation virtual workshops) and individual work. Participants in the scenario development step, which is the subject of a companion report (Runyon et al. 2024), are included here to show how the participant pools for each of these steps relate to each other. The participant pool for the adaptation strategy brainstorming phase included all scenario development participants plus additional participants (i.e., SMEs who were either previously unavailable or were intentionally brought in at this point to broaden thinking). In contrast, the adaptation strategy refinement step narrowed the pool to the subset of participants who typically provide input to inform WRST resource management decisions—i.e., NPS park, regional, national, and inventory and monitoring network staff.

Table A1-1. Workshop participants, affiliations, and roles.

Name	Organization	Scenario development participant?	Adaptation strategy brainstorming participant?	Adaptation strategy refinement participant?
Kate Baer	U.S. Forest Service	YES	YES	NO
Jennifer Barnes	NPS – Alaska Regional Office	YES	YES	YES
Davyd Betchkal	NPS – Natural Sounds and Night Skies Division	YES	YES	NO
Andrew Bliss	NPS – Southeast Alaska Inventory and Monitoring Network	YES	YES	NO
Dana Brown	University of Alaska – Fairbanks	YES	YES	NO
Paul Burger	NPS – Alaska Regional Office	YES	YES	YES
Matt Cameron	NPS – Yukon-Charley Rivers National Preserve and Gates of the Arctic National Park and Preserve	NO	YES	NO
Barbara Cellarius	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Grant Crosby	NPS – Alaska Regional Office	YES	YES	NO
Seth Danielson	University of Alaska – Fairbanks	YES	YES	NO
Shina duVall	NPS – Alaska Regional Office	YES	YES	YES
Heather Feil	NPS – Alaska Regional Office	YES	YES	YES
Melanie Flamme	NPS – Yukon-Charley Rivers National Preserve and Gates of the Arctic National Park and Preserve	YES	YES	NO
Scott Gende	NPS – Glacier Bay National Park and Preserve	YES	YES	NO
Kristen Gorman	University of Alaska – Fairbanks	YES	YES	NO
Dan Gorze	Ahtna Intertribal Resource Commission	NO	YES	NO
Jeff Gross	Alaska Department of Fish and Game	YES	YES	NO
Mary Hake	NPS – Alaska Regional Office	YES	YES	NO

Table A1-1 (continued). Workshop participants, affiliations, and roles.

Name	Organization	Scenario development participant?	Adaptation strategy brainstorming participant?	Adaptation strategy refinement participant?
Heidi Hatcher	Alaska Department of Fish and Game	YES	YES	NO
Jesse Heinbaugh	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	NO
Grant Hilderbrand	NPS – Alaska Regional Office	YES	YES	YES
Chad Hults	NPS – Alaska Regional Office	NO	YES	NO
John Jansen	National Oceanic and Atmospheric Administration	YES	YES	NO
Kyle Joly	NPS – Yukon-Charley Rivers National Preserve and Gates of the Arctic National Park and Preserve	NO	YES	NO
Caroline Ketron	Bureau of Land Management	YES	YES	NO
Nyssa Landres	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Amy Larsen	NPS – Central Alaska Inventory and Monitoring Network	YES	YES	YES
Dave Lawrence	NPS – Climate Change Response Program	YES	YES	NO
Adrienne Lindholm	NPS – Alaska Regional Office	YES	YES	YES
Jeremy Littell	U.S. Geological Survey – Alaska Climate Adaptation Science Center	YES	YES	NO
Mike Loso	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Kelsey Lutz	NPS – Alaska Regional Office	YES	YES	YES
Rachel Mason	NPS – Alaska Regional Office	YES	YES	YES
Mark Miller	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Odin Miller	Ahtna Intertribal Resource Commission	YES	YES	NO
Timothy Mullet	NPS – Kenai Fjords National Park	YES	YES	NO
Peter Neitlich	NPS – Alaska Regional Office	YES	YES	NO

Table A1-1 (continued). Workshop participants, affiliations, and roles.

Name	Organization	Scenario development participant?	Adaptation strategy brainstorming participant?	Adaptation strategy refinement participant?
Fleur Nicklen	NPS – Central Alaska Inventory and Monitoring Network	YES	YES	YES
David Payer	NPS – Alaska Regional Office	YES	YES	YES
Judy Putera	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Desiree Ramirez	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Pete Rand	Prince William Sound Science Center	YES	YES	NO
Lee Reininghaus	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Carl Roland	NPS – Central Alaska Inventory and Monitoring Network	YES	YES	YES
David Sarafin	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Josh Schmidt	NPS – Central Alaska Inventory and Monitoring Network	YES	YES	NO
Joshua Scott	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	YES
Trey Simmons	NPS – Central Alaska Inventory and Monitoring Network	YES	YES	YES
Mathew Sorum	NPS – Yukon Charley National Preserve	YES	YES	NO
Sterling Spilnek	Ahtna Intertribal Resource Commission	NO	YES	NO
Sarah Stehn	NPS – Central Alaska Inventory and Monitoring Network	YES	YES	NO
Melissa Valentin	2100 Consulting Public Benefit Corporation	YES	YES	NO
Jeff Wells	Alaska Department of Fish and Game	YES	YES	NO
Don Welty	NPS – Wrangell-St. Elias National Park and Preserve	YES	YES	NO
Jamie Womble	NPS – Southeast Alaska Inventory and Monitoring Network	YES	YES	YES

Literature cited in Appendix A

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Appendix 2. Facilitators

Effective participatory climate change adaptation relies on expert facilitators to design an efficient process, guide participants, make mid-course adjustments, distill intermediate products and foster group review and revision, and summarize findings. Successful processes minimize unnecessary burdens on participants, translate climate science into useful products, and empower participants to draw on their unique subject-matter expertise to help better understand and adapt to climate change. The 2021–2023 Wrangell-St. Elias Park and Preserve process included a large set of facilitators, and the following table identifies the subset of facilitators involved in the adaptation strategy development process described in this report and shares the affiliation and role(s) of each.

Table A2-1. Facilitator affiliations and roles.

Name	Organization	Role
Gregor Schuurman	NPS – Climate Change Response Program	Adaptation strategy development process lead; Facilitator: Wildlife, Aquatics
Amber Runyon	NPS – Climate Change Response Program	Facilitator: Hydrology, Human systems
Brecken Robb	USGS North Central Climate Adaptation Science Center	Facilitator: Vegetation, Wilderness
Morris Hylton III	NPS – Climate, Science, and Disaster Response Program	Facilitator: Cultural resources

Appendix 3. Full Terms for Acronyms Used by Participants in Their Above-Summarized Adaptation Strategy Development Work

Participants used numerous acronyms in developing and refining (particularly annotating) climate-informed resource management strategies. The important acronyms—i.e., established abbreviations of the names of places, organizations, and tools—are retained in this report's resource-specific summarizations and the meaning of each acronym is clarified in the table below. The meaning of each acronym is also provided alongside its initial use in the report, but this translation is provided because the participant-generated content in the report may not necessarily be used in such a way that it is read from start to finish. Note that acronyms introduced in the introductory material of this report that precedes participant outputs are not repeated here.

AIS:	Automatic Identification System
ARCN:	NPS Arctic Inventory and Monitoring Network
CAKN:	NPS Central Alaska Inventory and Monitoring Network
CUA:	Commercial Use Authorization
FACA:	Federal Advisory Committee Act (1972)
FHM:	USFS Forest Health Monitoring Program
FIA:	USFS Forest Inventory and Analysis Program
GLBA:	Glacier Bay National Park and Preserve
GLORIA:	Global Observation Research Initiative in Alpine Environments
GPS:	Global Positioning System
HABS/HAER/HALS:	Historic American Buildings Survey/Historic American Engineering Record/Historic American Landscapes Survey
KOP:	Kennecott Operations Plan
LiDAR:	Light Detection and Ranging
NHL:	National Historic Landmark
NOAA:	National Oceanic and Atmospheric Administration
OAS:	Department of the Interior's Office of Aircraft Services
ORV:	Off-road vehicle

RAD:	Resist-Accept-Direct framework
RSS:	NPS Resource Stewardship Strategy
SAR:	Search and Rescue
SEAN:	NPS Southeast Alaska Inventory and Monitoring Network
SEAPA:	Southeast Alaska Pilot's Association
SUP:	Stand-up paddle board
USFS:	U.S. Forest Service
USGS:	U.S. Geological Survey
VIDA:	Vessel Incidental Discharge Act
WiLDCAST:	Wildlife Potential Habitat Forecasting Project (USGS)
WRST:	Wrangell-St. Elias National Park and Preserve
YAK:	Yakutat airport
YK Delta:	Yukon-Kuskokwim Delta

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.

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