



Adapting to Climate Change-Driven Loss of Ecologically Important Species and Processes from Park Ecosystems

A Study of Management Options for Glacier National Park Streams in the Context of National Park Service Policy and Guidance—Public Version



Sunrise on Lower McDonald Creek, Glacier National Park.

NPS

Adapting to Climate Change-Driven Loss of Ecologically Important Species and Processes from Park Ecosystems: A Study of Management Options for Glacier National Park Streams in the Context of National Park Service Policy and Guidance—Public Version

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Abstract

The traditional paradigm in mainstream environmental stewardship assumes a stationary climate in which climatic and ecological change generally occur within bounds (e.g., “natural range of variability”) and managers can conserve ecosystems by preserving their historically co-occurring species, natural communities, and physical and biological processes. For example, 2006 Management Policies, the current NPS management policies document, suggests that by preserving ecosystem components and processes in their natural condition, the NPS will prevent resource degradation and thus avoid any subsequent need for resource restoration. But climate change challenges these long-held assumptions. As local climates become increasingly inhospitable for historically occurring species, managers confront the paradox that maintaining historical (i.e., natural) ecosystem structure and ecological processes may be increasingly difficult with such species. This report examines the NPS policy context for a diversity of potential management responses to this paradox in Glacier National Park, illustrating a type of resource-management challenge that many other parks face. Here, the focus is on a mid- to lower-elevation reach of a lake-connected stream in Glacier National Park that is losing its native top-predator fish species—the bull trout (*Salvelinus confluentus*)—due to synergistic impacts of (1) climate change (e.g., stream warming and increasingly frequent and long low-flow periods in summer and fall, as well as increasing frequency of rain-on-snow events and associated streambed scour) and (2) the nonnative lake trout (*Salvelinus namaycush*), which preys on and competes with bull trout. Loss of a top predator in stream ecosystems can cause cascading changes in abundances of other species and in resource flows throughout the aquatic food web and interconnected terrestrial ecosystems. To inform ongoing development of policy and guidance for climate-informed stewardship, this analysis considers potential management strategies developed using the resist–accept–direct (RAD) framework. It considers these strategies against NPS policies to identify where policy is prescriptive, permissive, prohibitory, or unclear, and concludes that current policy—as augmented by the August 2024 Policy Memorandum 24-03 (*Managing National Parks in an Era of Climate Change*)—recognizes the challenge and instructs managers not to expect park ecosystems to resemble those of the past and to plan and manage for future climatic and associated ecological conditions. Furthermore, NPS policy both expects managers to adapt to climate change “including by proactively resisting, accepting, or directing its impacts” and acknowledges that such actions may entail novel approaches, including substantial interventions or divestment of activities.

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We thank the NPS Climate Change Response Program for initiation and support of this study as part of a larger effort to examine policy implications of different climate change adaptation strategies applied to common NPS natural resource issues. We appreciate the park staff across the NPS who submitted descriptions of climate change-related issues in their parks in response to a survey request from the Climate Change Response Program. The survey identified climate change-driven loss of ecologically important species as an important concern nationwide and across multiple ecosystems. Parks that submitted issues associated with this concern include Catoctin Mountain Park, Denali National Park, Gates of the Arctic National Park, Glacier National Park, Golden Gate National Recreation Area, John Day Fossil Beds National Monument, Lake Roosevelt National Recreation Area, Mammoth Cave National Park, Mesa Verde National Park, Mount Rainier National Park, North Cascades National Park Complex (North Cascades National Park, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area), Organ Pipe Cactus National Monument, Redwood National Park, Voyageurs National Park, and Yellowstone National Park. We also thank staff at Glacier National Park who ensured that our analysis reflected current ecology and management of fish species and stream ecosystems in the park. Finally, we thank Chris Downs, Jason Dunham, Koren Nydick, John Wullschleger, and Cat Hawkins Hoffman for their helpful comments and suggestions, Cat Hawkins Hoffman for managing the peer review process, Kaylin Thomas for formatting help, and the following reviewers of earlier versions of this report: Greg Eckert, the late David Graber, Nick Fisichelli, Mary Foley, John Gross, Laurie Jenkins, Melinda Koslow, and Tom Olliff. This report is essentially identical to the first version of this report, which was published in April 2025 with restricted access.

Introduction

The traditional paradigm in mainstream natural resource stewardship assumes a stationary climate in which climatic and ecological change generally occur within familiar or knowable bounds¹ and an ecosystem can be conserved by preserving its historically co-occurring species, natural communities, and physical and biological processes. For example, the current National Park Service (NPS) management policies document, Management Policies 2006² (NPS 2006, Section 4.1), states³ that:

Natural resources will be managed to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities By preserving these components and processes in their natural condition, the Service will prevent resource degradation and therefore avoid any subsequent need for resource restoration.

Substantial past changes in ecosystems and the ephemerality of natural communities revealed by paleoecology (e.g., Jackson 2006; Jackson and Hobbs 2009) have not been seen as problematic in the context of this policy because such changes are understood to generally operate on geological, rather than human, timescales. However, modern anthropogenic climate change challenges long-held assumptions. Rapid, directional change in climate is redistributing Earth's biota at rates of kilometers per year (e.g., Lenoir et al. 2020; Pecl et al. 2017), driving changes in natural communities and species assemblages through extirpation and colonization (Comte et al. 2021). For example, ranges of freshwater fishes are expanding along elevational gradients at their upper limits and contracting at their lower limits (Comte and Grenouillet 2013; Hickling et al. 2006). Future distribution changes consistent with these observed shifts have been predicted for many freshwater fish species (Comte et al. 2013). These ongoing climate change-driven shifts in species assemblages and natural communities can cascade into changes in ecosystem structure and processes and ultimately wholesale ecological transformation within human timescales (Crausbay et al. 2022; Nolan et al. 2018).

¹ The term “natural range of variability,” which is often used as a guide or framework for environmental stewardship, is an expression of the understanding that developed in the latter half of the 20th century that “spatial and temporal variability is a vital attribute of nearly all ecological systems” (Landres et al. 1999, p. 1179) and that, for stewardship purposes, such variability (i.e., change) can be assumed to “fluctuate within an unchanging envelope of variability” (Milly et al. 2008, p. 573).

² Use of “Management Policies” (capitalized) throughout this report refers to Management Policies 2006 (NPS 2006), the current NPS management policies document which is part of a three-tiered policy system that also includes director’s orders and policy memoranda, reference manuals, and handbooks. In recognition of the ongoing need for adaptive change, Management Policies states that “interim updates or amendments may be accomplished through director’s orders (the second level of the Directives System), which also serve as a vehicle to clarify or supplement the *Management Policies* to meet the needs of NPS managers” (pp. 4–5).

³ Although Management Policies has a plural name, it is a single document and is generally referred to in the singular.

Although NPS Management Policies directs the agency to preserve resources in a natural condition, defined as “the condition of resources that would occur in the absence of human dominance over the landscape” (NPS 2006, p. 36), a subsequent policy memorandum (Policy Memorandum 12-02: *Applying National Park Service Management Policies in the Context of Climate Change* [NPS 2012]) recognizes that “‘natural conditions’ may be both increasingly difficult to characterize and ineffective as a guide for desired future conditions.” Furthermore, it states that “[w]idespread, cascading effects from climate change challenge park managers in ways unimaginable even a few decades ago,” and calls for the development of “a new paradigm for natural and cultural resource management for the National Park System” (NPS 2012).⁴ Since 2010, the NPS Climate Change Response Program has been developing tools to help managers fulfill the agency mission under the new reality of rapid and accelerating climate change (NPS 2023). This report is part of those efforts.

To understand and address needs of park managers, the Climate Change Response Program conducted a survey across the Service to identify challenging issues and questions, particularly those related to policy, that managers face in the context of addressing present and anticipated impacts of climate change. The NPS Natural Resource Stewardship and Science Directorate, regional offices, and park staffs identified over 300 specific climate change-related management concerns regarding protection of natural resources in parks⁵ across the country. Most wildlife-related concerns were associated with shifts of suitable climatic conditions for species into or out of parks, raising questions about both (1) conserving low-mobility species that cannot shift in space fast enough or face obstacles to keeping pace with their climate niches and (2) conserving park ecosystem structure and processes that depend on species that can no longer survive in the park. Addressing the first concern, a companion report focused on the desert tortoise (*Gopherus agassizii*) (Leong et al. 2026) examines management options—including translocation—in the context of NPS policy and guidance. This report examines NPS policies regarding the second concern: conserving ecosystem structure and processes in the context of climate change-driven extirpation of species that historically created or mediated these important ecological features.

To explore this concept, we selected the submission from Glacier National Park (hereafter also referred to as “the park”) regarding declines in native bull trout (*Salvelinus confluentus*) and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). We chose this submission because climate change vulnerabilities of both these species and their aquatic habitats are well known (e.g., Bell et al. 2021; Hall and Fagre 2003; Isaak et al. 2012, 2021; Jones et al. 2014; Muhlfield et al. 2014) and the park has a strong interest in actively responding to these vulnerabilities (e.g., Galloway et al. 2016; NPS 2022a). Both species are thermally sensitive native trout but they have distinct ecological roles; for the sake of simplicity, our analysis proceeds with a focus on the bull trout. The purpose of this

⁴ In addition, a report of the National Park System Advisory Board Science Committee in 2012 encouraged the NPS to “steward NPS resources for environmental changes that increasingly exceed historical experiences” (Colwell et al. 2012).

⁵ The term “park” in this report refers to any NPS unit (e.g., national park, national historic site, national monument, etc.).

analysis is to (1) document how existing guidance and policies inform potential management responses to loss of ecologically influential species and associated ecosystem structure and processes; and (2) highlight legal or policy gaps or contradictions as a foundation for future guidance or policy development. Additionally, although this analysis is grounded in a real-world context, its focus is understanding policy and guidance, and it is not intended to serve as the basis for management decisions.

Management Issue and Scientific Background

Climate change is among the major stressors on aquatic ecosystems and natural communities across the globe (Heino et al. 2009). It threatens native aquatic species in many United States national parks, including two important native coldwater salmonids in Glacier National Park—the federally listed bull trout (Threatened) and the westslope cutthroat trout (e.g., Muhlfeld et al. 2014). Increasing frequency of rain-on-snow events and associated streambed scour, glacier loss (Hall and Fagre 2003), and rising temperatures generate unfavorable low-flow/high-temperature stream conditions in summer and fall in lower stream reaches, thus fragmenting remaining habitat (Jones et al. 2014).

Salmonids are keystone species that perform important functions in these ecosystems and food webs such that loss of this trophic level could produce substantial cascading ecological changes in the aquatic food web and interconnected terrestrial ecosystems (Baxter et al. 2004; McIntosh and Townsend 1996; Meissner and Muotka 2006; Middleton et al. 2013; Power 1990; Rosenfeld 1997; Wainright et al. 2021). Potential changes include large increases or decreases (depending on the stream’s trophic structure) in abundance of other components of the aquatic food web, including predators and grazers, macroalgae, and diatoms and cyanobacteria. Such trophic changes can alter flows of resources to connected ecosystems, causing cascading effects, as illustrated by the finding that a decline in cutthroat trout in Yellowstone National Park contributed to increased predation on elk by grizzly bears, subsequently reducing calf recruitment and population growth (Middleton et al. 2013). NPS Management Policies (NPS 2006) recognizes the importance of conserving not just species and natural communities but also ecosystem structure and processes in stating that “[n]atural resources will be managed to preserve fundamental physical and biological processes ...” (Section 4.1 *General Management Concepts*). However, Management Policies does not anticipate threats to such processes arising from climate change-driven extirpation of keystone species, as evidenced in the following text:

The Service will not attempt to solely preserve individual species (except threatened or endangered species) or individual natural processes; rather, it will try to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems. (Section 4.1 General Management Concepts)

Higher-elevation regions of North America and elsewhere, including western Montana, are warming; mean air temperature in the Flathead River basin, for example, has warmed 0.16°C/decade since 1950 (Isaak et al. 2012). Glacier National Park is among the more than 80% of NPS units with significant natural resources experiencing mean temperatures that are extremely warm compared with the recent historical record (1901–2012, Monahan and Fisichelli 2014). Additionally, the park is expected to continue to warm significantly in the coming century (Knapp et al. 2023). In the near term, many factors, including anthropogenic climate change, large-scale climate oscillations (e.g., Pacific Decadal Oscillation), and inherent variability will influence climate in the northern Rocky Mountains; however, the underlying long-term trend is towards warmer conditions.

This study focuses on a mid- to lower-elevation reach within a lake-connected stream that spans a range of elevations in Glacier National Park. It examines the issue of how to respond to loss of trophic structure and ecological processes caused by the loss of the stream's population of native trout. In this case, the loss is due to the synergistic effects of climate change and a nonnative species—lake trout (*Salvelinus namaycush*)—that preys on and competes with bull trout.⁶ The bull trout, which has an upper thermal limit that is among the lowest of North American salmonids, is highly climate change-sensitive and is expected to experience substantial range contraction this century due to warming (Jones et al. 2014; Selong et al. 2001). Fundamental conservation questions associated with this issue include the following:

- Where climate change contributes to loss of trophic complexity and ecological processes by local extirpation of native species populations, how should we respond? Should managers ...
 - Endeavor to prolong a species' persistence, and if so, what actions are appropriate?
 - Do nothing to mitigate climate change impacts and simply observe how the system responds?
 - Introduce new species (or hybrids)—or favor those already introduced—that are better suited to current and anticipated future conditions and likely to help conserve trophic complexity, ecological processes, and visitor experience?
- Are current NPS management policies and guidance prescriptive, permissive, contradictory, or silent regarding these questions?

⁶ Lake trout do not occur in streams (although they are found in some deep rivers) but are abundant in lakes connected to streams. Bull trout, in contrast, use both lakes and streams. Some bull trout forms live in lakes and migrate into streams in the fall to spawn. Lake trout competition with and predation on bull trout in these lakes prevent bull trout from using them as coolwater refugia, and therefore may amplify the effects of warming streams.

Climate Change Adaptation Options

The process of addressing climate change vulnerabilities is known as climate change adaptation, which 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 2021a)

As in all management planning, key steps in climate change adaptation include defining current goals and evaluating whether current resource conditions and anticipated changes are consistent with those goals. Where goals and current or anticipated resource conditions are inconsistent, one option is to identify and apply additional actions to achieve the goal—for example, fish die-offs are already occurring at lower elevations in western states during low-flow/high-temperature periods, and managers periodically close fisheries to reduce other stressors, increasing the likelihood that the population will survive such episodes (Lynch et al. 2015; Rahel 2016). Another option, of course, is to revise the goal. Ultimately, the choice of approach depends on many factors, including the value and vulnerability of the resource and the feasibility of management options.⁷ To develop a broad set of potential approaches for this analysis (Table 1), we used the resist–accept–direct (RAD) framework (Lynch, Rahel et al. 2022; Rahel 2022; Schuurman et al. 2020, 2022; Thompson et al. 2021),⁸ which presents three fundamentally different management responses to a human-caused⁹ ecological trajectory:

⁷ A full exploration of the adaptation process and how resource vulnerability, social dimensions, management action feasibility, and evaluation of outcomes are considered is beyond the scope of this policy-focused report. For more on these topics, see the NPS adaptation guide *Planning for a Changing Climate* (NPS 2021b), as well as Stein et al. 2014; Clifford et al. 2022; Lynch, Thompson et al. 2022; Magness et al. 2022; and Miller et al. 2025.

⁸ The resist–accept–direct (RAD) framework was adapted from similar frameworks proposed by Fisichelli et al. (2016) and Aplet and Cole (2010) and has been further developed recently for fisheries-focused climate change adaptation by Lynch, Rahel et al. (2022) and Rahel (2022).

⁹ The NPS recognizes impacts of modern anthropogenic climate change as human-caused. For example, Policy Memorandum 24-03 *Managing National Parks in an Era of Climate Change* (NPS 2024) states that “ubiquitous effects of climate change demonstrate modern human impacts even in the most remote areas of the planet, and on all types of resources,” and that “[t]he NPS Organic Act (54 USC 100101 et seq.) offers the broadest support for response by affirming NPS responsibility to address human-caused impacts to protect park resources and leave them unimpaired for future generations.”

1. **Resist** the trajectory, by working to maintain or restore ecosystem composition, structure, processes, or function on the basis of historical or current conditions;
2. **Accept** the trajectory, by allowing ecosystem composition, structure, processes, or function to change autonomously; or
3. **Direct** the trajectory, by actively shaping change in ecosystem composition, structure, processes, or function toward preferred new conditions.

The framework, increasingly used in United States federal resource management agency climate change adaptation (e.g., DOI 2021; NPS 2021b, 2024; USFWS 2024), encourages transparent and strategic conservation decisions that reckon explicitly with environmental non-stationarity. The example actions below (Table 1) cover a range of potential tactics aligned with strategies of resisting, accepting, or directing the climate change-driven ecological trajectory. Management interventions like restoring or moving fish, closing fisheries, building or removing barriers, and managing hydrology and riparian vegetation are not new,¹⁰ but their intentional application in climate change adaptation (Stein et al. 2014) may be very different than in past applications, and warrants discussion. Adaptive management, including monitoring, is a key component of natural resource management that is consistent with RAD framework application (Lynch, Thompson, et al. 2022; Schuurman et al. 2025) and ideally is an ongoing practice, consistent with United States Department of the Interior policy (e.g., DOI 2023). In addition, as with all management decisions—including resisting, accepting, or directing climate change-driven change—engaging early and often with stakeholders and rights-holders may be an important action (Bamzai-Dodson et al. 2021). Finally, the preferred adaptation strategy may vary within a park—for example, among developed, frontcountry, and backcountry locations.

¹⁰ Climate change adaptation includes not only novel approaches but also many familiar management actions. For this reason, it is important to avoid the temptation to simply “relabel existing practices and projects as adaptation” and to instead “demonstrate an explicit understanding or hypothesis for how [adaptation actions] are likely to reduce key climate-related vulnerabilities or take advantage of climate-related opportunities” (Glick and Stein 2014, pp. 38–39).

Table 1. Potential climate change adaptation actions associated with either intervening to conserve trophic structure and key ecological processes (e.g., predation, resource and energy transfer among interconnected aquatic and terrestrial ecosystems) or allowing autonomous change in a warming mid- to lower-elevation stream reach in Glacier National Park. As denoted by an “X,” each action is categorized in terms of whether it (1) conserves trophic structure and ecological processes by either resisting or directing change in the fish assemblage or (2) is associated with accepting climate change-driven loss of these ecosystem components and processes. Actions are largely drawn from Rahel (2022). Many of these actions, whether they focus on resisting, accepting, or directing, can be used simultaneously in different parts of a landscape or sequentially in a given place (Magness et al. 2022).

Action	Resist	Accept	Direct
Enhance or restore stream shading to reduce temperatures	X	–	–
Enhance or restore hydrology to maintain flows and reduce temperatures	X	–	–
Use fisheries closures during warm spells to enhance native fish survival	X	–	–
Prohibit harvest of species of conservation concern	X	–	–
Use fish rescue techniques to buffer effects of low-survival periods ¹¹	X	–	–
Bolster the native fish population via stocking	X	–	–
Conserve or restore genetic diversity	X	–	–
Translocate thermally tolerant native fish strains (genotypes) into the population ¹²	X	–	–
Intentionally fragment habitat to prevent colonization by nonnative species better adapted to new conditions	X	–	–
Restore connectivity for historically native species to allow access to refugia and recolonization	X	–	–
Remove or control nonnative fish species (especially those favored by climate change)	X	–	–
Engage with stakeholders and rights-holders regarding changes in management goals or actions	X	X	X
Introduce new fish species or hybrids adapted to new conditions	–	–	X

¹¹ Rahel (2022) points out that “[r]escue efforts straddle the Resist–Accept categories in that they involve accepting abiotic changes (even if only temporarily) while resisting biotic changes (by moving and later repatriating species).” In this case, where the focus is biotic changes (including loss of trophic structure and ecological processes), fish rescue is therefore categorized exclusively as a resistance action.

¹² Categorizing actions under the RAD framework requires specificity in terms of the focus. Because the focus here is ecosystem structure and process, modification of the native fish population’s genetics to enhance its likelihood of persistence is a means of supporting an ecosystem process and therefore is a resistance activity. However, if the focus were instead the fish species itself and conserving it “as it was, where it was” then this action would be categorized as directing change (Schuurman et al. 2023).

Table 1 (continued). Potential climate change adaptation actions associated with either intervening to conserve trophic structure and key ecological processes (e.g., predation, resource and energy transfer among interconnected aquatic and terrestrial ecosystems) or allowing autonomous change in a warming mid- to lower-elevation stream reach in Glacier National Park. As denoted by an “X,” each action is categorized in terms of whether it (1) conserves trophic structure and ecological processes by either resisting or directing change in the fish assemblage or (2) is associated with accepting climate change-driven loss of these ecosystem components and processes. Actions are largely drawn from Rahel (2022). Many of these actions, whether they focus on resisting, accepting, or directing, can be used simultaneously in different parts of a landscape or sequentially in a given place (Magness et al. 2022).

Action	Resist	Accept	Direct
Limit harvest of new fish species or hybrids adapted to new conditions	–	–	X
Improve habitat to benefit new species or hybrids adapted to new conditions	–	–	X

A resistance strategy aims to maintain current conditions (or restore past conditions in impacted systems), which in this case would mean preserving trophic structure and ecological processes by preserving the historically occurring fish species assemblage. Actions focus on resisting the effects of increasing stream temperatures and declining flows through efforts such as restoring or enhancing riparian shading and hydrology, as well as bolstering fish populations directly via harvest prohibitions and temporary fisheries closures (Rahel 2022), using *ex situ* “fish rescue” programs¹³ to conserve lifetime survival rates by circumventing low-survival periods (Lopez Arriaza et al. 2017; Beebe et al. 2021), stocking, conserving or restoring genetic diversity, introducing thermally tolerant strains of native fish, removing harmful nonnative fish species, and reducing non-climate stressors.¹⁴ Depending on the context, a manager may also resist change by either restoring connectivity to provide native fishes access to refugia during times of stress or intentionally fragmenting habitat to prevent colonization by species not native to the stream (Fausch et al. 2009; Snyder et al. 2022).

An acceptance strategy does not aim to steer conditions towards a past state or move them towards a particular future state but may include management actions that support a system’s or species’ capacity to respond to changing conditions. Actions generally focus on reducing existing non-climate

¹³ Costs of “fish rescue” intervention can be high—including in terms of impact on the population itself (Beebe et al. 2021)—illustrating how attempts to resist change in a changing climate require careful evaluation.

¹⁴ Reducing other stressors (e.g., reducing runoff/pollutants, restoring degraded habitat, controlling competing or predatory nonnative species) can also be considered part of a resistance strategy if such actions explicitly and deliberately address climate change impacts (Dunham et al. 2022; Stein et al. 2014).

stressors, and in cases like this might seek to control harmful nonnative¹⁵ species like the lake trout and reduce runoff and pollution.

A directing-change strategy attempts to facilitate ecosystem change towards a preferred new condition. The management action to conserve trophic structure and ecological processes in this case would involve replacing the lost/declining native trout with another fish species (or a hybrid). Such an ecological replacement¹⁶ could occur by introducing new species drawn from a pool of regionally native species, as the Grand Portage Band of Lake Superior Chippewa did on their lands by introducing yellow perch (*Perca flavescens*) and walleye (*Sander vitreus*) to an important inland lake in response to warming-driven declines in brook trout (*Salvelinus fontinalis*) (Moore and Isaac 2026). In contrast to the resistance action of introducing thermally tolerant strains of the historically occurring population, replacement of that population with a hybrid or a distinct species is considered a directing-change strategy in part because the new population would likely only partially replace the lost species' ecological function (e.g., Benjamin and Baxter 2012). Alternatively, where trophically similar species have already been introduced into the ecosystem (e.g., nonnative trout), ecological replacement could be fostered by discontinuing eradication efforts and perhaps taking additional steps to favor them, including limiting harvest and managing habitat for their specific needs.

¹⁵ NPS Management Policies uses the term “exotic species” to refer to “those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities” and recognize “nonnative species,” “alien species,” and “invasive species” as synonyms (NPS 2006, Section 4.4.1.3). In this report we use “nonnative” to refer to such species because “exotic” is sometimes understood as referring to a subset of nonnative species from distant geographies.

¹⁶ Webster and Schindler (2024) explore the topic of ecological replacement, including potential risks and benefits, in the context of preserving or restoring the functional roles of corals on reefs.

Policy Analysis

This section assesses the spectrum of adaptation options for fish and aquatic habitat management in Glacier National Park relative to guidance found in NPS Management Policies (NPS 2006), NPS Policy Memorandum 12-02: *Applying National Park Service Management Policies in the Context of Climate Change* (NPS 2012), and recent NPS Policy Memorandum 24-03: *Managing National Parks in an Era of Climate Change* (NPS 2024). Together, these documents (1) frame a foundational understanding for stewarding both ecological processes and species, (2) acknowledge natural change, and (3) recognize the challenges of climate change, in calling on managers to:

- “preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities” (NPS 2006, Section 4.1 *General Management Concepts*);
- “not attempt to solely preserve individual species (except threatened or endangered species) or individual natural processes, but maintain all components and processes of naturally evolving park ecosystems, including natural abundance, diversity, and genetic and ecological integrity of plant and animal species native to those ecosystems” (NPS 2006, Section 4.1);
- Recognize natural change “as an integral part of the functioning of natural systems” (NPS 2006, Section 4.1);
- “address the inevitable movement, loss, or gain of species associated with parks” due to climate change (NPS 2012);
- “[engage] partners and [use] the best available science, including climate change science, to inform park planning and the implementation of cooperative solutions” (NPS 2012); and
- “promote climate change response to understand, prepare for, and adapt to, climate change impacts on park resources, infrastructure, and visitor experiences, including by proactively resisting, accepting, or directing those impacts” (NPS 2024).

Resisting Change

A resistance approach in this case would seek to maintain or restore ecosystem structure and processes by managing habitat and the historically occurring fish assemblage to prevent or reverse climate change impacts (Table 1). If such an impact were considered by managers to be an “adverse” or “unacceptable” impact, NPS Management Policies (NPS 2006) would generally call for management interventions to prevent or reverse it. Section 1.4.3 *NPS Obligation to Conserve and Provide for Enjoyment of Park Resources and Values*, for example, calls for appropriate resistance-oriented actions in general (“NPS managers **must always seek ways to avoid, or to minimize to the greatest extent practicable, adverse impacts on park resources and values**”¹⁷), and Section 1.6 *Cooperative Conservation Beyond Park Boundaries* offers a similar mandate: “**The Service will use all available tools to protect park resources and values from unacceptable impacts.**” Note,

¹⁷ Bold font (strong emphasis) here and throughout the report’s quoting of NPS documents indicates our emphasis.

however, that “**Management Policies (2006) do not require what is impossible, economically infeasible, or likely ineffectual**” (NPS 2012).

Section 4.1 *General Management Concepts* also calls for intervention to prevent or reverse impacts on natural resources if they are considered departures from a “naturally evolving” park ecosystem, and provides more specific information about intervention objectives: “The Service ... will try to **maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.**”

Section 4.1.5 *Restoration of Natural Systems* calls for intervention in natural biological or physical processes to reverse climate change impacts if the impacts are considered a result of “human disturbances,” rather than natural phenomena:

The Service will reestablish natural functions and processes in parks Impacts on natural systems resulting from human disturbances include the introduction of exotic species; the contamination of air, water, and soil; changes to hydrologic patterns and sediment transport; the acceleration of erosion and sedimentation; and the disruption of natural processes. The Service will seek to return such disturbed areas to the natural conditions and processes characteristic of the ecological zone in which the damaged resources are situated.

Resistance-oriented fish management tactics may include stocking to augment or retain a population,¹⁸ intensive genetic management in increasingly fragmented ranges (e.g., translocation to conserve genetic diversity and minimize genetic drift), reducing existing stressors such as nonnative species that compete or hybridize with the natives, and manipulating population genetics away from the historical condition. Regarding categorization of genetic manipulation as a resistance action, note that, as discussed in footnote 11 (in the Climate Change Adaptation Options section), clearly identifying the action’s focus (in this case, ecological processes) and ultimate purpose (i.e., to conserve an ecological process) is critical. From the perspective of conserving a species in a park, such an intervention would be a directing-change action because it does not conserve the species “as it was, where it was” (Schuurman et al. 2023), but from the perspective of conserving an ecological process it is a resistance action because it seeks to maintain or restore the process.

Under climate change, stocking to augment or retain a population could be undertaken as a short-term “buying-time” approach while longer-term approaches are developed, and is defensible under Section 4.1.5 *Restoration of Natural Systems* (“**The service will reestablish natural functions and processes ...**”) and Section 4.1 *General Management Concepts* (“**to restore natural ecosystem functioning that has been disrupted by past or ongoing human activities**”) as preservation of

¹⁸ Even if captive-reared fish are genetically appropriate, the NPS generally does not stock a stream segment if it is believed that a self-sustaining population is not possible (J. Wullschleger, NPS fisheries biologist, pers. comm. 2015).

trophic structure and trophic interactions including important natural processes such as predation and resource and energy transfer. Management to conserve native species' genetics is consistent with NPS management policy: "The Service ... **will try to maintain all the components and processes of naturally evolving park ecosystems**, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems" (Section 4.1 *General Management Concepts*). Removal of nonnative species—whether by direct agency action or simply through fishing regulations that permit high harvests of nonnatives—is also consistent with NPS policy (Section 4.4.4.2 *Removal of Exotic Species Already Present*).

NPS Management Policies cited above assumes that management can simultaneously reestablish or retain "components," "conditions," "functions," and "processes." Indeed, in many cases traditional approaches to restoring or maintaining historical conditions and functions (e.g., water leasing, geomorphic restoration, native riparian enhancement, grazing reductions and rotations) will be implemented in response to climate change. Ongoing climate change, however, may require processes or conditions that differ from those of the past. For example, conserving native trout in a mid- to low-elevation stream while air temperatures warm and glacial input diminishes may require **different** hydrology (e.g., temporarily pumping groundwater to discrete points within the stream during thermally stressful periods; Kurylyk et al. 2015) or **different** genetics (i.e., introductions of warm-adapted variants of the trout species whose functions are sought) than those in the past. Such efforts would simultaneously follow these sections of Management Policies in conserving top aquatic predators and violate them if pursued through ahistorical hydrology patterns and genetics. The main exceptions that may allow for such manipulation are found in Section 4.1 *General Management Concepts*, and include both prescriptive text ("Natural resources will be managed to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities") and permissive text ("The Service will not intervene in natural biological or physical processes, except ... when a park plan has identified the intervention as necessary to protect other park resources ..."). Section 4.2.2 *Management of Native Plants and Animals*, however, limits such interventions to those that "will not cause unacceptable impacts to the populations of the species or to other components and processes of the ecosystems that support them."

For ecosystems and species, unacceptable impacts are defined in policy in terms of being inconsistent with park purposes or values or impeding attainment of desired future conditions as identified through a park's planning process. This definition clearly restrains hasty action, but its focus on values and planning, combined with Section 4.1's recognition that management must sometimes seek to "**maintain the closest approximation of the natural condition when a truly natural system is no longer attainable**," provides some flexibility based on careful deliberation. Parks have historically employed this flexibility to pursue actions in appropriate cases that fall short of restoring a truly natural condition or process and that may cause impacts. Prescribed burning and control of ungulates where their predators have been extirpated are two cases in which an important ecological process is "restored" to a system via artificial means that clearly do not completely mimic the original process but seek to do so to the greatest degree possible. An aquatic example is development

of beaver-dam analogs¹⁹ (where beaver cannot be restored—for example, in areas where people do not tolerate them), which slow water flow, increase groundwater table heights, maintain late-summer flow, and promote more riparian vegetation that can ultimately increase stream shading (Bouwes et al. 2016; Pearce et al. 2021). Application of this language in light of climate change, however, may be very different because of the reality that, in a novel climatic context, the system’s original elements may no longer co-occur in their historical condition. Intervention in an ecosystem process in these cases does not necessarily seek to achieve the “closest approximation of the natural condition” of the element under direct management control (hydrology and genetics, in this example), but may in fact deliberately alter it away from a natural or historical condition in order to retain another element of the system (native salmonids and associated ecosystem structure and processes, in this example), thereby achieving the “**closest approximation** of the natural condition” of the system as a whole. Deliberately altering an element of a natural system to maintain the system itself in “the closest approximation of the natural condition” is not directly addressed in Management Policies,²⁰ but is likely to become an increasingly common practice as climate change proceeds. The fact that retaining ecosystem components (e.g., species) in a changing climate may require ahistorical conditions or processes (discussed in Fisichelli et al. 2015), however, is a paradox not anticipated in Management Policies nor addressed by Policy Memorandum 12-02 (NPS 2012).

Policy Memorandum 24-03 (NPS 2024) is an important policy update that fills this vacuum and liberates a manager from such paradoxes and associated policy interpretations and management dilemmas previously unanticipated and unaddressed by the body of NPS policy. It addresses and loosens the constraints of Management Policies’ assumptions that a manager can simultaneously reestablish or retain components, conditions, functions, and processes by stating that:

- “[d]ue to changes in temperature, precipitation, storm events, and other factors experienced under accelerated warming caused by climate change, national parks will increasingly look and function differently,”
- “NPS managers cannot expect the future to resemble the past,”
- “managers must anticipate and plan for a range of plausible future conditions based on climate change projections for their areas,” and

¹⁹ We provide this aquatic example as a general illustration that management action can at least partially restore important ecological processes and conditions via artificial means. However, context is highly important and any management action requires careful project-level evaluation; beaver-related restoration can in some cases negatively impact aspects of water quality to which salmonids are sensitive, including temperature and dissolved oxygen levels (Stevenson et al. 2022).

²⁰ Persistent traditional stressors (e.g., dams) often limit overall restoration potential and may in some cases compel tough choices about which elements of the ecosystem to conserve (e.g., use limited control over flow regimes to provide habitat for one native species that may reduce habitat for another), but a change in climatic context is different in that maintenance of some elements paradoxically may require deliberate management of other components **away** from the historical condition.

- “[n]ovel responses outside of traditional practices may be required, including significant interventions....”

The memorandum places the following common-sense constraints on novel adaptation approaches: (1) risk analysis, (2) solid grounding in science and other relevant knowledge, (3) consideration of scientific uncertainty, (4) consultation with NPS leaders, Indigenous partners, and appropriate stakeholders, and (5) documentation of rationales and decisions.

NPS Management Policies language cited above is also prescriptive and, in isolation, could be interpreted as mandating extraordinarily costly or impractical management actions. However, considered in their entirety as required, and further emphasized in NPS Policy Memorandum 12-02 (NPS 2012),

Management Policies (2006) do not require what is impossible, economically infeasible, or likely ineffectual. Climate change does not alter these principles Our policies are clear that managers cannot be held accountable for impairment from external sources—particularly those of global dimensions—over which managers have no control.

NPS Management Policies could thus be understood to call for resistance to climate impacts if such impacts are considered unnatural—but not beyond the point where the management response becomes “impossible, economically infeasible, or likely ineffectual” or causes unacceptable impacts to other ecosystem components and processes.²¹ Furthermore, in stating that “NPS leaders and managers are expected to... adapt to climate change impacts on park resources, infrastructure, and visitor experiences, including by proactively resisting, accepting, or directing those impacts,” Policy Memorandum 24-03 (NPS 2024) recognizes and places options to accept or direct climate change impacts on par with resistance and therefore grants a manager additional latitude and discretion.

Accepting Change

An acceptance strategy allows climate change-driven ecological change. Under this strategy, the ecosystem responds autonomously to climate change and managers do not aim to steer its trajectory towards past conditions or move it towards a defined future state. Acceptance is the default approach where other strategies are impossible, infeasible, or likely ineffectual (see NPS 2012, 2024); risk impairing other park resources and values; or cause unacceptable impacts to other ecosystem components and processes (NPS Management Policies Section 1.4.4 *The Prohibition on Impairment of Park Resources and Values* and 4.2.2 *Management of Native Plants and Animals*, respectively).²² Accepting anthropogenic change that cannot be feasibly resisted is not new, but it often happens too

²¹ NPS Policy Memorandum 24-03 (NPS 2024) reiterates this point by stating that “[n]ovel responses outside of traditional practices may be required, including...divestment of activities that present unacceptable risk or are outside the feasible range of NPS management response.”

²² Although accepting change means taking no action to influence the ecological trajectory, this choice obligates a manager to “monitor, document, and communicate ongoing changes through its programs and activities” (NPS 2024).

late—i.e., only when management resources are exhausted and increasingly intensive resistance-focused interventions can no longer be sustained. The RAD framework supports a more forward-looking, strategic approach by naming and elevating acceptance as a potentially valid and intentional choice to be critically evaluated against alternatives of resisting or directing the trajectory. Consistent with this approach and with the need to make strategic use of limited management capacity, Policy Memorandum 24-03 (NPS 2024) clarifies that “NPS leaders and managers are expected to...understand, prepare for, and adapt to, climate change impacts on park resources, infrastructure, and visitor experiences, including by **proactively** resisting, **accepting**, or directing those impacts.” Policy Memorandum 24-03 also directs managers to “monitor, document, and communicate” about changes and impacts that are accepted. Finally, per Policy Memorandum 24-03, if acceptance represents a novel approach then a manager is expected to have previously “conduct[ed] appropriate risk analyses, use[d] best available science and Indigenous knowledge, consider[ed] the level of scientific uncertainty, consult[ed] with NPS leadership, Tribes, and appropriate stakeholders, and properly document[ed] analyses and decision rationales.”

An acceptance approach may also be chosen under adaptive management as a control treatment to monitor the unmitigated effects of climate change and evaluate adaptation interventions in similar areas. Finally, acceptance may be chosen because the changes that come with it are small enough that, at least for some time, they do not constitute impairment.

Directing Change

A directing-change approach attempts to steer change towards preferred new conditions. In the context of a warming mid- to lower-elevation stream reach in Glacier National Park, a directing-change approach accepts that significant warming and changes in flow regime will continue and that native trout will likely be lost; thus, an important management question is whether to foster persistence of this lost species’ ecological role through new species that are better adapted to emerging conditions. NPS Management Policies generally prohibits intervention in natural biological or physical processes, but Section 4.1 *General Management Concepts* provides several exceptions where intervention is permitted, including “**to restore natural ecosystem functioning that has been disrupted by past or ongoing human activities**,” and recognizes that complete restoration may in some cases not be possible (“...processes altered in the past by human activities may need to be actively managed to restore them to a natural condition or **to maintain the closest approximation of the natural condition when a truly natural system is no longer attainable**.”). NPS Management Policies supports intervention to mediate change and restore trophic structure and important ecological processes if climate change-induced extirpation of a system’s top predators is considered a human-caused disruption of ecosystem function (as is the case; see footnote 8 in the Climate Change Adaptation Options section) and if the impacted fish assemblage is considered outside of natural conditions due to human influence (see Section 4.1.5 *Restoration of Natural Systems*). Loss of top predators from an aquatic ecosystem is likely to lead to cascading effects including loss of trophic complexity and changes in resource and energy flows. Ecological replacement with a species or hybrid that tolerates warmer conditions could therefore be interpreted as an effort to at least partially restore ecological integrity by restoring a trophic level and associated resource and energy dynamics. Sportfishing is also an important part of the visitor experience in Glacier National Park, and

stakeholders and members of the public may strongly urge intervention to retain this aspect of recreational opportunities.²³

NPS Management Policies Section 4.4.4.1 *Introduction or Maintenance of Exotic Species*, however, states that “**in general, new exotic species will not be introduced into parks,**” and other sections stipulate that replacement of the lost species would generally be permitted only if the substitute species is (1) a closely related species native to the park (i.e., occurs in other drainages) or (2) (under very limited conditions) a closely related nonnative species. Section 4.4.2.4 *Management of Natural Landscapes* states: “where a **natural area has become so degraded** that restoration with gene pools native to the park has proven unsuccessful, **improved varieties or closely related native species may be used.**” Additionally, Section 4.4.4.1 *Introduction or Maintenance of Exotic Species* states:

In rare situations, an exotic species may be introduced or maintained to meet specific, identified management needs when all feasible and prudent measures to minimize the risk of harm have been taken and it is

- *A closely related race, subspecies, or hybrid of a native species extirpated from the park,*
- *An improved variety of a native species in situations in which the natural variety cannot survive current, human-altered environmental conditions, or ...*
- *Necessary to provide for intensive visitor use in developed areas and both of the following conditions exist:*
 - *Available native species will not meet park management objectives, and*
 - *The exotic species is managed so it will not spread or become a pest on park or adjacent lands.*

NPS Management Policies could thus be understood to provide very limited support for directing-change strategies, and to strongly constrain them where they are permitted. Support is limited because it derives from exceptions embedded in text that otherwise specifically calls for restoration of impacted resources, and thus applies only where resistance becomes “impossible, economically infeasible, or likely ineffectual” or causes unacceptable impacts to other ecosystem components and processes. Constraints on the degree to which one may direct change are strong, and generally suggest a conception of natural systems varying within familiar bounds around relatively stable baselines, rather than experiencing accelerating directional change outside of recent historical precedent. Thus, in this case the expectation is that the most suitable replacement for a historically

²³ NPS Management Policies Section 4.4.3 *Harvest of Plants and Animals by the Public* constrains such intervention as follows: “In some special situations, the Service may stock native or exotic animals for recreational harvesting purposes, but only when such stocking will not unacceptably impact park natural resources or processes and when the stocking is of fish into constructed large reservoirs or other significantly altered large water bodies and the purpose is to provide for recreational fishing; or the intent for stocking is a treaty right or expressed in statute, other applicable law, or a House or Senate report accompanying a statute.”

occurring species that cannot be restored is a species as similar to it as possible. If, by way of hypothetical example, a closely related “southern bull trout” existed, introducing it (or a hybrid of it and the historically occurring species) into this system would be easier under policy than introducing a less closely related fish. Management Policies thus constrains directing-change strategies based on introducing new species and in this case precludes them because no species meet the conditions as described in section 4.4.4.1 (i.e., a closely related race, subspecies, or hybrid of an extirpated species, or improved variety of a native species). Finally, even if the “southern bull trout” existed, these constraints could ultimately preclude effective action if ongoing warming soon exceeds the (hypothetically slightly higher) thermal tolerance of that close relative.

In some areas, as noted above (see Climate Change Adaptation Options section), a trophically similar nonnative species may already exist in the ecosystem, raising questions about whether such a circumstance provides an option. Specifically, might Management Policies more readily allow halting control measures and even action to maintain or promote the already-present species? The answer seems to be “no,” because the tight constraints in the above-quoted Section (4.4.4.1 *Introduction or Maintenance of Exotic Species*) make no distinction between introduction and maintenance. Furthermore, in the somewhat analogous situation of altered plant communities on which threatened and endangered species depend, Management Policies directs managers to use only native plants (Section 4.4.2.5 *Maintenance of Altered Plant Communities*). However, because in this case the already-present nonnative species mediates longstanding natural processes that the historically occurring species can no longer support (e.g., predation, resource and energy flows), an argument against removal and even control efforts could be made based on the directive in Section 4.4.4.2 *Removal of Exotic Species Already Present* that “[p]rograms to manage exotic species will be designed to avoid causing significant damage to native species, natural ecological communities, **natural ecological processes**, cultural resources, and human health and safety.” As with interpretation of the “closest approximation” clause to argue for altering an element of a natural system to maintain natural processes (discussed above), the paradox in which removal of a nonnative species directly threatens significant damage to natural ecological processes is not anticipated in policy and therefore this interpretation is novel.

Policy memoranda are a means of augmenting the body of NPS policy (see footnote 2 in the Introduction), and therefore differences between a new memorandum and the rest of the body of policy are resolved in favor of the new addition. In the context of adapting to climate change, Policy Memorandum 24-03 (NPS 2024) augments NPS policy, granting managers more latitude by providing guidance to contend with conditions not envisioned in Management Policies. The memorandum directs managers to proactively adapt to climate change, including via large interventions that differ from past management actions. The memorandum clarifies that such interventions may be used not only to “resist” change, but also to “direct” change, and refers managers to the NPS resist–accept–direct (RAD) web page (NPS 2022b) where “directing change” is defined as “actively shaping ecosystem change toward preferred **new** conditions.” As noted in the “resisting change” and “accepting change” policy analysis sections above, the memorandum places

the following common-sense constraints on unprecedented adaptation approaches: (1) risk analysis,²⁴ (2) solid grounding in science and other relevant knowledge, (3) consideration of scientific uncertainty, (4) consultation with NPS leaders, Indigenous partners, and appropriate stakeholders, and (5) documentation of rationales and decisions. Therefore, if the body of policy before augmentation by Policy Memorandum 24-03 were understood by a manager as largely proscribing interventions to shape ecosystem change towards conditions that have not previously occurred in an area, the addition of this memorandum—and in particular its text permitting directing change and pointing to an NPS web page that defines the term as “actively shaping ecosystem change toward preferred new conditions”—overrides that previous interpretation. Drilling to the level of specific management actions, an action that directs change by introducing a new-to-the-park species for the purposes of ecological replacement (in this case, with the intention to conserve natural ecological structure and processes) would in almost all cases have been proscribed by NPS policy—specifically, Section 4.4.4.1 *Introduction or Maintenance of Exotic Species*—but can now be understood as permissible, provided the manager operates within the above-mentioned five constraints.

²⁴ A manager can assess risks associated with ecological replacement using the NPS’ *Ecological risk assessment of managed relocation as a climate change adaptation strategy* (Karasov-Olson et al. 2021). The term “managed relocation” is defined as “[t]he intentional movement and release of an organism outside its indigenous range” (NPS 2021a) and is similar to—but not necessarily synonymous with—terms such as “assisted colonization” and “assisted dispersal.”

Conclusions

This analysis seeks to clarify the NPS policy context for a diversity of adaptation actions to address loss of important ecological processes resulting from climate change-driven extirpation of native species. Broadly, NPS policy empowers managers to “understand, prepare for, and adapt to, climate change impacts on park resources, infrastructure, and visitor experiences, including by proactively resisting, accepting, or directing those impacts” (NPS 2024).

Resisting Change

Among resistance options, traditional approaches such as assisting native populations through stocking, genetic management, fisheries closures, and controlling existing stressors (e.g., removal of nonnatives) are all consistent with longstanding policy, as is restoration of past conditions and processes to mitigate climate change impacts. Resistance interventions that seek to maintain or restore historically occurring trophic structure and ecological processes via means other than restoring past ecological conditions—including manipulating fish population genetics by introducing more thermally tolerant strains (alleles)—present tradeoffs about whether the climate change impact or the actions to resist them constitute the least acceptable impact. Examples of actions to resist climate change impacts that may, themselves, represent substantial impacts (i.e., departures from the natural condition) include installing and operating irrigation infrastructure to prevent impacts of climate change-enhanced drought, as proposed for consideration for the endangered Karner blue butterfly (Schuurman et al. 2023), and covering glaciers with geotextile “blankets” to reduce melting rates (e.g., Huss et al. 2021). The possibility that an action to retain or restore a species might itself cause impacts—and the idea that the wisdom or permissibility of the action should be considered in light of such impacts—is not new. What is new in the context of ongoing climate change is the fact that **permanent**²⁵ alteration of one component or process of the system away from historical conditions may be essential for retaining another. Although this difference raises a fundamental question about whether policy provides sufficient flexibility to assess these novel tradeoffs and act, the policy update via Policy Memorandum 24-03 (NPS 2024) affirms the authority of managers to do so if substantiated by careful analysis. Specifically, it states that “[p]ark and program managers are **directed and empowered** to...[implement] climate change adaptation actions” and that “[novel] responses outside of traditional practices may be required, including significant interventions that involve proactive resource stewardship actions....”

Accepting Change

NPS policy permits accepting anthropogenic ecological change if alternatives are impossible, infeasible, or likely ineffectual; risk impairing other park resources and values; or cause unacceptable impacts on other ecosystem components and processes. Policy Memorandum 24-03 (NPS 2024) clarifies that proactive acceptance is a valid option that a manager should consider explicitly

²⁵ Listed species recovery sometimes requires alteration of an ecosystem component or process away from the natural condition (e.g., suppression of naturally occurring fire or reduction of predator abundances) but such actions are generally considered a temporary necessity to be discontinued when recovery has been achieved.

alongside the alternatives of intervening to resist or direct the change, and that acceptance may involve either ceasing ongoing management actions or choosing not to intervene in the first place. NPS policies also direct managers to “monitor, document, and communicate” about changes and impacts that are accepted (NPS 2024).

Directing Change

In terms of directing change, NPS policies explicitly recognize the “inevitable movement, loss, or gain of species associated with parks” due to climate change, as well as the increasing challenge in using “natural conditions”²⁶ as a guide for desired future conditions (NPS 2012). However, before the advent of Policy Memorandum 24-03 (NPS 2024), policies imposed tight constraints on directing-change strategies. Limited support is derived from exceptions in NPS Management Policies (NPS 2006) text that otherwise specifically calls for restoration of impacted resources, and thus applies only where resistance (1) becomes “impossible, economically infeasible, or likely ineffectual” (NPS 2012) or (2) causes unacceptable impacts to other ecosystem components and processes. In the context of seeking to maintain or restore natural processes and trophic structure disrupted by the climate change-driven loss of the native species that mediate them, NPS policies—particularly NPS Management Policies Section 4.4.4.1 (*Introduction or Maintenance of Exotic Species*)—would prevent ecological replacement of the bull trout in a warming reach of a Glacier National Park stream.

Policy Memorandum 24-03 (NPS 2024) changes the picture by directing managers to anticipate and plan for a range of plausible future conditions and empowering them to proactively resist, accept, or **direct** climate change impacts. The NPS defines directing change as “actively shaping ecosystem change toward preferred **new** conditions” (NPS 2022b). Within the context of current policy, managers are thus empowered to engage in ecological replacement as they manage for future conditions that will differ from the past. Importantly, however, this policy also stipulates that managers seeking to apply novel approaches “conduct appropriate risk analyses, use best available science and Indigenous knowledge, consider the level of scientific uncertainty, consult with NPS leadership, Tribes, and appropriate stakeholders, and properly document analyses and decision rationales.” In addition, for all adaptation actions the memorandum calls on managers to “assess effectiveness of the actions over time, and modify future actions as needed based on results and as new information becomes available.”

²⁶ NPS Policy Memorandum 12-02 (NPS 2012) states that “‘natural conditions’ may be both increasingly difficult to characterize and ineffective as a guide for desired future conditions.”

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