National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager

Natural Resource Report NPS/NRSS/CCRP/NRR—2020/ 2213

ON THE COVER

Multiple federal agencies, including the National Park Service (Bandelier National Monument), tribes, and others steward the East Jemez Mountains ecosystem of New Mexico, an ecologically transforming landscape where massive forest die-off is projected to occur more frequently in the future. Piñon pines, normally evergreen, have reddish-brown foliage in October 2002 (left). By May 2004 (right), the dead piñon pines lost all their needles, exposing gray trunks and branches. The photos were taken from the same vantage point near Los Alamos, N.M. Forest drought stress is strongly correlated with tree mortality from poor growth, bark beetle outbreaks, and high-severity fire.

Credit: C. Allen, USGS

Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager

Natural Resource Report NPS/NRSS/CCRP/NRR—2020/2213

Gregor W. Schuurman[1], Cat Hawkins Hoffman[1], David N. Cole[2], David J. Lawrence[1], John M. Morton[3], Dawn R. Magness[4], Amanda E. Cravens[5], Scott Covington[6], Robin O'Malley[7], Nicholas A. Fisichelli[8]

[1]National Park Service, Climate Change Response Program, Fort Collins, CO 80525

[2]Missoula, MT 59801*
*Aldo Leopold Wilderness Research Institute (retired)

[3]Alaska Wildlife Alliance, Anchorage, AK 99520*
*U.S. Fish and Wildlife Service (retired)

[4]U.S. Fish & Wildlife Service, Kenai National Wildlife Refuge, Soldotna, AK 99669

[5]U.S. Geological Survey, Fort Collins Science Center, Fort Collins, CO 80526

[6]U.S. Fish and Wildlife Service, National Wildlife Refuge System, Falls Church, VA 22041

[7]Robin O'Malley LLC, Fort Collins, CO 80526*
*U.S. Geological Survey (retired)

[8]Schoodic Institute at Acadia National Park, Winter Harbor, ME 04693*
*formerly with the NPS Climate Change Response Program

December 2020

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

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

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

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

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available in digital format from the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Schuurman, G. W., C. Hawkins Hoffman, D. N. Cole, D. J. Lawrence, J. M. Morton, D. R. Magness, A. E. Cravens, S. Covington, R. O'Malley, and N. A. Fisichelli. 2020. Resist-accept-direct (RAD)—a framework for the 21st-century natural resource manager. Natural Resource Report NPS/NRSS/CCRP/NRR—2020/ 2213. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2283597.

NPS 909/174934, December 2020

Contents

Figures and Tables

Executive Summary

An assumption of stationarity—i.e. “the idea that natural systems fluctuate within an unchanging envelope of variability” (Milly et al. 2008)—underlies traditional conservation and natural resource management, as evidenced by widespread reliance on ecological baselines to guide protection, restoration, and other management. Although ecological change certainly occurred under the relatively stable conditions of the recent past, the nature of change under intensifying global change is different; it is unidirectional, and rapidly pushing beyond the bounds of historical variability. In the past, a manager could plausibly work to reverse or mitigate many stressors or their impacts to approximate pre-disturbance ecological conditions, but now accelerated warming, changing disturbance regimes, and extreme events associated with climate change reduce that potential. Indeed, even ‘holding the line’ in the face of inexorable human-caused change is ever more difficult and costly. Thus, the convention of using baseline conditions to define goals for today’s resource management is increasingly untenable, presenting practical and philosophical challenges for managers. As formerly familiar ecological conditions continue to change, bringing novelty, surprise, and uncertainty, natural resource managers require a new, shared approach to make conservation decisions. How, for example, should a manager respond to projections of loss of the Joshua tree from much of its current range, or to the emergence of new and different vegetation communities after a large fire event? The RAD (Resist-Accept-Direct) decision framework has emerged over the past decade as a simple tool that captures the entire decision space for responding to ecosystems facing the potential for rapid, irreversible ecological change. It assists managers in making informed, purposeful choices about how to respond to the trajectory of change, and moreover, provides a straightforward approach to support resource managers in collaborating at larger scales across jurisdictions, which today is more urgent than ever.

Acknowledgments

We appreciate the collaboration of our colleagues in the Federal Navigating Ecological Transformation (FedNET) working group in defining key concepts and terminology related to the RAD framework and its application. FedNET works with diverse partners to foster a community of practice regarding managing transforming ecological systems and includes members from the National Park Service (NPS) (Wylie Carr, Cat Hawkins Hoffman, David Lawrence, Joel Reynolds, Gregor Schuurman), Aldo Leopold Wilderness Research Institute (David Cole [retired]), National Oceanic and Atmospheric Administration (NOAA) (Jay Peterson, Wendy Morrison), U.S. Fish and Wildlife Service (USFWS) (Scott Covington, Michael Hudson, Dawn Magness, John Morton [retired], Danielle Ross-Winslow), U.S. Forest Service (USFS) (Linh Hoang, David Peterson [retired]), Bureau of Land Management (BLM) (Karen Prentice, Bruce Rittenhouse), and U.S. Geological Survey (USGS) / Climate Adaptation Science Centers (Aparna Bamzai-Dodson, Katherine Clifford, Shelley Crausbay, Amanda Cravens, Stephen Jackson, Robin O'Malley [retired], Nathan Stephenson). We also thank key partners for their work with the NPS to develop, test, and share the RAD framework, including staff from the National Wildlife Federation, Wildlife Conservation Society, Parks Canada, Michigan Department of Natural Resources, Department of the Interior North Central Climate Adaptation Science Center, USGS Northern Prairie Wildlife Research Center, and NOAA / Earth Sciences Research Laboratory Physical Sciences Division. We are grateful to peer review manager J. Reynolds, as well as M. Holly and L. Perez for assistance with images and with guiding this report from the peer review process through to publication. Finally, we acknowledge and thank reviewers of this report, J. Burgett, M. Cross, and C. Knapp.

Introduction

The United States has a strong tradition of natural resource conservation, rooted in recognition of the vast promise conservation holds for sustaining biodiversity and human society (Coggins 1983; Shafer 1999; Fischman 2003; Organ et al. 2012). This legacy includes the world's first national park, designated wilderness areas, sustainable ocean, fisheries, and wildlife management, and comprehensive fire management. An assumption of stationarity—i.e., "the idea that natural systems fluctuate within an unchanging envelope of variability" (Milly et al. 2008)—underlies this approach to conservation and resource management, as evidenced by widespread reliance on ecological baselines (characterizations of initial ecological conditions) to guide protection, restoration, and other management. This assumption has successfully guided managers in the face of many long-standing management challenges.

However, expectations that future conditions will largely reflect the past seem increasingly unrealistic in this time of intensifying global change (Thomas 2020). Indeed, some studies project that under the current trajectory of global emissions, the mean climate of a given location may enter a state continuously outside the bounds of historical (1860-2005) variability as early as mid-century (Mora et al. 2013; Kusunoki et al. 2020), while models consistently suggest that changes in extreme events (extreme precipitation or heat) are already occurring (Seneviratne et al. 2012; King et al. 2015). Although there is debate over the timing of climatic variables moving beyond the range of historical experience (Hawkins et al. 2014; Power 2014), such changes are expected over wide areas before 2100, and even more-modest changes well in advance may have significant consequences for humans and ecosystems (Power 2014).

The current trajectory of environmental conditions reflects a complex of rapidly intensifying, additive human stressors, rather than relatively stable (on human timescales) geological and orbital forces. "Stationarity is dead" (Milly et al. 2008) as ecological change accelerates in response to intensifying anthropogenic stress. Changes that formerly occurred on geological timescales now occur on human timescales or faster. As familiar ecological conditions continue to change, bringing novelty, surprise, and uncertainty, natural resource managers will require a new, shared approach to make conservation decisions.

Transforming Ecological Systems Challenge the Current Conservation Model

This increasingly non-stationary world reflects the interacting effects of global climate change and a mix of regional to local stressors such as land use change, overharvest, pollution, and non-native species introduction (e.g., Christiansen 2006; Bates et al. 2017; Jenny et al. 2020). Fire across the western U.S. sends formerly forested lands with important management legacies on uncertain and complex trajectories (Coop et al. 2020). Midwestern and northeastern-U.S. aquatic ecosystems experience exponentially larger pollution impacts associated with intensifying precipitation extremes (e.g., Carpenter et al. 2018). Animal species assemblages are changing rapidly as motile species' ranges shift within the constraints of a fragmented landscape and more vulnerable populations expire, with marine systems changing fastest (Staudinger et al. 2013; Wiens 2016; Pecl et al. 2017). At the site level, the pervasive effects of air pollution and climate change impact even the most remote locales on the planet (AMAP 2017, 2019) and threaten areas once thought to be "stable 'climax communities' which under protection perpetuate themselves indefinitely" (Bouliere et al. 1962).

Climate change compounds traditional stressors' impacts on ecological systems and, importantly, precludes returning to 'normal' even if those stressors were eliminated (e.g., Blumenthal et al. 2016; Fusco et al. 2016; Shen et al. 2016; Crausbay et al. 2017; Carpenter et al. 2018; Zscheischler et al. 2018; Jenny et al. 2020). Under the current rate of climate change, temperatures "are projected to increase by an amount at least twice as great as the current natural variability" in most seasons across localities recognized as globally significant biodiversity areas (Warren et al. 2018). Whereas in the past a manager could plausibly work to reverse or mitigate many stressors or their impacts to approximate pre-disturbance ecological conditions (e.g., via habitat and species restoration, pollution reduction and mitigation of local impacts, non-native species removal), accelerated warming, changing disturbance regimes, and extreme events associated with climate change reduce that potential. Indeed, even 'holding the line' in the face of inexorable change is ever more difficult and costly (e.g., Chapin et al. 2009; Folke et al. 2010; Ingeman et al. 2019; Coop et al. 2020). For example, Cole et al. (2011) foresee "the future elimination of Joshua tree throughout most of the southern portions of its current range," thus invalidating a past premise of stability of the Joshua tree as a climax species (Box 1). Even where feasible, resistance to change in fundamental ecological components or processes may require sustained and intensifying efforts (Millar et al. 2007), as well as trade-offs regarding other ecological components or management objectives. For example, stream diversions and snow fencing may prevent a climate change-induced desiccation of a wet meadow but would likely impact many other important ecological features and processes (e.g., the stream from which water is diverted or wildlife movement patterns) as well as the human experience.

This declining ability to undo or forestall human-induced ecological change represents a substantial practical and philosophical challenge for managers accustomed to conserving natural systems and restoring impacted systems. At best, longstanding and important conservation goals may only be achievable via very different means and only in some places, while many others will require substantial updating to reflect new, attainable conditions. Non-stationarity clearly creates new challenges for managers and agencies in engaging with their stakeholders and society at large and may require reexamining the values that guide management choices. Extreme and persistent ecological changes can have important consequences for human communities through changes in the availability, quality, or type of ecosystem goods and services (Millar and Stephenson 2015), which may lead to significant shifts in how individuals or groups use or interact with natural systems.

The nature of this change may be incremental or sudden—in either case resulting in large and enduring ecological shifts—and is increasingly referred to as ecological transformation or ecosystem transformation (e.g., Shriver et al. 2019). As applied by the interagency Federal Navigating Ecological Transformation working group (FedNET)[1], ecological transformation is defined as a

[1] The interagency Federal Navigating Ecological Transformation working group (FedNET) works with diverse federal partners to foster a community of practice regarding managing transforming ecological systems. See the acknowledgements section for a list of FedNET members.

dramatic and irreversible shift in multiple ecological characteristics of an ecological system, the basis of which is a high degree of turnover in ecological communities (Shimadzu et al. 2015), and not just change in a single species. At its core, ecological transformation characterizes lasting shifts in multiple components of an ecosystem that cannot easily be reversed with changes in management. Many natural systems have a propensity for transformation; long-term ecological records demonstrate that "a multitude of ecological realizations arise and dissolve as the environment changes" (Jackson and Hobbs 2009). The difference is that such change is now widespread and frequent because of intensifying global change.

Limits on the ability to preserve or restore natural systems to a completely natural or historical condition are not new. Since its creation in 1916, the National Park Service (NPS) has deliberated the appropriate extent of 'hands on' management vs an idealized concept of protection alone as sufficient to maintain national park resources and values "unimpaired." The agency's first policy directives in 1918 and 1925 declared that the paramount duty of the Service was to maintain parks "in absolutely unimpaired form...in essentially their natural state" (Lane 1918), and "untouched by the inroad of modern civilization in order that unspoiled bits of native America may be preserved" (Work 1925). Essentially, national parks were to "remain under Nature's own chosen conditions" (Work 1925).

> "…which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."
>
> *H.R. 15522, An Act to establish a National Park Service, engrossed August 5, 1916*

In a prescient statement in 1932, George Melendez Wright, the agency's first head of its new Wildlife Division discerned that "[p]rotection, far from being the magic touch which [heals] all wounds, [is] unconsciously just the first step on a long road." He noted that "perpetuation of natural conditions will have to be forever reconciled with the presence of large numbers of people…[i]t will challenge the conscientious and patient determination of biological engineers" (Wright et al. 1932). Since then, NPS policy has continued to evolve, but maintaining natural conditions remains central to NPS natural resource management (Box 1).

Today's challenges, however, are particularly perplexing. Rapid, unidirectional ecological change challenges the practice of protection or restoration of 'natural' or historical conditions as the rubric of conservation. Recognizing these challenges, a 2012 NPS policy memorandum affirmed that "[t]he pervasiveness of climate change requires that we reexamine our approaches to park management and consider what a larger magnitude of change means for our [stewardship] responsibilities…" (NPS 2012). A report of the National Park System Advisory Board Science Committee in 2012 recommended that a new, overarching goal for NPS resource management should be to "steward

NPS resources for continuous change that is not yet fully understood…” (Colwell et al. 2012). This is a forward-looking goal urging managers and decision makers to rely on science in understanding and managing “novel conditions, threats, and risks to parks now and in the future” (Colwell et al. 2012).

Box 1. Natural Resource Management Policy Progression in the National Park Service[2]

With the untimely death of George Melendez Wright in a 1936 car accident, application of contemporary science to conservation practices in the NPS stagnated for over two decades (Dilsaver 1994). Pressure to reinvigorate the NPS Wildlife Division ultimately led to several reports suggesting research needs and management principles for the agency (Dilsaver 1994). In 1963, the 'Leopold Report,' a review of NPS wildlife management, recommended a goal for national parks of maintaining historical conditions as closely as possible to those “of primitive America” (Leopold et al. 1963). The report described a spectrum of management actions, projecting that “the traditional, simple formula of protection” would be enough to maintain “such climax associations as arctic-alpine heath, the rain forests of Olympic peninsula, or the Joshua trees and saguaros of southwestern deserts,” while disturbance-adapted biomes (e.g., grasslands, savannas, etc.) “may call for very different treatment” and that “[r]eluctance to undertake biotic management can never lead to a realistic presentation of primitive America, much of which supported successional communities that were maintained by fires, floods, hurricanes, and other natural forces” (Leopold et al. 1963).

In 1967, the agency’s Administrative Policies affirmed that “[p]assive protection is not enough. Active management of the natural environment, plus a sensitive application of discipline in park planning, use, and development, are requirements for today” (NPS 1967). Simultaneously, that edition of NPS policies also described the primary management task as a seemingly simple undertaking: “[safeguard] forests, wildlife, and natural features against direct removal, impairment, or destruction,” and “[apply] ecological management techniques to neutralize the unnatural influences of man, thus permitting the natural environment to be maintained essentially by natural agents” (NPS 1967).

Maintaining natural conditions (“the condition of resources that would occur in the absence of human dominance over the landscape” [NPS 2006]) remains a central goal of management in the NPS, the U.S. Fish and Wildlife Service (USFWS), and many of the lands and waters managed by such agencies as the Bureau of Land Management (BLM), U.S. Forest Service (USFS), and National Oceanic and Atmospheric Administration (NOAA). For example, the National Marine Sanctuaries Act of 1972 (16 USC 1431 b(3)) establishes sanctuaries “to maintain the natural biological communities in the national marine sanctuaries, and to protect, and, where appropriate, restore and enhance natural habitats, populations, and ecological processes,” BLM policies for National Conservation Lands direct the agency to “restore, to the extent feasible, the natural system function and species composition of disturbed areas...” (USDIBLM 2012), and USFWS National Wildlife Refuge System policies state “The highest measure of biological integrity, diversity, and environmental health is viewed as those intact

[2] This section reports views of the time related to management of the National Park System as expressed through policy or policy-related documents. The authors provide this section to illustrate evolution in the policies of one agency, not to analyze historical public land management perspectives.

and self-sustaining habitats and wildlife populations that existed during historic conditions" (USFWS 2001).

Agency policies are not static. For example, NPS policy memos issued from 2012-2015 recognize that "'natural conditions' may be both increasingly difficult to characterize and ineffective as a guide for desired future conditions" and that climate change and its effects "challenge us to think in new ways," requiring the agency to "reexamine our approaches to park management" (NPS 2012). For cultural resources and facilities, these policy memos direct that vulnerability to climate change must be considered in setting priorities for inventory and protective actions for cultural resources (NPS 2014) and for design, siting, repair or retention of infrastructure (NPS 2015).

An NPS Director's Order developed in 2016 embraced and adopted recommendations of the *Revisiting Leopold* report (Colwell et al. 2012), stating that "the overarching goal of resource stewardship…is to manage NPS resources in the context of continuous change" (NPS 2016) and signaling continued evolution in NPS management policies.

Towards a New Management Paradigm

Modern natural resource management recognizes that change is inherent in natural systems (e.g., "natural change will also be recognized as an integral part of the functioning of natural systems" NPS 2006). However, this awareness alone does not prepare an individual manager or resource management organization for the increasingly common (Biggs et al. 2018) transformational ecological changes on the lands and in the waters they manage. Given the dwindling potential to maintain or restore conditions that would prevail if not for modern human influence, many managers—even those most ready to "steward...resources for continuous change that is not yet fully understood"—report feeling rudderless as they grapple with how to respond. Because it is not possible to reverse or truly "neutralize the unnatural influences of man" (NPS 1967), a straightforward, agency-neutral framework for decisions to steward resources for continuous change can benefit NPS resource managers as well as those of other federal, tribal, and state agencies and organizations. On all managed lands and in managed waters, as climate change and other unidirectional drivers cause conditions to deviate more and more from the past, it will be necessary for managers to frequently reconsider their objectives and management decisions.

The imperative for land managers to collaborate at larger scales across jurisdictions is today more urgent than ever (Carter et al. 2020). Indeed, successful conservation in an era of rapid and widespread ecosystem change requires cooperation among managers and stakeholders to develop and achieve shared goals, reflecting recognition of the intimate relationship between societal values, stakeholder expectations or attitudes, and management decisions (Doyle-Capitman and Decker 2018; Doyle-Capitman et al. 2018). A shared decision framework can provide a foundation for these discussions.

Resisting, Accepting, or Directing Change—A Framework for Managing Under Conditions of Continuous Change

The RAD (Resist-Accept-Direct) decision framework emerged over the past decade in recognition of the shortcomings of the concepts of 'naturalness' or historical range of variability as clear guides for natural resource management. In their contribution to a 2007 workshop on rethinking park and wilderness stewardship in an era of rapid change, Aplet and Cole (2010) asserted that there are only three possible management responses to transformational change. Managers can actively resist change by intervening to reduce vulnerability to change and/or restore conditions where change has occurred. Alternatively, they can accept change, allowing ecosystems to drift into new, unprecedented conditions, often with uncertain consequences. The third option is to guide, direct, or facilitate change by intervening to transform ecosystems into new states more concordant with emerging climates and better able to sustain desired ecosystem services. Consensus has built around these three contrasting response options, although different terms are sometimes used (Fisichelli, Schuurman, and Hawkins Hoffman 2016; Fisichelli, Schuurman, Symstad, et al. 2016; Aplet and McKinley 2017; Thompson et al. 2020; Lynch et al. in press). In its work with parks and partners in scenario-based vulnerability assessment and climate change adaptation, the NPS has emphasized the term 'direct' to explicitly encompass the potential for intensive intervention to steer trajectories of change at a site, or broader level (Fisichelli, Schuurman, and Hawkins Hoffman 2016; Fisichelli, Schuurman, Symstad, et al. 2016; Schuurman et al. 2019). The RAD framework uses the following definitions for managerial response options, as formalized by FedNET:

1. **Resist** the trajectory of change, by working to maintain or restore ecosystem processes, function, structure, or composition based upon historical or acceptable current conditions.
2. **Accept** the trajectory of change, by allowing ecosystem processes, function, structure, or composition to change, without intervening to alter their trajectory.
3. **Direct** the trajectory of change, by actively shaping ecosystem processes, function, structure, or composition towards desired new conditions.

The three RAD options vary in the degree to which managers intentionally intervene to shape the trajectory of ecosystem change. Where and when they do decide to intervene, managers can choose desired ecological outcomes that vary from return to a historical benchmark to persistence of existing (non-historical) conditions or emergence of conditions for which there may be no local precedent (Fig. 1).

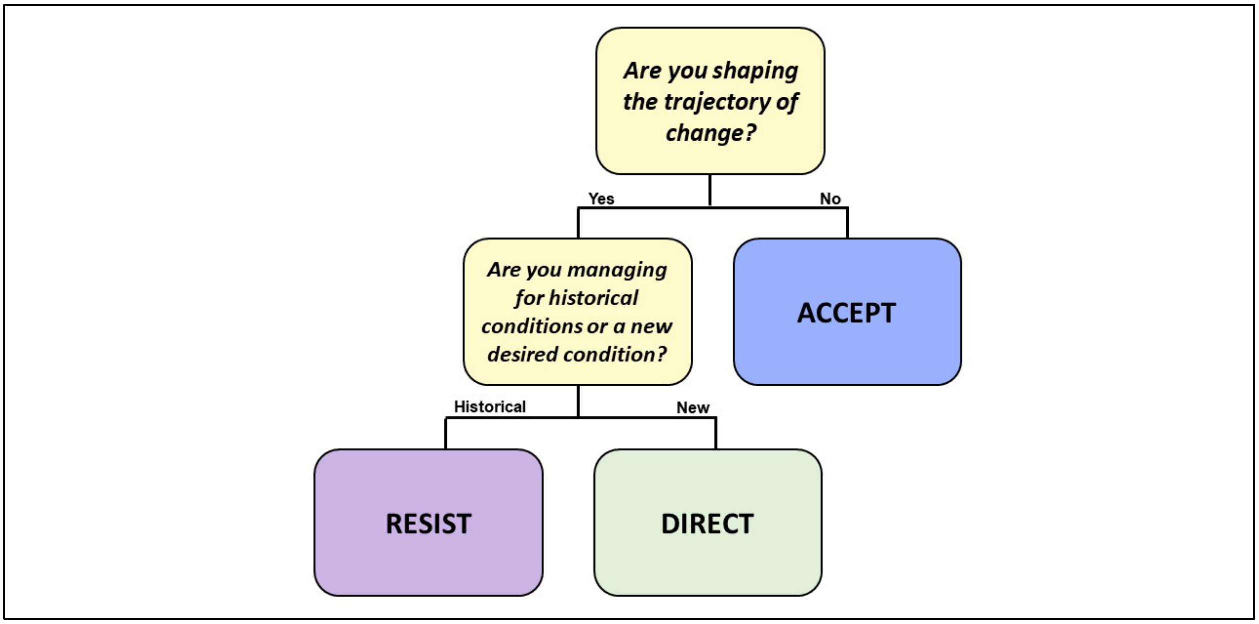

Figure 1. Decision tree depicting the three possible management responses to the trajectory of change under the Resist-Accept-Direct (RAD) framework.

All three RAD options have a legitimate place in natural resource management. Although accepting change explicitly means absence of intervention to alter the trajectory of change, it does not necessarily mean absence of management for other goals and resources. For instance, one might choose to fight acid rain in a northeastern stream via liming, but not address unrelated climate change-driven changes in that aquatic ecosystem. Similarly, one might manage intensively to combat poaching while accepting transformation in species' ranges. Although such examples might be simplistic compared to actual practice, they illustrate that the RAD framework leaves open the possibility of addressing challenges at a range of scopes. Moreover, although accepting change is often a default option due to limited capacity or funding, it can be a purposeful choice if the result of acceptance is considered desirable or intervention is considered undesirable. Where acceptance is appropriate, the key is to transition from implicit acceptance to acceptance as an intentional and explicit decision reached upon due consideration of all potential paths.

The three management response options in the RAD decision framework capture the entire decision space for responding to the trajectory of ecological change; i.e., there are no other possible responses. This is an important point. Although only one option can be implemented for a given time, place, and resource, the other options in the portfolio should be considered and acknowledged. While resist, accept, and direct are conceptually distinct, managers can use them in a complementary manner. Managers might direct some trajectories of change and accept others, perhaps by intervening infrequently rather than chronically. They might encourage the persistence of some historical or iconic elements, while directing or accepting trajectories of change in other elements. They might intentionally accept compositional change but not structural or process change. Managers might accept the infeasibility of maintaining a particular species assemblage where it occurred historically but attempt to provide for that species assemblage (or something close to it) elsewhere, in a location where emerging climatic conditions are more compatible. They might accept loss of historical fidelity at the local level, while maintaining historically occurring biodiversity at a regional or broader level (Stein et al. 2014; West and Julius 2014). This implies the importance of landscape-/seascape-scale collaboration, goals, and desired conditions (White et al. 2010).

There is a temporal component to managers' options. Managers can emphasize different adaptation options sequentially. For example, they might direct the trajectory of change such that an ecosystem transforms into one that is new and expected to be stable. At that point, they might shift approaches from directing change to accepting gradual or incremental change within the new system. Alternatively, they may find that the new system is less stable than anticipated. In this case, they may direct change towards other new conditions. They may change the emphasis of their approach as management goals and societal values change, as new information becomes available, or as interventions fail under continual stress. Particularly common in the near term might be attempting to resist a trajectory of change, finding this approach to be futile (or at least too costly to justify), and then either accepting or directing change. Applying the RAD framework will help managers consciously anticipate these possibilities early on, using monitoring and adaptive management (Williams et al. 2009) to better evaluate success (or lack thereof) as they resist or direct.

There is also a spatial component to managers' options. Because vulnerability to climate change varies spatially, so should adaptation strategies. Agency missions, stakeholder preferences, and management objectives also vary spatially; management applications will need to vary spatially in response. For example, many national parks contain historic landscapes, endangered species, as well as designated wilderness. Park managers might resist change to preserve historic landscapes and direct change elsewhere to facilitate the persistence of endangered species. On wilderness lands, however, where allowing the free play of nature is a central goal, managers may choose to accept many of the changes that occur. Pursuing different options in different places can—if well-coordinated—promote landscape-scale diversity and redundancy and therefore help manage the risks associated with climate change, its biotic effects, and the effectiveness of responses to change (Magness et al. 2011). A range of options across space also provides a way to address diverse stakeholder values and expectations in responding to changing ecosystems.

Goals and Desired Outcomes

Each RAD option supports a different set of desired goals and outcomes (Table 1). Given the pace and irreversibility of transformative change, managers will likely need to periodically revisit goals and desired outcomes (Cole and Yung 2010; Stein et al. 2014). The foremost motivation for resisting change is often to avoid impairment and, if necessary, repair anthropogenic disturbance. Using a retrospective benchmark, resisting change emphasizes retaining existing uses or ecosystem services, as well as historical continuity—preserving ecosystems so subsequent generations can experience them as previous generations have. As global change intensifies, however, resisting ecological change will likely become more difficult and costly and therefore focused on a more limited number of higher-value sites.

Table 1. Differences in Resist-Accept-Direct (RAD) approaches in terms of what each involves, underlying goals and values, and motivations for taking each approach.

	RESIST Change	**ACCEPT Change**	**DIRECT Change**
How is the approach defined?	Work to maintain or restore ecosystem processes, function, structure, or composition based upon historical or acceptable current conditions	Allow ecosystem processes, function, structure, or composition to drift autonomously (away from historical conditions), without intervening to alter the trajectory of change	Actively shape ecosystem processes, function, structure, or composition, resulting in a new ecosystem configuration based upon desired conditions and ecosystem services
What each approach may entail	Reduce the magnitude of directional transformative forces Reduce the ecosystem effects of forces Restore changing ecosystems to a more historical condition Monitor to look for unforeseen consequences and evaluate success and feasibility of resisting	Avoid acting to alter the magnitude, trajectory, or ecological outcome of directional transformative forces Monitor to see what happens, look for unforeseen consequences, and consider the need for active intervention Possibly take management actions other than active intervention (e.g., visitor communication)	Act to direct the magnitude and effects of directional transformative forces Direct ecosystems toward a specific condition that differs from the past but is more resilient to future climatic conditions Monitor to look for unforeseen consequences and assess if trajectory of change aligns with expectations
Desired Outcome/ Goals	Persistence or restoration of historical conditions and services, using a retrospective benchmark	New conditions and services resulting from intentionally not guiding change No specific benchmark needed	New conditions, clearly defined, intentionally sought and ideally part of a self-sustaining system
Motivations for each approach	Conserve historical or current conditions Retain existing or re-create former ecosystem services Buy time for autonomous species response or further management actions	Conserve some ecosystems in an unmanipulated condition Insufficient resources or inability to shape the trajectory of change Desirable ecosystem services are not threatened	Provide a new set of conditions and ecosystem services preferable to those that would result from accepting change, or where resisting change is considered futile New conditions can be envisioned from geographic analogs or as novel systems

Change may be accepted due to lack of funding, lack of concern, or the infeasibility of actively intervening. A more purposive goal of accepting change is to allow species and ecosystems to respond and adapt to transformational forces as they will, rather than as humans intend. When intentionally accepting change (i.e., for reasons other than the inability to do otherwise) the emphasis is on protecting 'the autonomy of nature' to respond; this may be an important value for many, particularly on lands designated as wilderness. One inherent challenge in intentionally accepting change is that in some cases defining a specific desired outcome may not be possible, in terms of resultant conditions on the ground, and there may be no a priori benchmark. In such cases, managers could consider defining 'undesired' conditions which would trigger a different response strategy (resist or direct).

The goal of directing the trajectory of change is to facilitate transformation to a new ecosystem condition that is presumably more ecologically stable—better adapted to projected change in climatic and other directional drivers —while providing desired resource uses, ecosystem services, and/or cultural values, even if conditions no longer resemble the past. Using a prospective view, the attributes emphasized by directing change include adaptability and the efficiency of working with, rather than against, the directional forces of change. This is particularly the case if resultant systems are to be self-sustaining for an extended period.

An example of the application of this framework to address a hypothetical resource management issue appears in Table 2.

When directing change, managers may choose to plant species better adapted to changing climatic conditions. Credit: S. Simons, NPS

Table 2. Example application of the Resist-Accept-Direct (RAD) framework to articulate climate change adaptation strategies to meet desired or achievable future conditions (NPS 2021). Defining the range of desired (or achievable) future conditions is a prerequisite to selecting a strategy, although in practice the articulation of future conditions and strategy selection will likely be an iterative rather than linear process.

Natural Resource	Climate Impact	Desired or Achievable Future Condition	Strategy	Actions
Montane riparian wetland vegetation	Shifts in hydrology due to lower snowpack and earlier runoff lead to drier conditions and changes in riparian vegetation	Persistence of existing native wetland meadow	**Resist**: Maintain summertime water flows and actively manage vegetation	Replace undersized culverts that constrain flows Restore beaver to watershed to increase water storage Reroute trails that alter water flows Remove encroaching woody species Interpret and communicate change to visitors and staff
	Shifts in hydrology due to lower snowpack and earlier runoff lead to drier conditions and changes in riparian vegetation	Conversion from wet meadow to woodland or shrubland	**Accept**: Allow eventual transformation from meadow to woodland or shrubland	Remove damaged wetland vegetation, as necessary Interpret and communicate change to visitors and staff
	Shifts in hydrology due to lower snowpack and earlier runoff lead to drier conditions and changes in riparian vegetation	Conversion from wet meadow to grassland	**Direct**: Actively manage transition to grassland	Conduct supplemental seeding with grassland species projected to thrive in emerging and projected conditions Implement prescribed fire to control woody encroachment Interpret and communicate change to visitors and staff

Careful consideration of goals, values, and feasibility is key to determining desired conditions and selecting an option for getting there. Much of the climate change adaptation literature emphasizes the vulnerability of ecological systems to climate change and the importance of their persistence when choosing among response options. However, many other factors must be considered as well (e.g., societal and stakeholder preferences, legislative mandates and agency policies, availability of requisite resources and knowledge). Moreover, single-minded focus on continued persistence of existing ecological systems may yield results that are ineffective, if not harmful, under some circumstances (Harris et al. 2006). Every situation is unique and context-sensitive, and therefore requires careful consideration of numerous factors including the trajectory of change and feasibility of management response options. From the site-specific to large landscape or seascape scale, the Resist-Accept-Direct framework is a useful tool that can support conversations within, and across management units.

Prolonged drought events can lead to ecosystem transformation. Credit: R. Harrison, NPS

Conclusion

> "In managing early Yellowstone, for example, the NPS first eliminated the ecological influences of Native Americans on the landscape [such as the application of fire as a landscape management tool]. Then we (the NPS) eliminated the impacts of recently arrived Euroamericans, the market hunters. Next, we eliminated the 'bad animals'—the predators. Then we controlled populations of the 'good animals'—the herbivores. Then we stopped controlling populations of all native animals. We later began adding back the species we earlier eliminated…The point here is that societal values evolve and policies for management of public resources follow suit…Conclusiveness of our supporting science increases the longevity of our decisions, but it does not make them immortal." (Huff 1997)

Modern natural resource management and conservation is an inherently complex endeavor made much more so by intensifying global change. Stewarding natural systems under unprecedented conditions and rapid change may seem daunting. However, critical opportunities to conserve species and ecosystems and preserve important ecosystem services lie in action that proactively reckons with the challenges and uncertainties (Stein et al. 2014). Natural resource conservation and management is an evolving enterprise. Just as many decisions of the past have been revisited, revised, or even reversed in response to new information or changes in societal values, the challenge of managing transforming ecosystems will likely also drive evolution in manager and stakeholder expectations and attitudes, monitoring needs, decision making processes and other agency structures or procedures. Humility, continual learning, and the willingness to course-correct that have always been important in effective long-term stewardship will only become more vital as change intensifies.

Literature Cited

Arctic Monitoring and Assessment Programme (AMAP). 2017. Chemicals of emerging arctic concern. Summary for policy-makers. This document presents the policy-relevant findings of the AMAP 2017 assessments of Chemicals of Emerging Arctic Concern (CEAC). Available at: https://www.amap.no/documents/doc/Chemicals-of-Emerging-Arctic-Concern.-Summary-for-Policy-makers/1533 (Accessed 16 December 2020).

Arctic Monitoring and Assessment Programme (AMAP). 2019. AMAP Assessment 2018: Biological effects of contaminants on Arctic wildlife and fish. Summary for policy-makers. Available at: https://www.amap.no/documents/download/3297/inline (Accessed 16 December 2020).

Aplet, GH and DN Cole. 2010. The trouble with naturalness: rethinking park and wilderness goals. In: D.N. Cole and L. Yung, eds. Beyond naturalness: rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington DC. pp. 12-29.

Aplet, GH and PS McKinley. 2017. A portfolio approach to managing ecological risks of global change. Ecosystem Health and Sustainability 3(2): DOI: 10.1002/ehs2.1261.

Bates, AE, RD Stuart-Smith, NS Barrett, and GJ Edgar. 2017. Biological interactions both facilitate and resist climate-related functional change in temperate reef communities. Proceedings of the Royal Society B: Biological Sciences 284:20170484.

Biggs, R, GD Peterson, and JC Rocha. 2018. The Regime Shifts Database: a framework for analyzing regime shifts in social-ecological systems. Available at: http://scholar.sun.ac.za/handle/10019.1/106491 (Accessed 16 December 2020).

Blumenthal, DM, JA Kray, W Ortmans, LH Ziska, and E Pendall. 2016. Cheatgrass is favored by warming but not CO_2 enrichment in a semi-arid grassland. Global Change Biology 22:3026-3038.

Bourliere, F (Chair), MA Badasha, IO Buss, C Cottam, A deVos, LA Garrison, IR Grimwood, R Knobel, AS Leopold, A Ory, JS Owen, LM Talbot, MH Talbot, J Verschuren, and J Vincent. 1962. Committee report, Management in National Parks, In First World Conference on National Parks, AB Adams, (Ed.) (364-365), Superintendent of Documents, U.S. Government Printing Office.

Carpenter, SR, EG Booth, and CJ Kucharik. 2018. Extreme precipitation and phosphorus loads from two agricultural watersheds. Limnology and Oceanography 63:1221-1233.

Carter, SK, DS Pilliod, T Haby, KL Prentice, CL Aldridge, PJ Anderson, ZH Bowen, JB Bradford, SA Cushman, JC DeVivo, and MC Duniway. 2020. Bridging the research-management gap: landscape science in practice on public lands in the western United States. Landscape Ecology 1-16.

Chapin III, FS, GP Kofinas, C Folke, and MC Chapin. 2009. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer Science & Business Media.

Christensen, MR, MD Graham, RD Vinebrooke, DL Findlay, MJ Paterson, and MA Turner. 2006. Multiple anthropogenic stressors cause ecological surprises in boreal lakes. Global Change Biology 12:2316-2322.

Coggins, GC. 1983. The Law of Public Rangeland Management IV: FLPMA, PRIA, and the Multiple Use Mandate. Environmental law 14:1.

Cole, DN and L Yung (eds.). 2010. Beyond naturalness: rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington DC.

Cole, KL, K Ironside, J Eischeid, G Garfin, PB Duffy, and C Toney. 2011. Past and ongoing shifts in Joshua tree distribution support future modeled range contraction. Ecological Applications 21:137-149.

Colwell, R, S Avery, J Berger, GE Davis, H Hamilton, T Lovejoy, S Malcom, A Mcmullen, M Novacek, RJ Roberts, and R Tapia. 2012. Revisiting Leopold: resource stewardship in the national parks. National Park System Advisory Board Science Committee, Washington, DC, USA.

Coop, JD, SA Parks, CS Stevens-Rumann, SD Crausbay, PE Higuera, MD Hurteau, A Tepley, E Whitman, T Assal, BM Collins, and KT Davis. 2020. Wildfire-driven forest conversion in western North American landscapes. BioScience 70:659-673.

Crausbay, SD, AR Ramirez, SL Carter, MS Cross, KR Hall, DJ Bathke, JR Betancourt, S Colt, AE Cravens, MS Dalton, and JB Dunham. 2017. Defining ecological drought for the twenty-first century. Bulletin of the American Meteorological Society 98:2543-2550.

Dilsaver, LM (ed.). 1994. America's National Park System: The Critical Documents. Rowman and Littlefield Publishers, Inc.

Doyle-Capitman, CE and DJ Decker. 2018. Facilitating Local Stakeholder Participation in Collaborative Landscape Conservation Planning: A Practitioners' Guide. Human Dimensions Research Unit Publ. Series 17-12. Dept. of Nat. Resources., Coll. Agric. and Life Sci.,Cornell Univ., Ithaca, NY.

Doyle-Capitman, CE, DJ Decker, and CA Jacobson. 2018. Toward a model for local stakeholder participation in landscape-level wildlife conservation. Human Dimensions of Wildlife 23:375-390.

Fischman, R. 2003. The National Wildlife Refuges: Coordinating a Conservation System through Law. Island Press.

Fisichelli NA, GW Schuurman, and C Hawkins Hoffman. 2016. Is 'Resilience' Maladaptive? Towards an Accurate Lexicon for Climate Change Adaptation. Environmental Management 57:753-758.

Fisichelli, N, G Schuurman, A Symstad, A Ray, J Friedman, B Miller, and E Rowland. 2016. Resource management and operations in central North Dakota: Climate change scenario planning workshop summary November 12-13, 2015, Bismarck, ND. Natural Resource Report NPS/NRSS/NRR—2016/1262. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2230834 (accessed 15 December 2020).

Folke, C, SR Carpenter, B Walker, M Scheffer, T Chapin, and J Rockström. 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and society 15(4).

Fusco, EJ, JT Abatzoglou, JK Balch, JT Finn, and BA Bradley. 2016. Quantifying the human influence on fire ignition across the western USA. Ecological Applications 26:2390-2401.

Harris, JA, RJ Hobbs, E Higgs, and J Aronson. Ecological restoration and global climate change. Restoration Ecology 14:170-176.

Hawkins, E, B Anderson, N Diffenbaugh, I Mahlstein, R Betts, G Heger, M Joshi, R Knutti, D McNeall, S Solomon, R Sutton, J Syktus, and G Vecchi. Uncertainties in the timing of unprecedented climates. Nature 511, E3–E5 (2014).

Huff, DE. 1997. Wildlife Management in America's National Parks: Preparing for the Next Century. The George Wright Forum 14:25-33.

Ingeman, KE, JF Samhouri, and AC Stier. 2019. Ocean recoveries for tomorrow's Earth: Hitting a moving target. Science 363(6425), p.eaav1004.

Jackson, ST and RJ Hobbs. 2009. Ecological restoration in the light of ecological history. Science 325:567-569.

Jenny, JP, O Anneville, F Arnaud, Y Baulaz, D Bouffard, I Domaizon, SA Bocaniov, N Chèvre, M Dittrich, JM Dorioz, and ES Dunlop. 2020. Scientists' Warning to Humanity: Rapid degradation of the world's large lakes. Journal of Great Lakes Research.

King, AD, MG Donat, EM Fischer, E Hawkins, LV Alexander, DJ Karoly, AJ Dittus, SC Lewis, and SE Perkins. 2015. Environmental Research Letters 10 094015.

Kusunoki, S, T Ose, and M Hosaka. 2020. Emergence of unprecedented climate change in projected future precipitation. Scientific Reports. 10:4802.

Lane, FD. 1918. Letter to Stephen T. Mather, Director, National Park Service. National Park Service Handbook of Administrative Policies for Natural Areas, 1968 (68-71), In America's National Park System: The Critical Documents, LM Dilsaver, (Ed.), 1994 (48-52). Rowman and Littlefield Publishers, Inc.

Leopold, AS, SA Cain, CM Cottam, IN Gabrielson, and TL Kimball. 1963. Wildlife Management in the National Parks; Advisory Board on Wildlife Management Appointed by Secretary of the Interior Udall. In: Administrative Policies for Natural Areas of the National Park System. U.S. Department of the Interior, National Park Service.

Lynch, AJ, LM Thompson, EA Beever, DN Cole, AC Engman, C Hawkins Hoffman, ST Jackson, TJ Krabbenhoft, DJ Lawrence, D Limpinsel, RT Magill, TA Melvin, JM Morton, RA Newman, JO Peterson, MT Porath, FJ Rahel, GW Schuurman, SA Sethi, and JL Wilkening. In press. Managing for RADical Ecosystem Change: Applying the Resist, Accept, or Direct (RAD) Framework. Frontiers in Ecology and the Environment.

Magness, DR, JM Morton, F Huettmann, FS Chapin III, and AD McGuire. 2011. A climate-change adaptation framework to reduce continental-scale vulnerability across conservation reserves. Ecosphere 2:1-23

Millar, CI, NL Stephenson, and SL Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17:2145-2151.

Millar, CI and NL Stephenson. 2015. Temperate forest health in an era of emerging megadisturbance. Science 349:823-826.

Milly, PCD, J Betancourt, M Falkenmark, RM Hirsch, ZW Kundzewicz, DP Lettenmaier, and RJ Stouffer. 2008. Stationarity is dead: Whither water management? Science 319:573-574.

Mora, C, A Frazier, RJ Longman, RS Dacks, MM Walton, EJ Tong, JJ Sanchez, LR Kaiser, YO Stender, JM Anderson, and CM Ambrosino. 2013. The projected timing of climate departure from recent variability. Nature 502:183-187.

National Park Service (NPS). 1967. Compilation of the Administrative Policies for the National Parks and National Monuments (Natural Area Category) of the National Park System. United States Department of the Interior.

National Park Service (NPS). 2006. Management Policies. U.S. Department of the Interior, National Park Service, Washington, D.C.

National Park Service (NPS). 2012. Policy Memorandum 12-02: applying National Park Service management policies in the context of climate change. U.S. Department of the Interior, National Park Service, Washington, D.C. Available at: https://www.nps.gov/policy/PolMemos/PM_12-02.htm (accessed 10 December 2020).

National Park Service (NPS). 2014. Policy Memorandum 14-02: climate change and stewardship of cultural resources. U.S. Department of the Interior, National Park Service, Washington, D.C. Available at: https://www.nps.gov/policy/PolMemos/PM-14-02.htm (accessed 10 December 2020).

National Park Service (NPS). 2015. Policy Memorandum 15-01: addressing climate change and natural hazards for facilities. U.S. Department of the Interior, National Park Service, Washington, D.C. Available at: https://www.nps.gov/policy/PolMemos/PM_15-01.htm (accessed 10 December 2020).

National Park Service (NPS). 2016. National Park Service. 2016 (rescinded, 2017). Director's Order 100: resource stewardship for the 21st century. U.S. Department of the Interior, National Park Service, Washington, D.C.

National Park Service (NPS). 2021. Planning for a Changing Climate: Climate-Smart Planning and Management in the National Park Service. National Park Service. Fort Collins, CO. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2279647 (accessed 15 December 2020).

Organ, JF, V Geist, SP Mahoney, S Williams, PR Krausman, GR Batcheller, TA Decker, R Carmichael, P Nanjappa, R Regan, and RA Medellin. 2012. The North American model of wildlife conservation. The Wildlife Society Technical Review 12, no. 04.

Pecl, GT, MB Araújo, JD Bell, J Blanchard, TC Bonebrake, IC Chen, TD Clark, RK Colwell, F Danielsen, B Evengård, and L Falconi. 2017. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science, 355(6332), p.eaai9214.

Power, S. 2014. Expulsion from history. Nature 511:38–39.

Schuurman, G. 2019. Resist, Accept, or Direct? A decision framework for navigating climate change-driven ecological transformations [NOAA National Marine Protected Area Center webinar]. Available at: https://www.openchannels.org/webinars/2019/resist-accept-or-direct-decision-framework-navigating-climate-driven-ecological (accessed 10 December 2020).

Seneviratne, SI, N Nicholls, D Easterling, CM Goodess, S Kanae, J Kossin, Y Luo, J Marengo, K McInnes, M Rahimi, M Reichstein, A Sorteberg, C Vera, and X Zhang. 2012. Changes in climate extremes and their impacts on the natural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [CB Field, V Barros, TF Stocker, D Qin, DJ Dokken, KL Ebi, MD Mastrandrea, KJ Mach, G-K Plattner, SK Allen, M Tignor, and PM Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

Shafer, CL. 1999. National park and reserve planning to protect biological diversity: some basic elements. Landscape and Urban Planning 44:123-153.

Shen, L, LJ Mickley, and E Gilleland. 2016. Impact of increasing heat waves on US ozone episodes in the 2050s: Results from a multimodel analysis using extreme value theory. Geophysical Research Letters 43:4017-4025.

Shimadzu, H, M Dornelas and AE Magurran. 2015. Measuring temporal turnover in ecological communities. Methods in Ecology and Evolution 6:1384-1394.

Shriver, RK, CM Andrews, RS Arkle, DM Barnard, MC Duniway, MJ Germino, DS Pilliod, DA Pyke, JL Welty, and JB Bradford. 2019. Transient population dynamics impede restoration and may promote ecosystem transformation after disturbance. Ecology Letters.

Staudinger, MD, SL Carter, MS Cross, NS Dubois, JE Duffy, C Enquist, R Griffis, JJ Hellmann, JJ Lawler, J O'Leary, and SA Morrison. 2013. Biodiversity in a changing climate: a synthesis of current and projected trends in the US. Frontiers in Ecology and the Environment 11:465-473.

Stein, BA, C Hawkins Hoffman, and P Glick. 2014. Reconsidering conservation goals in light of climate change. In Stein, BA, P Glick, NA Edelson, and A Staudt, eds. 2014. Climate-smart conservation: putting adaptation principles into action. National Wildlife Federation, Washington DC.

Thomas, CD. 2020. The development of Anthropocene biotas. Philosophical Transactions of the Royal Society B 375:20190113.

Thompson, L, A Lynch, E Beever, A Engman, J Falke, S Jackson, T Krabbenhoft, D Lawrence, D Limpinsel, R Magil, T Melvin, JM Morton, R Newman, J Peterson, M Porath, F Rahel, S Sethi and J Wilkening. 2020. Responding to ecosystem transformation: Resist, accept or direct? Fisheries.

U.S. Department of the Interior Bureau of Land Management (USDIBLM). 2012. BLM Manual 6100 – National Landscape Conservation System Management Manual. Rel. No. 6-131.

U.S. Fish and Wildlife Service (USFWS). 2001. U.S. Fish and Wildlife Service Manual, 601 FW 3 (3.10), Biological Integrity, Diversity, and Environmental Health. Available at: https://www.fws.gov/policy/601fw3.html (accessed 10 December 2020).

Warren, R, J Price, J VanDerWal, S Cornelius, and H Sohl. 2018. The implications of the United Nations Paris Agreement on climate change for globally significant biodiversity areas. Climatic Change 147:395-409.

West, JM and SH Julius. 2014. The art of the possible: identifying adaptation options. In Stein, BA, P Glick, NA Edelson, and A Staudt, eds. 2014. Climate-smart conservation: putting adaptation principles into action. National Wildlife Federation, Washington DC.

White, PS, L Yung, DN Cole and RJ Hobbs. 2010. Conservation at large scales: systems of protected areas and protected areas in the matrix. In: D.N. Cole and L. Yung, eds. Beyond naturalness: rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington DC. pp. 197-215.

Wiens, JJ. 2016. Climate-related local extinctions are already widespread among plant and animal species. PLoS Biology 14(12), p.e2001104.

Williams, BK, RC Szaro, and CD Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Work, H. 1925. Memorandum for the Director, National Park Service. National Park Service Handbook of Administrative Policies for Natural Areas, 1968 (72-75), In America's National Park System: The Critical Documents, LM Dilsaver, ed., 1994 (62-65). Rowman and Littlefield Publishers, Inc.

Wright, GM, JS Dixon, and BH Thompson. 1932. Fauna of the National Parks of the United States; A Preliminary Survey of Faunal Relations in National Parks. Contribution of Wild Life Survey, Fauna Series No. 1. United States Government Printing Office, Washington, D.C.

Zscheischler, J, S Westra, BJ Van Den Hurk, SI Seneviratne, PJ Ward, A Pitman, A AghaKouchak, DN Bresch, M Leonard, T Wahl, and X Zhang. 2018. Future climate risk from compound events. Nature Climate Change 8:469-477.

NPS 909/174934, December 2020

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

EXPERIENCE YOUR AMERICA ™