Adapting to Climate Change

Guidance for protected area managers and planners

Edited by John E. Gross, Stephen Woodley, Leigh A. Welling, and James E.M. Watson

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Foreword

"Climate change isn't a prediction. It is happening." *Dr. James Hansen*

These guidelines are written for people who work hard to preserve nature with protected areas. We all face enormous challenges in doing that—a lack of resources, invasive species, poaching, and development to name to just a few. Now along comes a threat that is bigger than all the previous ones and even interacts with most of them. Climate change is real and is an enormous challenge for us all.

Our message to you is that much can be done to both mitigate and adapt to climate change. Although we are entering uncharted waters in protected areas management, we have learned an enormous amount about how to manage these places we love. These past lessons are important and still relevant as we move forward. In our collective future, we will need to stand on this knowledge base and try new things to adapt to a changing future.

Perhaps our greatest human strength is our ability to share and learn from each other. These guidelines are based on sharing what we collectively understand. It offers a way of moving forward based on applying best practices, learning and adapting. The advice given here is not a recipe, and it will certainly be imperfect. It is aimed at protected area managers and is an addition to a growing knowledge base on climate change adaptation.

Protected areas are a critical part of adapting to climate change. They represent a "natural solution" to the climate change problem. Yet they are also affected by changing climate. For them to work best, we must be smart, be flexible, and learn as we go. We need to try new solutions and share lessons, knowledge, and experience. We need to think about not only adaption within protected areas, but planning and building regional and centennial-scale conservation networks that function in the face of climate change.

Yes, the challenge is great. But it is useful to reflect on how far we have progressed. Protected areas are now a mainstream part of planning on land and sea, growing dramatically in extent in recent decades. We have international commitments to continue to expand protected area systems and to make them more effective. This is critical to our conservation future.

The IUCN World Commission on Protected Areas is committed to making climate change mitigation and adaptation in protected areas a key part of the management of these special places. Following the World Parks Congress 2014 in Sydney, we established the Protected Areas Climate Change Specialist Group. This provides a vehicle and forum to work with protected area managers, the IUCN Regions, and other Commissions, working groups and task forces to share knowledge, ideas, and successful solutions. These guidelines are not an end, but only a beginning.

Kathleen MacKinnon

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p. 76—American pika: sevenstar; western larch: Jesse Taylor; Siberian crane: Alastair Rae.

Abbreviations and acronyms

AR5	IPCC Fifth Assessment Report
CBD	Convention on Biological Diversity
CEC	Commission for Environmental Cooperation
CONANP	Comisión Nacional de Áreas Naturales Protegidas, México
COP	Conference of Parties (of UN Conventions)
EbA	Ecosystem-based adaptation
EEA	European Environment Agency
FAO	Food and Agriculture Organization of the United Nations
GCM	Global Climate Model (or General Circulation Model)
GEF	Global Environment Facility
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICCA	Indigenous Peoples' and community-conserved territories and/or areas
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
M&E	Monitoring and evaluation
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Adaptation Programmes of Action
NASA	National Aeronautics and Space Administration (USA)
NGO	Non-governmental organization
NPS	United States National Park Service
OECD	Organisation for Economic Co-operation and Development
PA	Protected area
RCP	Representative concentration pathway
REDD	Reducing Emissions from Deforestation and forest Degradation
REDD +	Reducing Emissions from Deforestation and forest Degradation + Conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks
TEK	Traditional ecological knowledge
TK	Traditional knowledge
TNC	The Nature Conservancy
UKCIP	United Kingdom Climate Impacts Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNEP-WCMC	United Nations Environment Programme, World Conservation Monitoring Centre
VA	Vulnerability assessment
WCPA	IUCN World Commission on Protected Areas
WCMC	World Conservation Monitoring Centre of UNEP
WCS	Wildlife Conservation Society
WDPA	World Database on Protected Areas

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Meeting the challenge of climate change

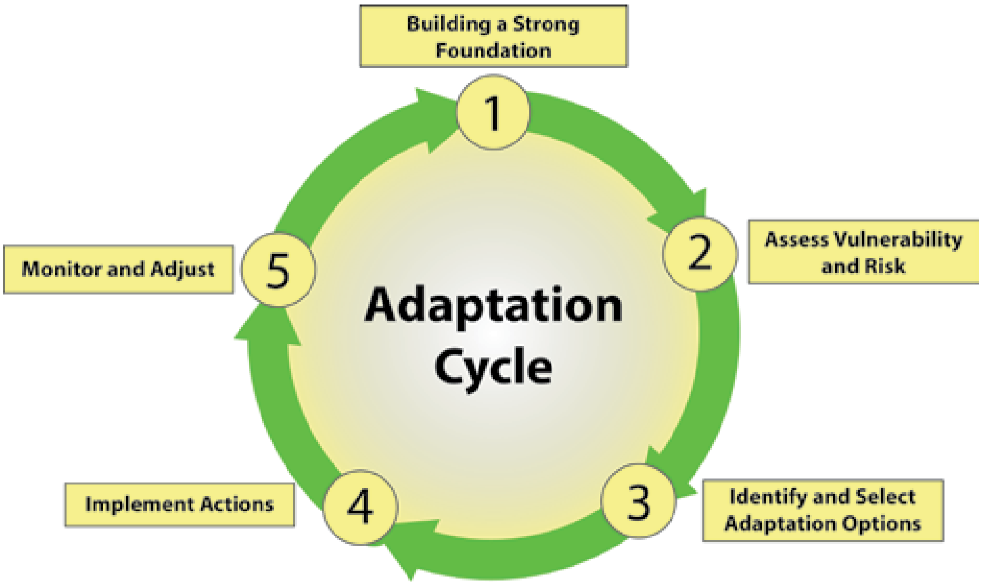
Climate change is one of the most important threats to nature and it will increasingly challenge the way we manage protected areas. Some of the changes already underway due to the rapidly changing climate include rising global temperatures, large-scale melting of snow and ice, longer and more frequent droughts, changes in the intensity and timing of storms, changes in the timing of seasons, rising sea level and associated impacts along coastlines, and increased acidification of marine environments. In response to these changes, some plant and animal ranges are shifting and the timing of seasonal events are being disrupted. In some cases, entire ecological regions are rapidly changing, especially in polar, alpine, coral and forest ecosystems. Climatically-driven changes interact with many other environmental stresses, such as habitat fragmentation and loss, pollution, spread of invasive species, and overharvest. The impacts of many of these stresses are cumulative.

The challenge of managing the cumulative impacts of climate change and other stresses on protected areas is large, but there is much we can do. In fact, protected area managers and planners play a critical role in mounting an effective societal response. Protected areas hold great promise because they provide "natural solutions" to climate change and its associated effects. The relatively intact ecosystems within protected areas contribute benefits and effective solutions across many sectors of human society, including providing significant carbon sequestration and storage, clean water, resilience to storms and other natural hazards, and a host of other ecosystem services. Additionally, large intact protected areas allow many species to adapt to the rapidly changing climate by providing refugial habitat and the room needed for species to move and respond to changing local conditions. Every protected area has a role to play, but climate adaptation often requires different approaches to protected area management. To be part of the solution, protected areas must be managed in a way that takes climate change into account.

Climate change response can be divided into "mitigation" (actions that reduce the amount of carbon dioxide and other heat-trapping gases in the atmosphere) and "adaptation" (an adjustment by human or natural systems to the changing climate). Protected area managers must do all that they can to enhance the ability of natural systems to capture and store carbon and to reduce emissions from protected area operations. But the primary focus of these guidelines is on adaptation. The world's climate is changing rapidly and protected areas are an increasingly important component of national and international climate change adaptation strategies. These guidelines articulate essential elements for adaptation planning and implementation, and it describes additional resources that site managers can use right away. The basic steps for climate change responses described in these guidelines are given in Executive Summary Figure 1. The chapters and associated best practices generally follow these steps.

Step 1: Build a Strong Foundation that involves assembling available knowledge and resources, planning for change, and developing a long-term capacity for informed, flexible management.

Step 2: Assess Vulnerability and Risk means undertaking quantitative or qualitative analyses to determine which species, ecosystems, and other values are most vulnerable to



Executive Summary Figure 1. The generalized adaptation cycle consists of five basic steps and is an iterative process (adapted from EEA, 2015).

changing conditions, and identifying the key vulnerabilities that pose the greatest risk to achieving conservation goals.

Step 3: Identify and Select Adaptation Options emphasizes the need for structured approaches to recognize and prioritize strategic and tactical actions to achieve short and long term adaptation goals in protected areas.

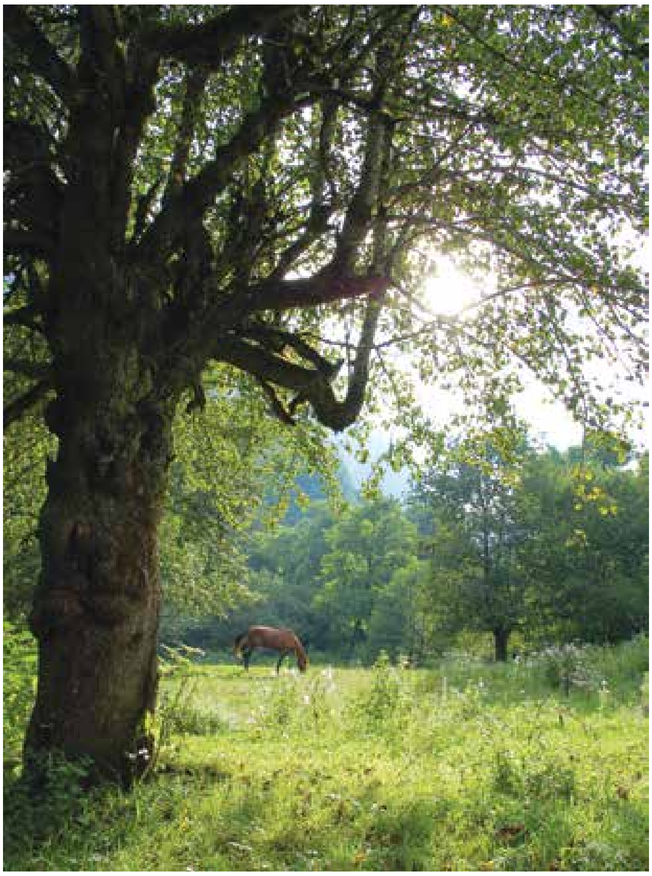
Step 4: Implement Actions is where the protected area takes action based on all of the previous analysis and deliberation.

In **Step 5: Monitor and Adjust,** the protected area managers and their staff measure indicators of success and failure and use that information to evaluate and recalibrate their decisions.

Step 1: Build a strong foundation

Planning for change

Protected areas that were established to conserve particular resources, conditions, or qualities generally were created with no consideration for climate change. However, with the rates of climate change we are now experiencing, many protected areas will eventually support habitats and species assemblages very different than those they were initially designed to protect. As a result, it is now essential to consider current and future climate change and its associated ecological impacts in protected area management. This will require evaluation of both existing and future goals. Five best practices address climate change considerations for protected area planning, with a focus on how conservation goals need to be flexible to adjust to changing circumstances and conditions.



Protected areas having high physiographic diversity, such as Borjomi-Kharagauli National Park in Georgia's Caucasus Mountains, are more likely to harbor climate change refugia—areas that naturally resist the impacts of global warming (IUCN Photo Library / © Karen Hoyer).

- Best Practice 2.1: Manage for change, not just persistence
- Best Practice 2.2: Reconsider goals as well as strategies
- Best Practice 2.3: Adopt forward-looking and climate-informed goals
- Best Practice 2.4: Link adaptation actions to climate impacts
- Best Practice 2.5: Integrate climate change considerations into existing planning

Given the scope and magnitude of climate change impacts, conservation goals that focus only on maintaining the persistence of existing systems may no longer be achievable, regardless of how important those goals may be. Open and honest dialogue about potential climate futures is necessary when reviewing existing goals, which may either be validated or require modifications. Developing and adopting forward-looking and climate-informed goals may mean protected areas need more active management rather than just protection for the persistence of existing systems.

Adaptation planning is place-specific. It is important to consider the threats and needs of a particular protected area and to evaluate what is most suitable and cost-effective for that location, while also considering the broader context of the surrounding landscape and/or seascape. Although lists of adaptation strategies increasingly are available, simply adopting widely cited and popular strategies (for instance, enhancing connectivity) may not be the best approach. Often the most appropriate adaptation actions will contribute to other important social goals as well, so effective planning for climate change may be most successful when integrated with other planning processes.

Building capacity for climate adaptation

Building climate adaptation capacity starts with a commitment to include climate change in discussions with others and supporting staff in bringing climate issues into their day-to-day operations. Communication and sharing ideas and experiences is at the core of what is known as a "learning organization". Leadership, collaboration, and open-minded dialogue are key ingredients of the five best practices that help protected areas and other organizations prepare for rapidly changing and novel future conditions.

- Best Practice 3.1: Assemble baseline information from local, national, and international sources
- Best Practice 3.2: Create ongoing opportunities for knowledge exchange—cultivate a culture of learning
- Best Practice 3.3: Increase climate literacy within the professional workforce
- Best Practice 3.4: Communicate nature-based solutions to climate change
- Best Practice 3.5: Be flexible and learn when planning and implementing actions

Managers and their staffs can do much to build capacity by actively seeking information in various forms, such as internet sites, databases, reports, and climate change toolkits. The Appendix to these guidelines lists many useful web sites and other resources, but new ones appear constantly and protected areas need to be proactive in seeking information and advice. Many scientists, partners, and conservation groups can help managers understand climate change and its impacts. When seeking knowledge about how a protected area has already changed, remember to reach out to local and traditional knowledge holders. One of the most important

Flooded swamps in Ichkeul National Park, Tunisia. Changes in hydrological regimes are one of the most vexing likely impacts of global warming (IUCN Photo Library / © Hichem Azafzaf).

adaptation activities is to develop and sustain relationships and communication networks among scientists, community members, and other stakeholders. Climate change adaptation cannot be undertaken alone.

Overall, the key to building capacity is flexible management and an adaptive approach. This requires a management framework that allows and encourages responsiveness and reassessment, and a commitment to shared learning and long-term solutions. Protected areas are ideal locations to communicate about climate change, its effects, and how nature and culture can come together in these landscapes and seascapes to offer solutions for the future. Site-based and online training courses on climate adaptation for conservation are now available in a variety of languages and provide support for decision makers and those who interact with the public. These courses can help protected area personnel develop additional skills in ecosystem restoration, vulnerability assessment, connectivity conservation, monitoring for change, climate change interpretation, and other important skills.

Step 2: Assess climate change vulnerability and risk

Designing an assessment

Understanding the vulnerability of species, ecosystems, and ecological processes is an essential first step in effective adaptation planning. It is here that the "knowledge networks" are essential because most protected areas will need expertise in a variety of topics to organize and conduct climate change assessments. Three best practices are crucial in setting up and carrying out assessments.

- Best Practice 4.1: Design the vulnerability assessment to match the protected area and conservation needs
- Best Practice 4.2. Use a structured process to conduct the assessment
- Best Practice 4.3: Focus on key vulnerabilities

Vulnerability and risk assessments can be conducted in different ways and with different levels of input, responding to the needs of individual protected areas. Some are largely qualitative and may be accomplished by holding a multi-day expert workshop, while others are highly quantitative and rely on complex models of climate, vegetation, and species population dynamics. When designing a vulnerability assessment, it is important for the assessment to match the needs and capabilities of the protected area and the assessment team. Decisions that affect the type and scale of an assessment include available resources, geographical scope, level of detail needed, the period over which to evaluate change, the number and specific types of conservation targets to be assessed (e.g. species, ecosystem, or biome), and the methods and data to be used.

A common approach to understanding vulnerability is to conduct species-based assessments, and many different methods are available. Vegetation communities, ecological processes, or ecosystem services may also be the focus for a vulnerability assessment. While broader scale assessments—at continental or global scales—may only indirectly inform decision making at a specific site, it is useful to be aware of broad-scale assessments to understand the context and potential climate futures for a particular protected area. Regardless of the individual needs involved in tailoring an assessment, establishing the vulnerability of protected areas requires a thoughtful and structured process.

Ultimately, vulnerability assessments inform management action. Within the context of climate-informed goals, results from an assessment should help shape the adaptation process. To do so, it is necessary to evaluate the full spectrum of results from the vulnerability assessment, as this information provides an important link between conservation goals and adaptation actions. The specific process and criteria used to identify key vulnerabilities will vary, but may include those that affect a protected area's ability to achieve specific conservation goals, the ecological significance of the vulnerable species or ecosystem, whether or not the projected impacts may be reversible, the potential for successful adaptation, or many other factors. Armed with one or more vulnerability assessments and an evaluation of the key vulnerabilities that may need to be addressed, a protected area manager has a very good start toward effective planning and adaptation to a changing climate.

Step 3: Identify and select adaptation options

Developing a list of adaptation options

Under changing conditions, conventional management practices may no longer be adequate. Developing a list of potential adaptation strategies and actions is a road map for managing new combinations of species, patterns of fire, flooding or drought, or alterations to ecological processes that may occur with climate change. A variety of tools are available to support this, including scenario planning and various structured decision making techniques. Regardless of technique, it is important that participants in the process have varied backgrounds and a mix of topical expertise, protected area experience, decision-making responsibility, and other invested interests in and knowledge of the area. Best practices provide guidance for navigating this process.

- Best Practice 5.1: Identify options for alternative climate futures
- Best Practice 5.2: Identify a range of options at both site and system scales

Adaptation actions may be *reactive,* by responding to impacts already apparent, or they may be *anticipatory,* in that they prepare for future conditions. Because it is not possible to predict exactly how climate will change, or how ecological systems will respond, identifying actions that could be taken under alternative conditions is important. Anticipating and rehearsing actions under a range of different climate scenarios can help managers in a number of ways, including determining actions that are robust across all plausible futures ("no-regrets" actions) and revealing management strategies and actions that don't make sense under any plausible scenario. These kinds of exercises can effectively demonstrate that there are actions that can be taken—or in some cases prevented—to contribute now to the long-term sustainability of protected areas and the people who depend on them.

Evaluating and prioritizing adaptation options

There may be a broad range of potential adaptation options that address key vulnerabilities. But resources are always

Scientists have been aware of and studying climate change for over a century. In this image taken in 1989, researchers drill into a coral reef off of Mauritius to recover cores for paleoclimate reconstructions (Hannes Grobe, Alfred Wegener Institute).

limited, and there is a continual need to select, prioritize, and carry out the best options for putting adaptation in place. Creative thinking by managers and stakeholders will be required to evaluate strategies and identify those that will be most effective. Conceptually, we can think of the process of selecting actions as moving from goals to options and then to a strategy. However, in many situations the process is not a set of sequential steps; instead, it will require revisiting goals, potential actions, conservation targets, and other considerations. To guide the selection process, managers and planners can employ three strategic best practices.

- Best practice 6.1: Plan for climate change adaptation options at the level of a protected area system
- Best Practice 6.2: Select strategies by evaluating adaptation options
- Best Practice 6.3: Align options with desired outcomes

While on-the-ground actions must be tailored to site-specific situations, climate change is occurring at the global scale and it challenges us to think at multiple scales—from local to very broad. Therefore, while actions must be appropriate for an individual protected area, managers must also account for the broader context within which terrestrial and marine environments exist and how these are likely to change. An informative first step is to consider the broader scale of a protected area system, and then focus on selecting strategies for a particular protected area. Some broad principles to consider include reducing existing stressors, sustaining or restoring ecological processes, protecting intact and connected systems, securing locations that may protect displaced species, and identifying refugia (places where climate change effects are less severe or not evident).

Climate change will only add to the survival challenges faced by large carnivores, such as this "spirit bear" (*Ursus americanus kermodei*) a light-colored subspecies of the American black bear (GEDApix/GEDavis & Associates).

Adaptation options will vary considerably in terms of cost, feasibility, likelihood of success, and other criteria. Ranking options with a consistent set of criteria can often quickly separate actions that are simply not competitive or feasible from those that merit a more detailed examination. Most prioritization approaches will start with a "coarse-filter" evaluation to quickly identify a smaller subset of options. Ultimately, the best actions are likely to (1) address an important conservation goal; (2) be feasible and low-cost; (3) have a high probability of success; and (4) be effective under a range of climate change scenarios. These no-regrets actions should be a high priority.

Once you have identified key vulnerabilities and evaluated options, a picture of possible future management strategies will begin to emerge. Four very general strategies are managing for persistence, resisting change, accommodating change, and directed change. The course taken depends on how great the changes are anticipated to be, the resources available for management intervention, and how intact and resilient the system is. With relatively intact systems under low to moderate stress, supporting persistence is a common approach. Resisting change, on the other hand, is a strategy employed when there are high-value conservation targets under immediate threat. Persistence and resistance strategies may be implemented now as a way to "buy time" while preparing for future decisions. As climate change affects progress on the landscape, very few protected areas will remain unchanged and actions to accommodate and direct transformational change on the ground may be needed.

Step 4: Implement actions

After actions and strategies are determined, the adaptation plan needs to be implemented if it is to make a difference. As with all steps in the general adaptation cycle, implementing climate change adaptation actions is not a one-time decision but an ongoing process. Some actions may need to be implemented immediately while others can address long-term goals, and these will take more time and resources to put in place. This document offers no specific best practices for implementing climate change actions because this step, while obviously critical, is not inherently different than managing other issues. The important part is to act. That said, there are some aspects of planning and implementing decisions for climate change that are particularly challenging.

First, the long time needed to detect many climate changes can make it difficult to get the attention and commitment needed for effective management. Managers face so many near-term issues that it may be very difficult to justify actions that support long-term adaptation within the context of, for example, a two-to-five-year planning horizon. Leaders and stakeholders may need to be educated about the importance of framing near-term decisions within the longer-term climatic context. Additionally, as climate change impacts are felt across large areas, managers can find it difficult to consider their role in implementing solutions with implications that exceed their jurisdictional responsibility. To be successful, more effort than is typical will often be needed to build

Snares crested penguins (*Eudyptes robustus*), New Zealand. Under a changing climate, the future of many penguin species is imperiled by changes in populations of species upon which they depend for food, compounded by a loss of sea ice, which disrupts their life cycle (Liana Joseph).

support for individual projects, keep stakeholders informed and engaged, and coordinate with partners. A particularly difficult challenge is the range of plausible climate futures and the unknown effect that any individual management action may have. This is why these guidelines repeatedly stress the importance of a flexible management structure and a leadership environment that allows for changes when called for.

Step 5: Monitor and adjust

The final step in the adaptation cycle (see Executive Summary Figure 1) is monitoring and evaluation. These are essential elements of adaptive management. “Learning by doing” is critical for climate adaptation because we will be successful only by specifically directing attention to what works and what does not. Four best practices help to guide the design and implementation of successful monitoring for climate adaptation.

- Best Practice 7.1: Use established principles and support adaptive management
- Best Practice 7.2: Identify how monitoring and evaluation will contribute to climate change adaptation
- Best Practice 7.3: Anticipate and design monitoring for change
- Best Practice 7.4: Include adaptation-specific indicators into existing monitoring practices

All protected areas require routine monitoring, evaluation, and reporting as a foundation for management. While there are some special considerations for designing monitoring for climate adaptation, the elements of a robust monitoring program are consistent with established monitoring frameworks. As a general principle, monitoring for climate adaptation should be incorporated into existing monitoring and evaluation of resources and management effectiveness. If an existing framework is lacking, there are excellent resources described in the Appendix that can serve as a starting point. In this case, monitoring for climate adaptation should be included as a fundamental component from the beginning.

Monitoring and evaluation that are designed from the outset to contribute to learning and that facilitate exploration of emerging issues, such as climate change, will enhance general knowledge about the protected area and improve adaptation practices. One challenge to consider is the requirement to demonstrate results from monitoring over both short and long time frames. Many climate adaptation activities may take decades before outcomes are known, so keeping long-term change in mind is critical, even while looking for short-term indicators to improve and adjust the approach. In addition to monitoring ecosystem change, objectives for climate adaptation frequently include indicators such as management effectiveness, resource stewardship, operations sustainability, mitigation, restoration, and ecosystem services. Even where goals and strategies remain the same, changes in monitoring may be required to address shifts in species ranges, phenology, and community structure or composition. An increased emphasis on managing for change may translate into selecting ecological processes, communities, or services as monitoring targets rather than species.

Linking local adaptation planning to landscapes, seascapes, and beyond

Networks of protected areas provide global resilience to change

Preparing for change at protected area sites is critical. However, adaptation cannot be accomplished at the local level alone. Conservationists and protected area managers can help to build a stronger global resilience to change by contributing to collective planning and response. A different set of principles and guidelines is required in order to meet these new and complex expectations.

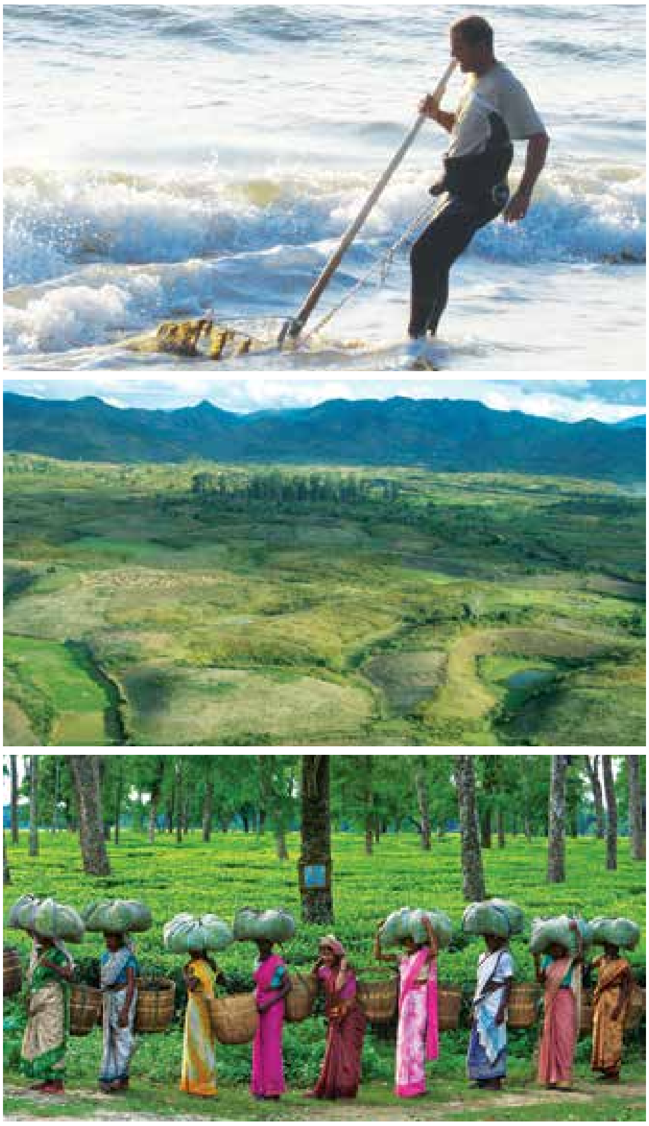
- Best Practice 8.1: Design networks to promote ecological resilience to climate impacts
- Best Practice 8.2: Manage networks to promote ecological resilience to climate impacts
- Best Practice 8.3: Grow and nurture relationships that support networks

Networks possess a variety of traits that make them inherently more resilient to climate impacts than individual sites, and informed management can further enhance the resilience of networks. Two characteristics that are inherent to an effective, resilient network include ecological representativeness and ecological redundancy of nature's diversity of species, populations, habitats, and ecosystems. Representativeness and redundancy help provide insurance for and spread risks from unpredictable shocks and stresses by allowing plants and animals to move and adjust to change. Protected area managers contribute to network-level resilience by understanding and addressing threats that extend beyond individual protected areas and by promoting diverse governance and managing across boundaries. Social resilience is also important for protected areas to consider. By following the best practices presented through these guidelines—especially those related to learning and adaptation through partnerships—managers make an essential contribution to sustaining both natural and human communities.

Mainstreaming protected areas as natural solutions

Protected areas have important and often underappreciated roles in addressing climate change, from local to global scales. In addition to conserving nature, protected areas capture and store carbon, reduce risk from natural disasters, improve human health and well-being, enhance scientific knowledge, and facilitate climate change adaptation. Mainstreaming protected areas into other sectors and plans, at local to international levels, is critical to the long-term support for climate adaptation and conservation of biodiversity. Protected area managers, conservation organizations, and others can help ensure mainstreaming occurs by following three best practices that are aimed at landscape (or seascape), regional, national, and international levels.

- Best Practice 9.1: Participate in landscape and seascape adaptation planning that extends beyond the boundaries of individual protected areas
- Best Practice 9.2: Encourage the incorporation of protected areas as key solutions into regional and national adaptation and mitigation strategies
- Best Practice 9.3: Seek opportunities for mainstreaming protected areas into national and international plans and agreements



When planning to adapt to climate change, PA managers must take into account the likely consequences for local communities that have traditionally depended on the area for food or other resources. (Top): Shell fishing using traditional methods, Doñana National Park, Spain (© IUCN / Arturo Mora). (Middle): Areas of cultivated land in Midongy du Sud National Park, Madagascar (IUCN Photo Library / © Geoffroy Mauvais). (Bottom): Toting freshly picked leaves at a tea plantation bordering Kaziranga National Park, India (IUCN Photo Library / © Steve Winter).

At the landscape or seascape scale, managers and other protected area professionals can act as knowledgeable experts and advocates about the benefits of protected areas to adjacent jurisdictions and other connected lands and waterways. They also can be proactive in convening discussions with local and regional Indigenous communities and other stakeholders to find creative, collective solutions. In a climate-altered future, protected areas will become even more critical for humans and nature to survive and thrive. However, as climate change is likely to cause a greater strain on both people's livelihoods and the availability of resources, the value and relevance of protected areas must become more visible to the human communities that live in or depend on them. By following the best practices articulated in these guidelines, managers advance not only their responsibilities as stewards of individual protected areas, they also make an essential contribution to the long-term sustainability of both natural and human communities.

Chapter 1

Setting the stage: Climate change and protected areas

Establishing protected areas (PAs) is the key way we conserve nature. All countries have PAs and they now cover more than 15% of land and 8% of coastal waters (Juffe-Bignoli, et al., 2014). Climate change is one of the most important threats to nature and to how we manage PAs. The challenge of climate change is large, perhaps greater than any humankind has ever faced, but it can be met—and PA managers and planners will be a critical part of the response. Likewise, every PA has a role to play, but it means taking some different approaches to how we manage them. These guidelines explore these new ideas and offer current best practices that managers and planners can use right now to respond to climate change.

The 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Paris Agreement in December 2015 to take collective global action on climate change. In the agreement, climate change is recognized as an “urgent and potentially irreversible threat to human societies and the planet” and all sectors and countries are called upon to act. A key outcome from COP21 was recognizing the importance of ecosystem-based approaches to achieving climate adaptation, including hazards reduction, and the role of PAs as a part of national responses to climate change. There is a large and very rapidly expanding number of reviews, policies, and advocacy publications on climate change, and there is a need for specific, practical guidance for PA site managers. These guidelines aim to meet that need.

1.1 The purpose of these guidelines

Protected area managers have an increasingly complex task to meet the demands of a growing diversity of stakeholders and to incorporate climate change into their management (see Worboys, et al., 2015). As the core objective of many PAs around the world is to conserve species and ecosystems, these guidelines are primarily focused on actions and strategies that help species and ecosystems adapt so that the core values and functions for which PAs were established can continue to persist under climate change. This may involve redefining management goals and will certainly mean consideration of how PAs fit into the broader issues of change in any given landscape or region. To begin, we look at the basic science of climate change.

Protected areas can store vast quantities of carbon (Larry Hamilton).

1.2 Climate change basics

Our world is already experiencing human-induced climate change and will continue to do so for decades and even centuries to come. According to the Intergovernmental Panel on Climate Change (IPCC), a consortium of thousands of scientists mandated by the United Nations to regularly report on the status of the Earth’s climate, human-caused warming is unequivocal and our generation is the first to feel the effects (IPCC, 2013, 2014a, 2014b). As the concentrations of greenhouse gases (GHGs)—those responsible for trapping heat from the sun—have increased, the atmosphere and oceans have warmed, the amount of snow and ice has diminished, and global sea level has begun to rise.

Human-induced global warming is caused primarily by an increase in the atmospheric concentration of GHGs, including water vapour, carbon dioxide (CO_2), methane, and nitrous oxide. Of these, the increase of CO_2 is of major concern because it is linked to widespread human activities, primarily fossil fuel burning and deforestation. Over the past 150 years, the concentration of CO_2 in the atmosphere has risen from 280 parts per million (ppm) to over 400 ppm, and is currently increasing at a rate of 2 ppm per year. The IPCC recently concluded that the increase in global warming due to GHGs is unprecedented within the past 10,000 years or more, and that humans have contributed the majority of the warming over the past 50 years (Figure 1.1). The IPCC summary for policy makers and the full report is online at http://www.ipcc.ch/. While the climate has always exhibited variability and major climatic shifts have occurred throughout geological history, warming during this century is likely to occur ten times faster than during any climatic shift in the past 65 million years (Diffenbaugh and Field, 2013).

Important physical changes resulting from global warming include the following (IPCC, 2013):

- Already there has been an increase of 0.8°C in the average global surface temperature since 1951 due to human-caused climate change, and temperature is projected to continue rising over the 21st century. With this warming, it is very likely that heat waves will occur more often and last longer.
- Energy in the atmosphere must be discharged, and as both the atmosphere and the oceans warm, this likely will happen in the form of more intense and frequent precipitation events, hurricanes, cyclones, and thunderstorms; higher-than-average winds; and other extreme events.
- Warmer air holds more moisture, and this is the basis for many forecasts of increasing precipitation in locations where it is already moist. At the same time, drought-prone areas become even drier because warmer temperatures cause increased evaporation.
- Oceans are becoming more acidic because they absorb CO_2 directly from the atmosphere and this CO_2 is converted to carbonic acid. Increased acidity is highly detrimental to many hard-shelled marine organisms.
- Globally there will be a rise in sea level caused by a combination of a warmer ocean water having a larger volume and the addition of freshwater from melting glaciers and polar ice caps. There is evidence that global

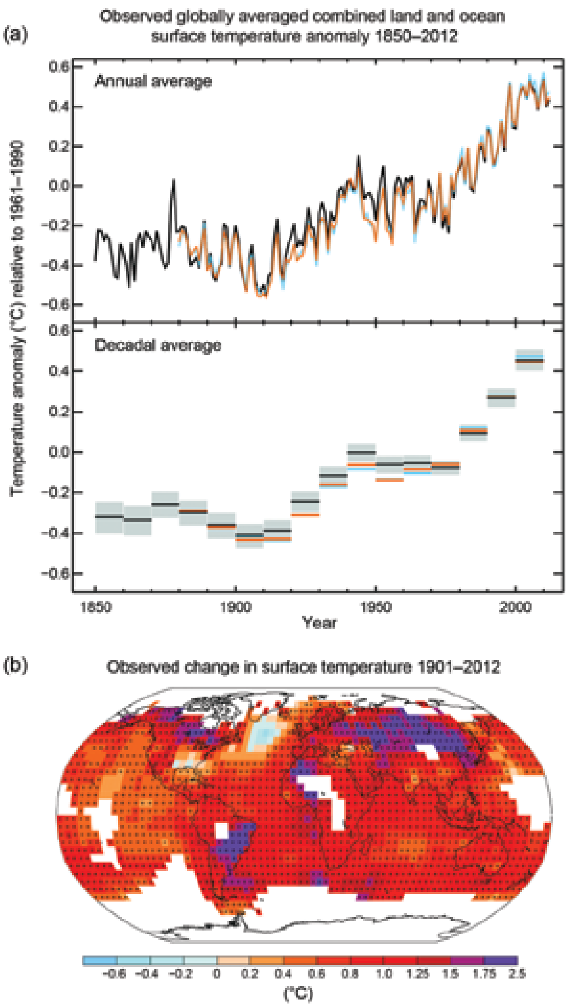


Figure 1.1. (a) Observed global mean combined land and ocean surface temperature anomalies (defined as a departure from a reference value or the long-term average) from 1850 to 2012, from three data sets. Top panel: Annual mean values. Bottom panel: Decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990. (b) Map of the observed surface temperature change from 1901 to 2012, derived from temperature trends determined by linear regression from one dataset (orange line in panel a) (from IPCC, 2013).

sea level began rising during the 19th century and this is expected to accelerate during the 21st. Sea level rise will affect many beaches and estuaries, as well as the values of many coastal, island, and oceanic PAs.

These changes have begun affecting all aspects of life on Earth. The seemingly small change in atmospheric temperature is already having a significant effect on species and ecosystems globally and in PAs (Walther, et al., 2002; Kroeker, et al., 2013; Cramer, et al., 2014). Even if production of GHGs were stabilized today, global temperatures would continue to increase because of the lag effect from the excess GHGs already in the atmosphere (Solomon, et al., 2009). This means major changes are in store for the world's PAs and the species and ecosystems they are designed to protect.

1.3 What are the current and likely future impacts of climate change on protected areas?

Climate change impacts have been documented across a range of systems (IPCC, 2013, 2014a, 2014b; Staudinger, et al., 2013). Table 1.1 summarizes examples of climate-driven changes that already have been observed in different regions of the world. Effects from global warming vary significantly from place to place, and are compounded by the fact that many species and ecosystems already are contending with many other environmental stresses, such as habitat fragmentation and loss, pollution, spread of invasive species, and overharvest (Butchart, et al., 2010; Watson, et al., 2013). Because of existing ecological stresses, many species and ecosystems will have less capacity to cope with the new or additional climate-related ones (Segan, et al., 2016). The impacts of all these streeses are cumulative.

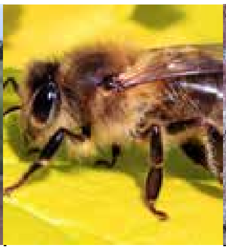
For PA managers, the fact that species respond to climate change in different ways and at different rates is a great concern because this makes it extremely difficult to predict how these responses and interactions among species and communities will occur. Chapter 4 of these guidelines

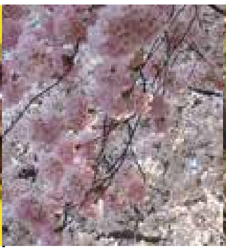
Smog in Harbin, China. Increasing greenhouse gas concentrations, most due to human activity, cause global warming (Fredrik Rubensson).

	Water, snow, and ice	Terrestrial ecosystems	Coastal and marine	Food and livelihood
Africa	↓ glaciers ↓ river flow ↑ surface warming and stratification in large lakes ↑ soil moisture drought	↓ tree density • Species range shifts ↑ wildfires	↓ tropical coral reefs	↓ fruit-bearing trees ↑ malaria ↓ fisheries - large lakes • Adaptation to changing rainfall
Europe	↓ glaciers • Rocks slope failure • Changes in extreme river discharge/flooding	• Earlier greening, leaf emergence, fruiting ↑ Alien plants • Earlier bird migration • Upward shift in treeline ↑ burnt forest area	• Northern shift of Atlantic marine species • Plankton phenology changes ↑ warm water species	↑ heat related deaths • Impacts on Sámi people livelihoods • Changing crop yields • Spread of livestock disease and pests
Asia	↓ alpine glaciers • Permafrost degradation • Changes in water supply • Changes in timing/ amount of river flow ↓ soil moisture • Surface water impacts	• Earlier greening and phenologic changes • Species distribution shifts northward and upslope • Invasion of larch by pine and spruce • Shrubs advance into tundra	↓ tropical coral reefs • Northward range shift of coral • Shift from sardine to anchovy fisheries ↑ coastal erosion	• Impact on Indigenous populations ↓ wheat / maize yields ↑ water-borne disease
Oceania	↓ glaciers ↓ snow depth ↑ hydrologic drought ↓ river flow	• Changes in genetics, growth, phenology of many species • Expansion of some biomes (e.g. wetlands, monsoon rainforest) at the expense of others (e.g. woodlands, savannah, grasslands • Earlier glass eel migration	• Southward distribution shift in marine species • Changes in timing of seabird migration ↑ coral bleaching and changes in disease patterns	• Advance timing of wine-grape maturation • Shift in winter vs. summer human mortality • Relocation or diversification of agricultural activities
North America	↓ glaciers ↓ snowpack ↑ runoff • Earlier peak stream flow	• Phenology and species distribution shifts ↑ wildfire frequency ↑ tree mortality and insect infestations	• Northward fisheries shift • Changes in musselbeds • Changes in salmon migration and survival ↑ coastal erosion	• Impacts on livelihoods of Indigenous groups
Central and South America	↓ glaciers • Changes in river and stream flow patterns	↑ tree mortality and forest fires ↑ rainforest degradation	↑ coral bleaching • Mangrove degradation	↑ vulnerability of Indigenous Aymara farmers ↑ agricultural yields in some locations
Polar Regions	↓ glaciers /continental ice ↓ snow cover and sea ice ↑ circumpolar rivers flows • Permafrost degradation ↑ lake temperatures	↑ shrubs in tundra • Advance of Arctic treeline • Impacts to subarctic birds ↓ snowbed ecosystems and tussock tundra ↑ warm species ranges	↑ coastal erosion ↓ seals and seabirds • Thinner foram shells ↓ krill	• Impact to livelihoods of Indigenous Peoples ↑ shipping traffic in the Bering Sea
Small Island States	↑ water scarcity ↑ extreme events	• Tropical bird population changes ↓ endemic plants • Upward elevation shifts in plants and animals	↑ coral bleaching • Degradation of mangroves, wetlands, seagrasses ↑ flooding and erosion • Fresh water impacts	• Degradation of coastal fisheries

Table 1.1. Observed regional changes relevant to PAs. The fifth assessment report of the IPCC assembled and synthesized a wide array of climate change effects that are already being observed across the planet (IPCC, 2014a, 2014b). The Summaries for Policy Makers from these reports are excellent references aimed at communicating key messages from the IPCC to managers and decision makers. Some of the highlights that may be most relevant to PAs are included in the table.

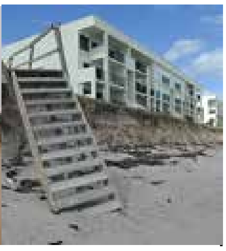

Changes in stream flow


Disrupted pollination


Changes in seasonality


Forest blowdowns


Flooded coasts


Beach erosion

describes vulnerability in more detail. Some of the spatial and temporal connections that have evolved over millennia—such as between pollinators and the flowers they fertilize, or breeding birds and the insects on which they feed—may fail as key ecological thresholds, or tipping points, are exceeded. For managers, this means that some of the features of existing PAs will be completely transformed. For local and subsistence communities that directly depend on these PAs for their livelihoods, the changes present tremendous challenges.

1.4 How can protected area managers respond?

To be part of the solution to nature conservation, clearly PAs must be managed in a way that takes climate change into account. Climate change response is usually divided into two separate approaches: mitigation and adaptation. For PA managers, the term *mitigation* generally means taking action to remove a threat or reduce negative impacts to protected ecosystems and resources, especially those caused by humans. With respect to climate change, mitigation involves taking direct action to reduce GHG emissions from operations and/or to enhance the capacity of PA ecosystems to remove (the scientific term is *sequester*) these gases from the atmosphere and store them in biomass and soils. When ecosystems function in this way, they are carbon "sinks" or carbon stores. As some of the world's richest carbon pools, PAs are important areas for conserving carbon (Campbell, et al., 2008). Mitigation actions include managing ecosystems to avoid or reduce emissions of GHGs as a result of the destruction or degradation of ecosystems, including maintaining peatlands and other carbon-dense communities, maintaining forest integrity, and managing fires. *Adaptation*, on the other hand, generally can be understood

Protected area managers are already taking a wide variety of actions in response to climate change. Here, a volunteer hand-waters drought-tolerant plants along the High Line, an former elevated railway line that is now a 1.45-mile-long linear public park in New York City, USA. The High Line's green roof system with drip irrigation is designed to allow the planting beds to retain as much water as possible; because many of the plants are drought-tolerant, they need little supplemental watering. When supplemental watering is needed, hand watering is used so as to tailor the amount of water to the needs of individual species and weather conditions, and to conserve water. Proactive responses like this are one way to tackle the challenges of climate change (Lance Cheung / US Department of Agriculture).

as an adjustment by human or natural systems to change. Many different definitions for adaptation exist. For the purpose of these guidelines, adaptation refers to a process that seeks to understand the vulnerability of biological systems to climate change effects and assist those systems to respond in ways that minimize negative impacts. In practice, climate change mitigation and adaptation often are not entirely separate and both are important for PA management. While we acknowledge the critical importance of mitigation within the context of PA management, and we touch on some of the elements of mitigation that managers can consider, the focus of these guidelines is on best practices for adaptation. Some highlights for mitigation are given in this section and in Chapter 8 (Mainstreaming), but a thorough consideration of mitigation strategies and actions is a rich topic that is beyond the scope of these guidelines. In reading climate change literature, the term “ecosystem-based adaptation” (EBA) is often encountered. This involves a wide range of ecosystem management activities to increase resilience and reduce the vulnerability of people and the environment to climate change. The IUCN has published principles and guidelines for the EBA approach to climate adaptation (Andrade, et al., 2011).

The good news is that PAs are in a relatively good position to better withstand climate impacts. Unlike other human-altered ecosystems, PAs are managed to reduce threats and are therefore more intact and less stressed.

Protected areas provide natural solutions for ecosystems and society

Protected areas hold great promise as part of a “natural solution” to climate change. As more human-modified ecosystems lose much of their ability to provide ecosystem services, PAs are going to become increasingly important for their capacity to do so (Dudley, et al., 2010). The forests, wetlands, grasslands, and marine ecosystems conserved in PAs store vast amounts of carbon in vegetation, soils, and water. The ability of natural systems to provide greater resilience to natural disasters, especially in coastal systems, is well documented (e.g. Murti and Buyck, 2014; Birkman, et al., 2014). Large intact PAs support adaptation by allowing species to move and respond to changing local conditions.

Protected areas already are used by all nations as a fundamental strategy to conserve nature, and will remain important for preserving biodiversity and ecological function, even as the species inhabiting them shift with the climate (Johnston, et al., 2013). Protected areas are increasingly expected to contribute to livelihoods for local communities, bolster national economies through tourism revenues, and replenish fisheries, among many other functions (Watson, et al., 2014). The work of managers to maintain or restore ecosystems takes on an even larger meaning as we acknowledge and promote the attributes of PAs that contribute to climate change mitigation and adaptation. Actions implemented now to protect and promote “natural solutions” for climate change—such as managing PA networks appropriately and expanding them sensibly, connecting natural spaces, restoring ecosystems and habitats, bringing back native species, and inspiring others to act too—will benefit both natural systems and human society for a long time to come. This is recognized by IUCN, which includes as one of its three programme areas “Deploying Nature-Based Solutions to Climate, Food and Development” (IUCN, 2016).

Mitigating the cause of climate change

While the primary focus of these guidelines is on adaptation, the absolutely critical first step is to not make the problem any worse. Many PA managers feel overwhelmed by the size of the problem. By reducing GHG emissions from operations and protecting natural stores of carbon, PA managers demonstrate their commitment to mitigating the cause of climate change. This is taking direct responsibility for a collective challenge and, over the long term, it will put PA managers on the right side of history (See Case Study 1.1). More and more incentives are being offered to manage carbon effectively and some of the resources and opportunities in this regard are referenced in Chapter 9 (Mainstreaming). For managers of large ecosystems, this is a real opportunity to make a difference.

As some of the world’s richest carbon pools, PAs are important areas for conserving carbon. The current PA system stores 312 gigatonnes (Gt) of carbon, or 1,145 Gt of carbon dioxide equivalents (CO_2eq) per year. If this carbon were released to the atmosphere, it would equal around 23 times the total global emissions (Campbell, et al., 2008; Scharlemann, et al., 2010). This may be compared with emissions from agriculture, forestry, and other land use practices, which are now estimated at 49 Gt CO_2eq per year (IPCC, 2014c). Deforestation alone accounts for around 4 Gt CO_2eq per year—about 12% of the total (FAO, 2014). By contrast, in forest PAs where afforestation, reforestation,

Severe bark beetle outbreaks and coral bleaching are two effects of climate change that are already occurring (top: Wilson 44691; bottom: Nick Hobgood).

Case Study 1.1

Mangroves and climate change: A mitigation and adaptation strategy

Mangroves cover only a small part of the globe, but are critically important to mitigating and adapting to the impacts of climate change by maintaining coastal ecosystem integrity. Despite their small spatial extent, destruction of mangroves may contribute as much as 10% of the carbon released due to global deforestation annually (Hutchison, et al., 2014). The reason is that mangroves store approximately four times more carbon per hectare than tropical forests, but their deforestation rate is three to five times greater than the global annual average (FAO, 2006). In the last 20 years, 25% of all mangroves have been lost. Maintenance and restoration of mangroves are crucial to reduce the vulnerability of coastal areas to flooding while increasing food security and the productivity of fisheries.

Mexico is one of the 10 countries with the highest mangrove deforestation rates in the world; it loses, on average, 10,000 hectares per year. It is important to quantify carbon stocks to calculate carbon emissions and storage throughout the years in order to include mangroves within climate change adaptation and mitigation strategies. In Mexico, this baseline was calculated in three biosphere reserves: Sian Ka'an in Quintana Roo, La Encrucijada in Chiapas, and Marismas Nacionales in Nayarit (Andrew Rhodes, pers. comm.). The Mexican study concluded that (1) mangroves sequester exceptionally large amounts of carbon, more than other terrestrial ecosystems; (2) carbon reserves are larger in forests that are nearer to rivers than to seas; (3) tall mangroves had the highest carbon stocks, followed by medium mangroves, dwarf mangroves, and marshes; (4) at all sites, soil carbon comprised the majority of the ecosystem carbon stocks; and (5) the highest carbon stocks were measured in soils that were relatively low in salinity.

Mangroves in Sian Ka'an Biosphere Reserve, Mexico (Àlex).

Mangrove protection and restoration is an effective strategy to mitigate climate change. For example, the carbon stocks in Sian Ka'an store the equivalent of about 40–46% of the total carbon emissions of Mexico during 2009. In other words, if mangroves were destroyed, the coastal wetlands of Sian Ka'an, which comprise only 0.09% of Mexico's land area, would release about half of the country's annual emissions (Adame, et al., 2013).

An example of mangrove protection as an adaptation strategy takes place in Viet Nam, where communities have been planting mangroves for coastal protection. An investment of US$1.1 million in replanting is estimated to save US$7.3 million/year in sea dyke maintenance; during Typhoon Wukong in 2000, the presence of healthy mangroves also reduced loss of life and property. In Surat Thani, Thailand, the sum of all measured goods and services of intact mangroves is 70% greater than revenues from shrimp farming and aquaculture on lands cleared of mangroves (MacKinnon, et al., 2012).

A Rwenzori double-collared sunbird (*Cinnyris stuhlmanni*). This species is endemic to Africa's Albertine Rift and one of a number of species expected to undergo range contractions as the climate warms (Liana Joseph).

and restoration are occurring, the size of the global carbon sink is actually being increased. By being free of land use practices that emit stored carbon, PAs are a crucial part of a nation's mitigation strategy (Soares-Filho, et al., 2010). So the first management action is to ensure that carbon stored in park ecosystems is conserved. This should be basic PA management, with or without the added pressures of climate change.

Why do protected areas need to adapt to climate change?
Human-caused climate changes are already affecting many PAs, and they will eventually alter values in virtually every PA on the planet. Informed, active management will be increasingly necessary to preserve biodiversity and other PA values; support communities that rely on PAs; promote ecosystem services such as provision of food, forage, and water; and mitigate climate hazards. In many PAs, current conservation goals, decision-making processes, and management practices will need to be revised to best meet the challenges posed by climate change. These revisions include considering PAs in a broader landscape context, thinking more strongly about connectivity and linkages between PAs, developing more forward-looking goals and practices, and considering how key values and roles of PAs may change in the future. Managers will need to use existing management tools in different ways, and adopt new practices to cope with climate changes.

Protected areas will become an increasingly important component of national climate change adaptation strategies as they support species and ecosystem integrity and maximize their potential to adapt to a changing climate (Mackey, et al., 2008a). Protected area managers need to begin—now—to learn how climate changes are likely to alter

Climate change is affecting the hydrological regimes of the world's forests. Th effects may be greatest at mid-to-high latitudes, as with this temperate coastal forest in south-eastern Alaska, USA. (GEDApix/GEDavis & Associates) their PAs and the communities that rely on them. Climate adaptation is a very new area, and we all need to participate as members of a worldwide, learning community to figure out how to best identify and implement actions that will preserve important PA values.

1.5 The structure of these guidelines

These guidelines describe a basic framework and the essential elements for doing climate adaptation planning and implementation. An Appendix lists many sources of more detailed information for each topic. Site managers who are just starting to think about climate adaptation, as well as those well into the process, can use information in these guidelines right away.

The basic steps for climate change response proposed in these guidelines are illustrated in Figure 1.2. The chapters and associated best practices generally follow these steps.

The best practices are presented in nine chapters, following a logical progression from assembling evidence for climate impacts through integration of PAs into international adaptation plans. Following this introductory chapter (Chapter 1), the next two chapters address Step 1 in the cycle (Build a Strong Foundation). In Chapter 2 we describe how to approach planning and conservation goals in an era of rapid and persistent change. Next (Chapter 3) we address the importance of building a long-term capacity for climate change response, which underlies all subsequent actions. Step 2 in the cycle (Assess Vulnerability and Risk) is addressed in Chapter 4, from the perspective of what managers need to know. A companion set of guidelines on assessing vulnerability for species is available from the IUCN Species Survival Commission (Foden and Young, 2016). Step 3 in the cycle (Identify and Select Adaptation Options) is addressed in Chapters 5 and 6, which explore management strategies and tactics for identifying and selecting adaptation options at local PA sites and landscape scales. Chapter 6 also includes guidance for Step 4 in the cycle (Implement Actions). Step 5 in the cycle emphasizes the importance of monitoring and evaluation, and these topics are discussed in Chapter 7. The final two chapters address best practices that go beyond the scale of any particular PA and reflect actions across all five steps in the adaptation cycle. In Chapter 8 we discuss considerations for planning and implementing ecological networks of PAs to support and build resilience in resisting, recovering from, and adapting to climate changes. Finally, Chapter 9 addresses "mainstreaming" (integrating) PAs into broader adaptation and mitigation activities.

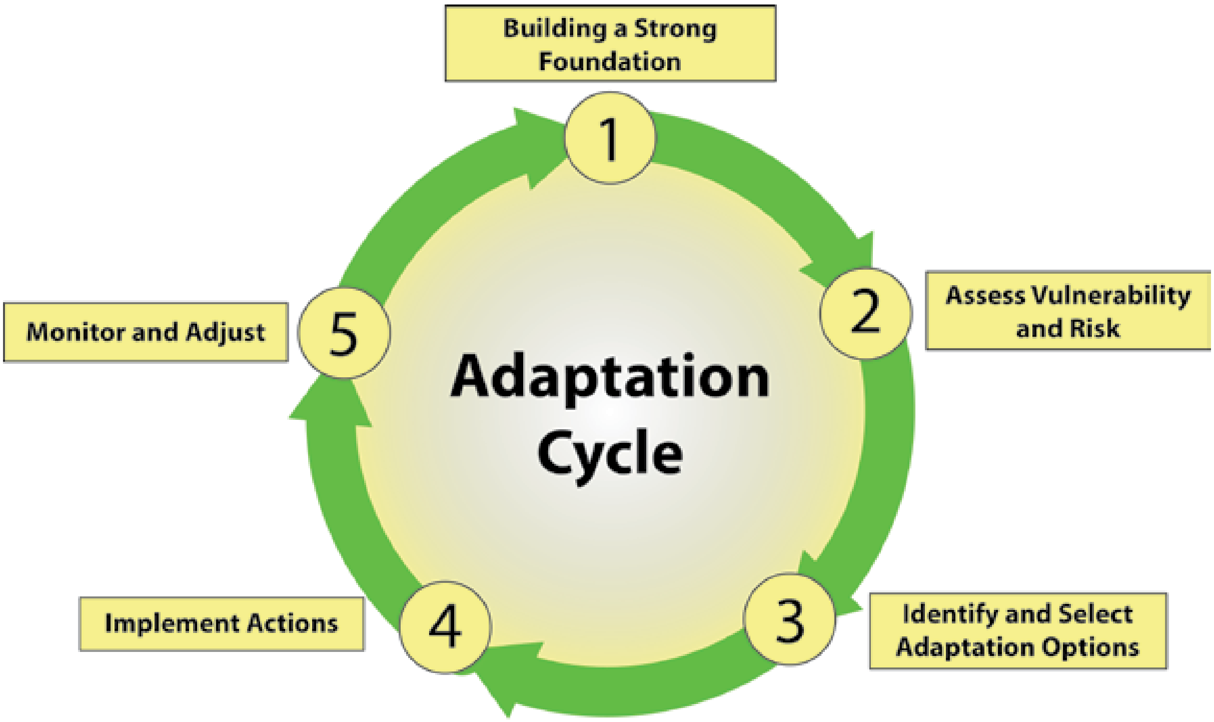


Figure 1.2. The generalized adaptation cycle consists of five basic steps and is an iterative process that includes assembling the necessary information, building capacity, incorporating climate change into planning, undertaking risk and vulnerability assessment, identifying and implementing options, and monitoring and evaluation (adapted from EEA, 2015).

Various parts of the globe are experiencing different rates of warming, which is especially pronounced at higher latitudes such as in the Arctic. Likewise, biomes, ecosystems, and species are sensitive to warming and associated climatic changes in different ways. For instance, although many tropical regions may experience lower overall rates of warming than the Arctic, topographic, ecological, and evolutionary factors may heighten the sensitivity of these areas to the changes that do occur. (Top): Kaiser Franz Josef Fjord Glacier, Northeast Greenland National Park, Denmark (Jerzy Strzelecki). (Bottom): Manú National Park, Brazil (Corey Spruit).

Chapter 2

Planning for change: Protected area goals in a warming world

Protected areas have long served as the cornerstone for national and global biodiversity conservation efforts. However, PAs that were set up to safeguard particular resources, conditions, or qualities generally were established assuming a constant climate. Because of climate change, some PAs will end up with habitat and species assemblages very different from those they were initially designed to protect—and with very different conditions under which resources must still be protected. As a result, it is now essential to consider climate change and its associated ecological impacts when planning for management of an existing PA, or for an entire PA system. Planning for change is an essential element of Step 1: Build a Strong Foundation, in the adaptation cycle (Figure 2.1).

Effective planning for climate adaptation necessarily will require consideration, or reconsideration, of PA goals. Clear goals are essential for effective PA management. Clearly articulated goals (1) clarify which resources (or conservation targets) are of particular interest or concern; (2) express desired conservation outcomes for these resources; (3) ensure that management strategies and conservation actions are designed in ways that help attain the outcome; and (4) serve as a benchmark for measuring the effectiveness of conservation actions.[1] But goals represent human values, and they can and do change. As PA managers carry out their planning in the face of a warming world, it is imperative to reconsider existing goals as part of the climate adaptation process.

2.1 Rapid environmental change: The new norm

Protected areas have long been designed and managed in a context where natural habitats are being destroyed or degraded, and with many species in decline at both local and global scales. Thus the reigning approach has been to try to maintain these sites—often the last remnants of previously widespread natural systems—in their current ecological state, or attempt to restore them to some historical or ecological reference condition. In North America, for instance, many PAs sought to replicate conditions thought to occur prior to European colonization (even though conditions from that period already were highly influenced by human activity). Insights from the palaeontological record have illuminated how pervasive climatic and ecological changes have been throughout time, making clear that any specific reference condition is simply a selected point on a long-term continuum of change, not an innate natural standard to be preferred over all others. Although environmental change has long been understood to occur on geologic or evolutionary time scales, most resource management has assumed a relatively stable climate over a management-relevant time span, an assumption referred to as climatic "stationarity." There has been increasing recognition, however, that even assuming a stable climate, considerable variability exists at annual and decadal scales, giving rise to the notion of managing natural resources within a "historical range of variability" (Landres et al., 1999), rather than attempting to manage towards a specific reference point. The climatic changes now evident make it clear that many environmental variables now exceed what has been understood to be this historical range of variability. Temperatures in more than 80% of national parks in the USA are already warmer than those recorded in 95% of the historical conditions going back to 1901 (Monahan and Fischelli, 2014). Indeed, in the words of Milly, et al. (2008), "stationarity is dead."

The degree of change to which any particular PA will be subjected depends on many factors operating at local, regional, and global scales. Various parts of the globe are experiencing different rates of warming, which is especially pronounced at higher latitudes such as in the Arctic. Likewise, biomes, ecosystems, and species are sensitive to warming and associated climatic changes in different ways. For instance, although many tropical regions may

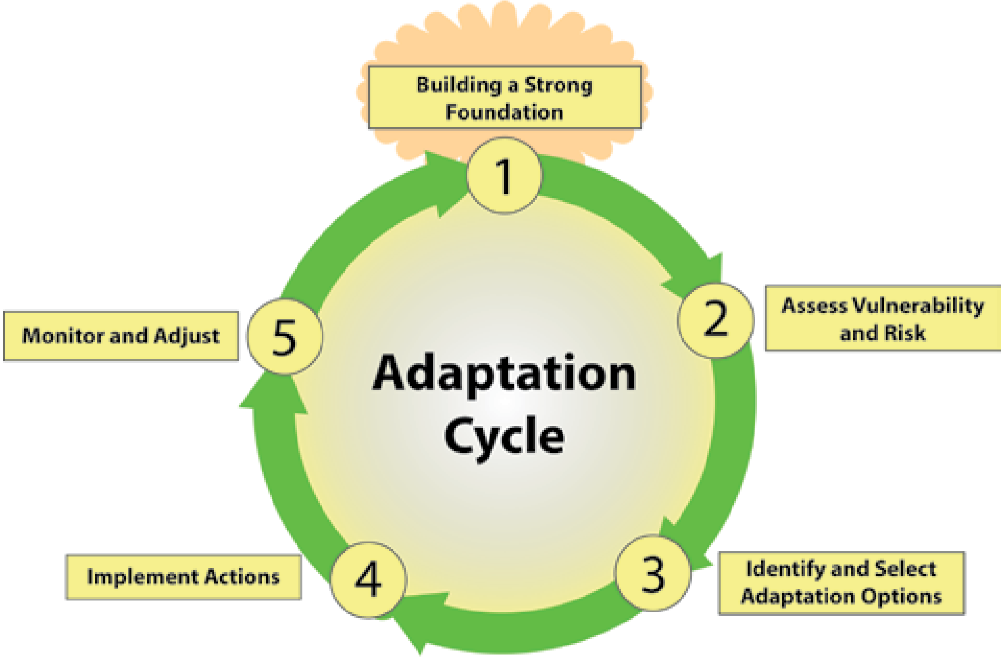


Figure 2.1. Step 1 in the generalized adaptation cycle is to build a strong foundation to enable effective decision making under climate change in both the short and long term. This includes best practices in Chapters 2 (Planning for Change) and Chapter 3 (Building Capacity for Climate Adaptation) (adapted from EEA, 2015).

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[1] A note about terminology: terms such as *purpose, goal, mission, vision,* and *objective* often are used in interchangeable and overlapping ways. Here we use *goal* to refer to a higher-level vision, with *objective* referring to more discrete and tangible measures toward achieving those goals.

In 1881, a circular area with a radius of six miles (9.6 km) from the summit of Mount Taranaki in New Zealand was protected as a forest reserve. Areas encompassing the older volcanic remnants of Pouakai and Kaitake were later added to the reserve and in 1900 all this land was gazetted as Egmont National Park, the second national park in New Zealand. With intensively farmed dairy pasture reaching right up to the mostly-circular park boundary, the change in vegetation is sharply delineated in satellite images. The fixed boundaries of PAs make them vulnerable to climate change (NASA/GSFC/MITI/ERSDAC/JAROS, and US/Japan ASTER Science Team).

experience lower overall rates of warming than the Arctic, topographic, ecological, and evolutionary factors may heighten the sensitivity of these areas to the changes that do occur (Colwell, et al., 2008, see also Chapter 4 on Assessing Vulnerability and Risk). Ultimately, the degree of climate change to which PAs will be exposed is highly dependent on society's ability to stabilize and reduce atmospheric greenhouse gas concentrations. There are limits to climate adaptation (Adger, 2005), and the ability for such measures to succeed will be tied closely to the magnitude and scope of future climate change (Stein, et al., 2013).

While there is still much uncertainty about the precise rate and magnitude of many of the climate changes underway, PA managers must accept that rapid environmental change is the new normal and is already underway. Managers should expect accelerating climatic changes, and corresponding ecological shifts and human responses, especially over the mid- and longer-term. Because climate change will be ongoing and continual, climate adaptation should be viewed as an ongoing process and not simply adjusting to a new, static regime.

2.2 The evolving nature of protected area goals

The goals and purposes for PAs—stated and unstated—have changed considerably over the past century, shifting from an early emphasis on values such as scenery and hunting opportunities, to more expansive visions of biodiversity conservation, to the provision of ecosystem services and other benefits to human communities. The broad-scale effects of rapid climate change on both natural and human-dominated systems will necessarily require a continued evolution in the values and goals underlying our protected lands and waters.

IUCN defines a PA as:

> *A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2013).*

Protected areas may be established to "maintain functioning natural ecosystems, to act as refuges for species and to maintain ecological processes that cannot survive in most intensely managed landscapes and seascapes," and may have a variety of direct human benefits, including opportunities for recreation and renewal, provision of environmental services, and protection of sacred sites. According to these guidelines, however, "conservation of nature" must always be a primary goal: "For IUCN, only those areas where the main objective is conserving nature can be considered PAs; this can include many areas with other goals as well, at the same level, but in the case of conflict, nature conservation will be the priority" (Dudley, 2013).

With regard to climate change and its effects on human populations and society, Dudley, et al. (2010) identify a number of ecosystem services PAs will continue to provide. These include preventing or reducing the effects of natural disasters, such as floods and tidal surges, landslides, and storms; providing secure and clean water supplies; addressing climate-related health risks; and protecting food supplies, including wild foods, crop wild relatives, and fisheries. These authors also highlight the important role PAs can play to help address the underlying cause of climate change by contributing to efforts to stabilize and reduce atmospheric concentrations of greenhouse gases. As noted in Chapter 1, PAs can contribute to climate mitigation through promoting the storage of carbon in natural systems—a strategy that is now part of an organized international effort called REDD (for "Reducing Emissions from Deforestation and Forest Degradation"). REDD projects seek to meet a (sometimes difficult) goal to store carbon in forests and preserve biodiversity (Venter et al., 2013; Panfil and Harvey 2016; see http://unfccc.int/land_use_and_climate_change/redd/items/7377.php for an introduction). The role of PAs in climate protection is an excellent example of how goals evolve: this important ecosystem service and societal value was scarcely recognized just two decades ago.

Here are five best practices for incorporating climate change considerations into PA planning, with a focus on how conservation goals will need to continue evolving:

- 2.1: Manage for change, not just persistence
- 2.2: Reconsider goals as well as strategies
- 2.3: Adopt forward-looking and climate-informed goals
- 2.4: Link adaptation actions to climate impacts
- 2.5: Integrate climate considerations into existing planning

Best Practice 2.1: Manage for change, not just persistence

Because widespread ecological changes are now underway and even greater changes are expected as a consequence of a shifting climate, PA managers increasingly will be challenged to actively manage for change, rather than just maintaining existing systems and values.

Most PA goals and objectives seek either to maintain existing levels of native biodiversity (at the population, species, and ecosystem levels) or restore key ecological elements and attributes that previously existed. Although sustaining these features will continue to be a cornerstone of conservation efforts, focusing on persistence alone at the site level will no longer be tenable. In particular, as climate-driven changes inevitably push many systems toward abrupt ecological changes, managers will need to take an active role in managing these transitions in an effort to ensure that the new ecological states are more, rather than less, likely to meet societal expectations and values. The bottom line is that, increasingly, we will need to manage for change, not just persistence. Many existing goals and practices will need to be

Some coastal PAs, such as Blackwater National Wildlife Refuge (Maryland, USA), face the possibility of becoming at least partially inundated as sea levels rise. Such major changes may force managers to reconsider the basic goals of the PA. Even if part of this refuge is inundated, other parts will remain key habitat for various species, including the formerly endangered, but still rare, Delmarva fox squirrel (*Sciurus niger cinereus*). Even in a changed climate, Blackwater is likely still going to be very valuable for biodiversity preservation (Ataraxy22).

Species that are not widely distributed are especially susceptible to the negative effects of climate change. (Left): A thorny devil, endemic to the deserts of Australia. Species in desert ecosystems are sometimes very fragile in the face of a changing climate, as they have adapted to extreme climate regimes and are thus sensitive to change (Liana Joseph). (Above): A mountain gorilla. This species is considered endangered, in part, by a changing climate given its restricted range (Liana Joseph).

realigned to support management for change. For example, persistence of species may become a goal for a network of PAs, rather than for a specific site.

A continuum of change

A continuum of change can be envisioned that ranges from status quo conditions (persistence) through complete system transformation. Similarly, a range of climate adaptation approaches have been described that mirror this continuum: *resistance, resilience,* and *realignment* (Millar et al., 2007, Glick et al., 2011). *Resistance* strategies are intended to maintain status quo conditions by fending off changes to a system. An example of a resistance strategy is to attempt to avoid loss of a climate-limited species anywhere within its historical range. *Resilience* generally describes the capacity for a system to rebound to its prior state following a disturbance, but the term has been defined in many different ways. For climate adaptation, the concept of resilience is that a system maintains or recovers key ecological functions, although perhaps with different species, in the face of climate disturbances. To be meaningful, resilience needs to be defined in terms of "resilience of what, to what". Adaptation strategies to increase resilience often include reducing non-climate stressors and promoting ecological integrity. *Realignment* (or *response* as it is sometimes called) focuses on strategies that can either facilitate passage of a system through an ecological transition, or seek to promote desirable characteristics in its new ecological state (e.g. as in a climate-driven transition from forest to a shrub community). It is worth noting, however, that the first generation of PA climate adaptation efforts has emphasized resistance, even in cases where the concept of "enhancing resilience" is invoked.

The dual pathways of persistence and change are highly dependent on the spatial scale under consideration: one may be managing for change at one level and persistence at another. For example, as species' ranges shift in response to changing climatic conditions, it may not be possible to sustain viable populations of all native species currently inhabiting a specific PA. At the regional or national level, however, it may be possible to sustain populations of those same species across an entire network of PAs, although not necessarily at their original localities. In this instance, one may be managing for change in species composition at the local scale while focusing on persistence at a broader scale.

Additionally, over time it may be appropriate to cycle between managing for persistence and managing for change. In some instances, it will make sense to purposefully manage for persistence (often referred to as "buying time") until the system begins reaching, or passes, an ecological transition or threshold. When a threshold is impending, shifting to a management strategy to accommodate change (realignment) may be appropriate to help shape the ecological outcome of the transition (Case Study 2.1). Once the transition has occurred, a manager may then cycle back to a persistence strategy that maintains the new state until the next threshold is reached. Predicting when ecological thresholds are approaching is extremely challenging, and often they become apparent only after the fact. Nonetheless, in the face of continual change, PA practitioners will need to determine when managing for persistence versus change is appropriate, and when to cycle between the two.

Best Practice 2.2: Reconsider conservation goals as well as management strategies

Clear and explicit conservation goals and targets are important in establishing and managing PAs for many well-established reasons (Margules and Sankar, 2007; CMP, 2013; Worboys et al., 2015). However, many conservation and PA goals are very general and sometimes even vague, and core values and assumptions rarely stated. The added challenges that climate change poses for place-based conservation make it even more important to be explicit about conservation goals at an individual site, as well as across an entire PA system. Given projected climatic shifts and the associated ecological and human responses, there will be difficult decisions to make that will require trade-offs among various resources, stakeholders, values, and goals. Being as clear as possible about PA goals, and the assumptions and values that underlie them, is essential to successfully incorporate climate adaptation into routine PA management.

Case Study 2.1

Translocation of an imperilled fish population in Glacier National Park, USA

The synergistic effects of invasive species and climate change are driving major shifts in management strategies in Glacier National Park, located in northwest Montana, USA. The park sits at the headwaters of three continental-scale river systems and provides outstanding physical habitat for the threatened bull trout, a cold-water species. Bull trout populations in the park have already been reduced by invasive non-native lake trout, and impending impacts from climate change (e.g., increasing water temperatures, altered precipitation and runoff patterns, reduced late-season snow- and ice-melt; Pederson, et al., 2010) put the long-term persistence of the species in the park in peril.

In an effort to conserve the genetic diversity and life history traits (breeding behaviour, phenology, etc.) of the current bull trout population, and ultimately to maximize the species' ability to adapt and survive in the park, managers have undertaken a translocation project to establish a new population in a high-elevation lake (Grace Lake) upstream of its current location (Logging Lake). Consistent with IUCN (2013) guidance for species translocations, the park is pursuing the following tasks:

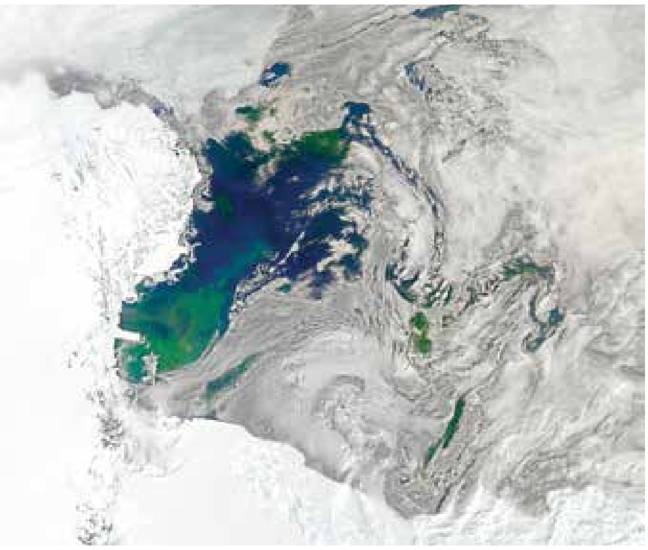
1. Evaluating potential for bull trout to establish a self-sustaining population upstream of the current population in Grace Lake and its associated stream network;
2. Evaluating potential impacts to the recipient habitat/aquatic community from the introduction of bull trout;
3. Assessing the impacts of removals of bull trout on the donor population (Logging Lake);
4. Attempting to establish a new self-sustaining bull trout population in Grace Lake through translocation; and
5. Monitoring the outcome of the bull trout translocation.

Evaluation of habitat suitability and potential ecological impacts suggested appropriate conditions for bull trout were present in Grace Lake, but the fish could not reach the lake on their own because it is located above an impassable waterfall (Galloway, et al., 2016). Park staff used backpack electrofishing to capture all remaining juvenile bull trout from downstream areas and moved them upstream of the waterfall into Grace Lake; 111 juveniles were translocated in 2014 and one additional individual in 2015. The vast majority (>90%) of the juveniles were young-of-the-year and preliminary results suggest the original population at Logging Lake is no longer viable.

The park and its partners either acted just in time—or perhaps too late—in attempting to conserve this bull trout population. By moving all the juveniles upstream, they conserved all remaining genetic diversity present in the donor population, and thus retained all genetic potential for the species to adapt to the new environment. The newly established population is also secure from invasive lake trout. However, the numbers are low and the young face increased predation risk from the Yellowstone cutthroat trout already present in Grace Lake. The park intends to supplement the population with additional donor stock and will continue to monitor genetics, movement, and spawning.

(Top left): Juvenile bull trout awaiting transport upstream to Grace Lake. (Bottom left): Impassable waterfall located between Logging and Grace lakes. (both Chris Downs, NPS)

(Above): Glacier National Park personnel transported 111 bull trout by backpack between Logging and Grace lakes in 2014, and one more in 2015 (NPS).



Satellite image of phytoplankton bloom, Ross Sea, Antarctica. These microscopic photosynthetic drifters form the basis of the marine food web, regulate carbon in the atmosphere, and are responsible for half of the photosynthesis that takes place on our planet. Warmer ocean temperatures are affecting not only the size of phytoplankton blooms, but their timing as well. The Ross Sea has been proposed as a marine PA and a climate change reference area, but to date such plans have not been agreed (Norman Turing/NASA).

Reconsider goals in light of climate change

Given the scope and magnitude of climate impacts, many current conservation goals and objectives may no longer be achievable, regardless of how important they may be. This particularly applies where stated goals are to retain all native species and communities (Box 2.1). In some circumstances climate adaptation for PA management will clearly require conducting an honest and open reconsideration of goals and objectives (Hobbs, et al., 2010; Poiani, et al., 2011; Stein, et al., 2014). Reviewing existing goals from a climate change perspective may either validate the continued relevance of those goals, or indicate the need for modifications. While the prospect of revising goals may be unsettling, the principles and practice of conservation have been far from static over time. Indeed, conservation goals are a reflection of human values, and there has been a continuing evolution in how society understands and values nature and PAs.

There are many existing approaches and best practices for goal-setting that incorporate some version of the so-called "SMART" framework: specific, measureable, achievable, relevant, and time-bound. From a climate change perspective, we must be particularly cognizant of the "achievable" element of goal-setting, since it makes little sense to articulate goals for an area or system that clearly will be unattainable. If, for instance, a particular fish species requires cold water and there is virtually no likelihood those conditions will persist far into the future, then a goal of maintaining long-term viability of that species at that site may be impossible to achieve without huge effort and expense. A goal focused on viability over a shorter period of time, however, might be appropriate.

Best Practice 2.3: Adopt forward-Looking, climate-informed goals

Many existing conservation goals are retrospective, focusing on past conditions as a template and guide for management actions. Past conditions, both climatic and ecological, can be highly informative, but with rapid climate change one needs to consciously shift towards developing and adopting forward-looking and climate-informed goals. We deliberately use the term "climate-informed" goals rather than "climate change goals": while there may be instances where goals specifically focus on climate change, in most cases the best approach is to incorporate climate considerations into existing decision-making and conservation efforts (see Best Practice 2.5).

Crafting climate-informed goals

Reconsidering long-held goals can be challenging and managers may have difficulty knowing where and how to start on this important task. Fortunately, modifications are often needed in just one or a few components, rather than a wholesale revision of a goal. Deconstructing goals into separate components can help facilitate a review of existing ones, and then crafting more climate-informed versions. To that end, goals can often be divided into the following:

- **What** (the *conservation target* or objective of the goal);
- **Why** (the *intended outcomes* or desired condition);

Box 2.1

Climate change may challenge conservation goals to retain all species

Rebecca Shaw and colleagues used climate-envelope models to examine shifts in climate space of 11 species that are representative of the Mount Hamilton Project area (MHPA) (California, USA), and showed that meeting conservation goals as climate changes through 2050 would require adding an additional 256,000 ha of protected area—a 332% increase over the existing extent. The cost of land acquisition and management was estimated at US$1.67–1.79 billion, or 40–50% more than the cost of achieving the same conservation goals with no climate change (Shaw, et al. 2012).

The Bay checkerspot butterfly (*Euphydryas editha bayensis*), native to the Mount Hamilton area, may be displaced by climate change (Fcb981).

As the IPCC has noted, adaptation is place- and context-specific, and a one-size-fits-all approach will not work. South Africa's Table Mountain National Park, for example, must plan its response not only in the context of national politics and priorities, but also taking into account its location next to a major international city—Cape Town (Shelly Crausbay).

- **Where** (the *geographic scope*); and
- **When** (the *time frame*).

What. Conservation targets can range from individual species to species assemblages, habitat or ecosystem types, ecological processes, or sets of ecosystem goods or services. Are existing conservation targets still appropriate, or is a change needed so that ecological features or processes should be the focus rather than species or an ecological community? Modifications might be either within a given category (e.g. shift from focusing on one species to another), or across categories (e.g. shift from focusing on particular species or habitats to underlying ecological processes).

Why. Are intended outcomes or desired conditions for the conservation targets still relevant and feasible, or is a change warranted to reflect changes in biological or ecological realities, or in societal values? Where emphasis is on the persistence of a particular species or ecosystem trait, does this continue to make sense, or is there a need to consider alternatives that look to transition-oriented outcomes?

Where. In what places or over what area is the goal or objective still appropriate? Will it continue to be feasible in some portions of a species' range or PA but not others? Modifications might be appropriate to specify a different area, or more clearly describe differing outcomes or time frames in goals and objectives.

When. For how long might existing goals or objectives be appropriate, or is there a need to modify time frames? Many current goals explicitly or implicitly assume a time frame of "in perpetuity". Modifications, where feasible, might be appropriate to distinguish between shorter- and longer-term goals and objectives, and to clearly identify relevant planning periods (e.g. 5–10 years, 20 years, more than 50 years). Choosing the relevant time frame for planning and setting goals will continue to be an important topic in the later chapters of these guidelines.

2.3 Respect the past but plan for the future

Recognizing how ecosystems (and societies) have responded to past climatic variability and disturbances can provide a powerful tool for understanding how such systems might respond to future changes. However, the use of past conditions as the benchmark for setting conservation goals is already problematic in many areas and will become increasingly so throughout the world. Accordingly, climate change adaptation requires conservation goals and objectives that focus on future, rather than past, climate and ecological conditions.

The concept of "historical fidelity" has played a particularly strong role in shaping the vision and goals of many PA systems. This concept focuses on replicating species assemblages, ecological conditions, and even visual resources that were present at some defined period in the past. However, achieving historical fidelity can mean forgoing other PA values, such as maintaining "naturalness" or, in the case of designated wilderness, maintaining nature in a state untouched by human hands, including active management (papers in Cole and Yung (2010) explore these issues). Certainly in the context of continual change, goals to maintain historical fidelity will be increasingly difficult or impossible to achieve.

It is uncertain how climate change will affect extremely long-lived species, such as these giant tortoises on Santa Cruz Island in Galápagos National Park, Ecuador. For the tortoises, it is thought higher temperatures might trigger migrations that could reduce nesting success. Increase in temperatures might also lead to a greater variety of insects on the islands, which could reduce hatching success (GEDApix / GEDavis & Associates).

Climate change requires a broad planning horizon

A core element for crafting climate-informed goals is to consider the wider landscape in PA planning and management. This means a broader physical landscape (i.e. space) and broader consideration of time, relevant institutions, and stakeholders. PAs exist within a matrix of other land uses and societal values. As climate change causes species to shift across the wider landscape, and exacerbates threats from within and outside PAs, it will be imperative to think at much broader spatial scales. In most instances "landscape-scale conservation" does not so much consist of carrying out actions across vast areas, but rather in taking the broader landscape into account when planning for and carrying out local-scale conservation actions, including collaborations with other institutions and stakeholders.

Agricultural expansion inside Niassa reserve in Mozambique is threatening the intergrity of the park and its ability to withstand climate change (James Allen).

Broadening the temporal aspect of planning also is important with regard to climate change. Certain climate-driven impacts already are underway, others can be expected in the near term, and still others may be a concern only over the longer term. PA planning will need to explicitly consider time by taking a long view (decades to centuries) but also accounting for near-term conservation challenges and needed transition strategies. The approach presented earlier for deconstructing goals includes consideration of this temporal aspect (i.e., "when"), recognizing that some goals and strategies may be appropriate or feasible only over specific periods.

Finally, there is a need to consider the broader institutional landscape given the more expansive spatial and temporal scales necessary for planning in the face of climate change. Engaging and collaborating with diverse stakeholders already constitutes a best practice for PA planning and management, but will become even more significant, especially as efforts are undertaken to enhance connectivity. It is worth highlighting, though, that the lands and waters outside of PAs have profound significance beyond their role as conduits for species to traverse among protected lands (deFries et al., 2007; Hansen et al., 2011). Indeed, successful biodiversity conservation efforts depend on the responsible stewardship of these lands and waters as a means to sustain species, ecosystems, and provide ecological services. As climate change increasingly affects both wildlife and human communities, forcing trade-offs and difficult decisions among resource users, there will be an even greater need to engage the diverse array of relevant and affected sectors, institutions, communities, and individuals in PA planning and goal setting.

Emphasize ecological and evolutionary processes

Many existing conservation goals focus on protecting existing *patterns* of biodiversity, particularly related to its composition (e.g., patterns of species occurrences) or structure (e.g., patterns of structural vegetation types). As climate impacts increase, many species are expected to shift ranges, and existing ecological communities are predicted to break up, with new communities forming in their place. While addressing patterns of diversity (both ecological and taxonomic) and preventing species extinctions will continue to be important conservation goals, increasingly PA goals will need to emphasize the *processes* that underlie and support those patterns and the viability of declining and threatened species. Such processes include hydrologic and nutrient cycles, fire regimes, and pollinator and seed dispersal networks. Although ecological processes and their associated functionality are often considered as support factors in PA planning, maintaining these types of processes may need to be viewed as the target of conservation goals in their own right under climate change.

Emphasizing evolutionary processes will also be increasingly important in a climate-altered future. Indeed, managing biodiversity under climate change has been described as "facilitating nature's response" (Prober and Dunlop, 2011), which suggests the need to emphasize goals and strategies that can promote the process of adaptation in an evolutionary sense (Hoffmann and Sgrò, 2011). One new and promising approach for incorporating evolutionary potential into goal setting focuses on identifying geophysical features, or land facets, associated with high levels of species diversity (Anderson and Ferree, 2010; Beier and Brost, 2010). In this sense, the emphasis is on protecting and sustaining the ecological "stage," rather than the current set of "actors," partly as a means to promote future evolutionary diversification. A special section examining this subject was published in *Conservation Biology* (2015) (open access at http://onlinelibrary.wiley.com/doi/10.1111/cobi.2015.29.issue-3/issuetoc).

Seabird species are vulnerable to several kinds of climate change impacts. (Left): A long-term study of the southern fulmar (*Fulmarus glacialoides*) found that the birds forego breeding altogether during warm water anomalies, probably because the availability of krill is so reduced (Liam Quinn). (Upper right): A brown booby (*Sula leucogaster*) in Ashmore Reef Commonwealth Marine Reserve, Australia. Sea level rise will imperil these low islands and affect the booby's nests (Liana Joseph). (Lower right): King penguins (*Aptenodytes patagonicus*) at Macquarie Island World Heritage Site, Australia. In addition to threats from sea level rise, king penguins are endangered by a changing climate due to changes in their food sources and because of loss of sea ice (Liana Joseph).

The flooded grasslands associated with Lake Enriquillo National Park in the Dominican Republic (also a Ramsar site) are part of a carbon-rich biome that has the potential for climate change mitigation measures (NASA).

Embrace uncertainty

For many PA managers, the uncertainty associated with future climate projections represents a major hurdle to planning and taking action on adaptation. Beyond the uncertainties inherent in projections, there also are uncertainties associated with the ecological responses to climatic changes, as well as those of people. Although significant uncertainties are associated with climate change, there are also emerging areas of consensus, and continuous improvements in projections. It is also worth distinguishing between uncertainties in the direction of trends (e.g. wetter or drier; hotter or colder) and in their rate and magnitude. Knowing the direction of the change often is far more important than having a precise understanding of its ultimate magnitude.

PA managers (and society as a whole) deal with uncertainty in virtually every decision. The heightened concern about managing in the face of climate-related uncertainties may be a reflection that this is something new. To overcome this psychological hurdle, managers can look to many existing approaches for addressing uncertainty in planning and decision-making, such as scenario-based planning, or structured decision-making. These topics are addressed further in Chapter 3 (Building Capacity for Adaptation) and Chapter 5 (Identifying Adaptation Options). PA goals and adaptation strategies should seek to be robust in the face of uncertainty, to keep options open depending on how the future ultimately plays out. Rather than succumb to “analysis paralysis” in the face of remaining uncertainty, we will need to learn to embrace it.

Best Practice 2.4: Link adaptation actions to climate impacts

Effective adaptation depends on identifying and carrying out conservation actions that are designed to address the climate impacts of most relevance to a given PA. Each PA is different, not only based on its ecological, social, and cultural setting, but also on the combinations of threats (climate-related and otherwise) to which it is subject now and will be in the future. As a result, it is essential that adaptation strategies be capable of addressing the most relevant impacts and vulnerabilities. Indeed, one of the IPCC’s (2014a) definitions of effective adaptation is that it is “place- and context-specific, with no single approach for reducing risks appropriate across all settings.” Although lists of adaptation strategies increasingly are available (e.g., Heller and Zavaleta, 2009), simply adopting widely cited and popular strategies (for instance, enhancing connectivity) may not be the most suitable and cost-effective approach for a particular situation. Instead, adaptation planning needs to consider specific threats and needs: what are the key climate-related impacts and vulnerabilities, and what strategies may be capable of reducing them?

As climate adaptation becomes a major theme in PA management and begins influencing funding and resource allocation decisions, there is a danger that the concept will be applied indiscriminately as a means of justifying all manner of existing efforts. Unfortunately, this type of relabelling is facilitated by use of such expansive and vague adaptation “strategies” as “reduce existing stressors” and “enhance resilience”, and by suggestions that “staying the course” constitutes an adequate adaptation response. Clearly, much sound climate adaptation will draw on existing conservation projects, practices, and tools, and many current efforts will continue to have significance. However, determining whether existing projects and practices continue to be appropriate from a climate adaptation perspective depends on being able to articulate how the actions address specific climate impacts and vulnerabilities, and helps achieve the type of forward-looking and climate-informed goals described above. Simply relabelling existing conservation efforts as “adaptation” regardless of their link to climate impacts can, at a minimum, delay needed action, and at worst may actually be counterproductive.

To be effective, climate adaptation must be carried out in a purposeful manner (Stein et al., 2014). This is true no matter whether new conservation approaches are indicated, or existing practices and strategies continue to make sense. Adaptation planning that is purposeful clearly articulates how proposed actions are intended to reduce the adverse effects of climate change, or to take advantage of possible beneficial effects. Given the uncertainties, there is no right or wrong answer; rather what is needed is to clearly express the rationale and logic for the proposed actions and the assumptions about how the system is likely to respond, both to projected climate effects and the intended conservation actions. Such logic models are consistent with existing best practice in conservation planning, including the Open Standards for the Practice of Conservation concept of “theory of change,” which describes how particular efforts will lead to desired conservation outcomes (CMP, 2013).

The sophistication and rigour with which this linkage is made will vary greatly depending on particular conservation and legal needs, available resources, and technical capabilities. In some instances, sophisticated scientific analyses and quantitative computer models may be appropriate and informative, while

Safeguarding the source of food supplies, including crop wild relatives such as this strain of wheat (*Triticum araraticum*) growing in Erebuni Reserve, Armenia, is now recognized as an important proactive role for protected areas under a changing climate (wowarmenia.ru/Wikimedia).

in instances where resources are more limited, managers may rely more on expert judgment and conceptual models. This range in complexity and sophistication mirrors most other aspects of PA planning and management. It is better to get started with simpler and less complex approaches than not to proceed at all.

Reduce vulnerability and risk

The very definition of adaptation provides an indication of the importance of linking actions and impacts. The IPCC's Fourth Assessment Report (IPCC, 2007), for example, variously defines adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" and as "adjustments in natural and human systems in response to actual or expected climatic stimuli that moderate harm or exploits beneficial opportunities." The recently released Fifth Assessment Report (IPCC, 2014a) provides an even more succinct definition: "the process of adjustment to actual or expected climate and its effects." Understanding adaptation as a means for reducing vulnerability and moderating risk makes clear why a vulnerability assessment is essential for identifying adaptation strategies and linking actions to climate impacts. This important topic is explored in more detail in Chapter 4.

Show your work

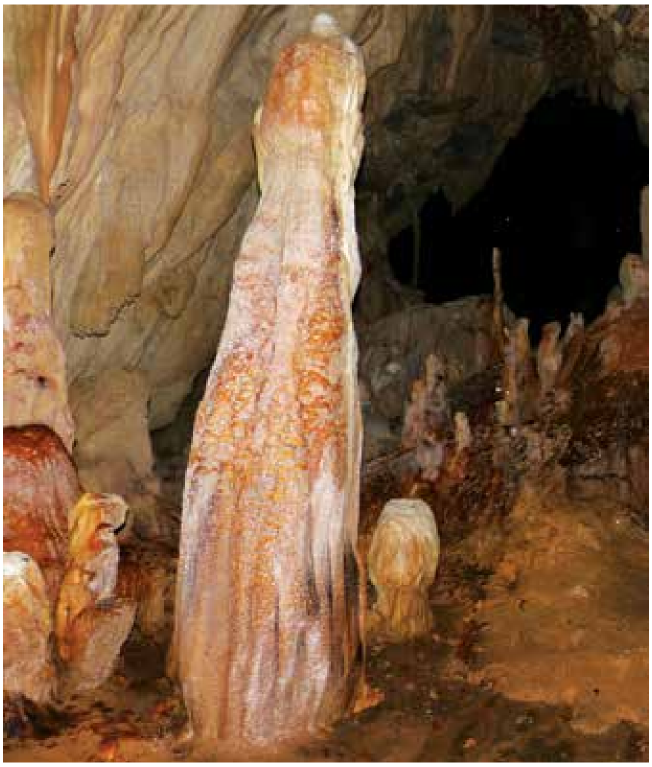
An important aspect of linking actions to impacts is the need to document those linkages and the scientific and management rationale for proposed adaptation strategies and actions. Such transparency not only can help gain support from others, including prospective funders, partners, and local communities, but provides the basis for adjusting management actions as ecological or climatic conditions change, or additional information emerges about the efficacy of the actions. Climate adaptation must be viewed as an ongoing process, rather than a one-time event. For this reason, there will be a premium on being agile and adaptive in PA management, and thinking of conservation and adaptation actions as hypotheses to be monitored, evaluated, and refined as needed.

Best Practice 2.5: Integrate climate into existing planning

For most PA managers, climate change is just one of many concerns, and often not the most pressing. Planning for the impacts of climate change—some of which may not become evident for many years—often is regarded as a lower priority than immediate threats. Similarly, most PA agencies have tight budgets, and asking managers to develop a climate adaptation plan can feel like an additional burden. Finally, many agencies and organizations have formalized processes and protocols for decision-making, and are resistant to carrying out parallel planning efforts to address climate adaptation. Thus, while there are times when stand-alone adaptation plans are appropriate, it is usually more effective to integrate climate considerations into existing processes.

To date, most adaptation work has focused on planning rather than implementation. Various hurdles to implementing adaptation actions exist, ranging from uncertainty about likely impacts to competing demands, limited resources (e.g., time, staff, money), and institutional inflexibility (Chapter 6; Moser and Ekstrom, 2010). Incorporating adaptation into existing processes can help overcome some of those hurdles. For instance, financing a stand-alone adaptation plan may be viewed as difficult or impossible, while incorporating adaptation into existing planning processes can help direct (or redirect) already allocated funds towards more adaptation-relevant activities. Adaptation actions often benefit other important social goals, and in some instances projects may be more likely to be carried out if they are incorporated into plans that emphasize those "co-benefits" (Chapter 9—Mainstreaming).

However, there are times when it makes more sense to carry out adaptation planning as a separate process. One example



(Top): Potential climate change impacts on caves include disruptions of surface–underground hydrological regimes, especially important to PAs such as Puerto Princesa Subterranean River National Park, Philippines (Mike Gonzalez). (Left): Scientists working in Gunung Mulu National Park, Sarawak, Malaysia, are studying stalagmites similar to this one to help reconstruct climate history in the tropics (Bernard Dupont). Another possibility is that drier conditions may prevail in some caves, affecting the development of formations. (Above): It is not yet well understood how changing temperature and moisture conditions might affect cave-adapted organisms, such as this Model Cave harvestman, currently known only from Great Basin National Park, Nevada, USA (NPS).

is when an agency is using climate change as the primary perspective on its planning, or is specifically interested in how climate impacts may affect its operations and practices. Because adaptation is still an emerging discipline, stand-alone plans may also be helpful as agencies or communities gain technical expertise and proficiency in its practice. Similarly, demonstrating success in adaptation planning and implementation on a pilot scale may be a necessary precursor to larger-scale adaptation investments. Eventually, we expect to see climate considerations become an important and integral component of virtually all PA planning and management.

2.4 Summary

Protected areas have long served as the cornerstone for national and global biodiversity conservation efforts. Under climate change we know that species will shift and many systems will be altered by increased disturbance. As a result, it is now essential to consider climate change and its associated ecological impacts when planning for management of an existing PA or networks of PAs. Key practices to guide evaluation and, where necessary, modification of goals are:

- Manage for change, not just persistence;
- Reconsider goals as well as strategies;
- Adopt forward-looking and climate-informed goals;
- Link adaptation actions to climate impacts; and
- Integrate climate considerations into existing planning.

Predators play a crucial role in maintaining diverse and stable ecosystems. Climate change can force predatory species to move in order to stay in their climatic comfort zones, potentially altering where other species live and how they interact—a "trophic cascade." (Top): Leopard (*Panthera pardus*), Chobe National Park, Botswana (Stephen Woodley). (Bottom): Saltwater crocodile (*Crocodylus porosus*), Bhitarkanika National Park, India (Bodhan nayek).

Chapter 3

Building capacity for climate adaptation

3.1 The capacity to address change

The institutional capacity of a conservation organization affects its ability to anticipate, prepare for, detect, and respond to changes affecting species and ecosystems (Armsworth, et al., 2015). Others have discussed practices for PAs to get and maintain the capacity to achieve conservation and development objectives (IUCN, 2015; Müller, et al., 2015). The ability of a PA organization to anticipate, prepare for, detect, and respond to climate change is *capacity for climate adaptation. Capacity development* refers to actions that increase the organization's ability to effectively enact climate adaptation. Here, we present recommendations for PA capacity development that are the most important for planning and management in the face of a changing climate. These recommendations apply regardless of the degree of change experienced by the PA or the particular threats posed to its resources and values.

Wilby and Vaughan (2011) note that organizations capable of adapting to climate change typically:

- Exhibit strong and visionary leadership;
- Set clear climate adaptation objectives;
- Develop risk and vulnerability assessments of high-priority resources and adaptation guidance for practitioners;
- Employ organizational learning and integrate climate into routine management, as well as adopt low-regret, anticipatory, adaptive management;
- Routinely work on projects with a variety of partners, using different working relationships;
- Emphasize monitoring and reporting progress; and
- Ensure effective communication.

Few PA management agencies exhibit all these traits and most agencies will benefit immediately from actions to develop their capacity.

By disrupting basic ecosystem function, climate change could undermine the capability of marine PAs to deliver increased fish numbers, both within their boundaries and as "spillover". Recent research has documented this effect in numerous marine PAs, including those shown here. (Clockwise from top left): humpback whale (*Megaptera novaeangliae*) in Abrolhos National Marine Park, Brazil (Marina C. Vinhal); reef in Wakatobi Marine National Park, Indonesia (Craig D); Soufriere Marine Management Area, St. Lucia (Mjr74).

Capacity development The process by which individuals, groups and organizations, institutions and countries develop, enhance and organise their systems, resources and knowledge; all reflected in their abilities, individually and collectively, to perform functions, solve problems and achieve objectives (OECD, 2006).

How is responding to climate change different than other issues?
Several aspects of climate change challenge traditional planning and decision making. First, the long time needed to detect many climate changes can make it difficult to get the attention of managers, who face much more immediate situations and decisions. Furthermore, climate changes will affect large areas that far exceed the jurisdiction of any single PA or PA agency. Perhaps most challenging are the uncertainties associated with predicting how these long-term and far-reaching changes will affect any particular PA. What can managers do to build an effective foundation for addressing both the anticipated and the unanticipated consequences of a changing climate? What can managers and agencies do to ensure that all PAs are working together to address climate change challenges?

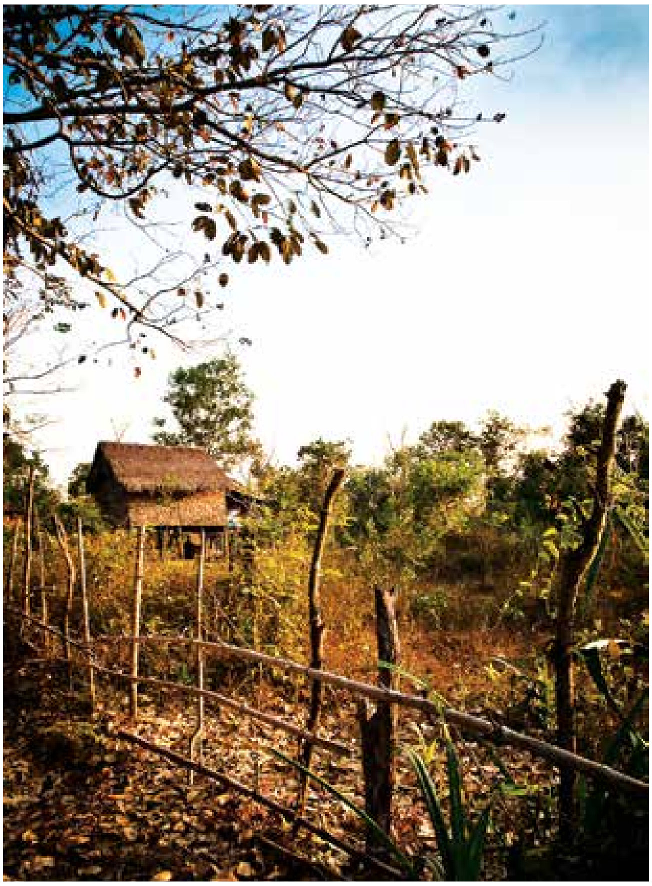
3.2 Start where you are

The best advice is to simply get started with the information and resources you already have. More than anything, building capacity to address climate change requires a commitment to initiate, follow through, connect, and communicate ideas, successes, and failures. The magnitude of management challenges posed by climate change will ultimately require PA institutions, personnel, and stewards to acquire new skills.

Raise awareness
Protected areas have an important role in raising awareness of how climate change is affecting the essential natural features and services of the planet as well as demonstrating how these systems can contribute as natural solutions to mitigation, adaptation, and hazards reduction. Many governments and NGOs are already working actively to raise awareness on climate change, but the magnitude of the change and the vast number of people and interests involved calls for engagement at a much greater scale.

Acknowledge and talk about the issues. What are the areas of particular concern for your PA and who are the people who depend on and care about it? What are the specific health effects, adaptation requirements, or changes in agricultural production that are already affecting the local community? Climate trends may be lengthening the fire season, or perpetuating a drought that influences crop yield in the area. Reach out to other managers and local communities to learn about their climate change concerns. Simply engaging in conversations with others and acknowledging the issues is an important starting point.

Access available information and knowledge
Protected area managers need information such as climate data, observations of changes over time, projections of future changes, and analyses of expected climate impacts. For most, a key obstacle to getting informed is simply finding time to sort through and read the huge volume of available information. There are an increasing number of internet-based “communities of knowledge” that encourage conversations on climate adaptation—questions posted for these forums often elicit informative responses (see the Appendix).



One of the villages in the buffer zone of Virachey National Park, Cambodia. Protected area managers will need to work closely with nearby communities to produce a coordinated response to the challenges of climate change (IUCN Photo Library / © David Tatin).

Best Practice 3.1: Assemble baseline information from local, national, and international sources
One of the greatest challenges is knowing which data and information are most relevant for understanding how climate change is affecting the specific sites and resources. If available, site-specific studies can provide results on particular resources within and around a specific PA. Regional and broader-scale analyses are valuable for establishing the context of change for PAs, and they can explain basic climatic trends, such as temperature and precipitation, and can provide insight into what is likely to be happening in the future. These guidelines refer to many kinds of information, tools, and approaches that are needed to plan and adapt to climate change, including:

- **Databases, toolkits, and synthesis reports.** There is a growing number of websites and reports that provide detailed descriptions of likely climate changes and their effects, access to tools and manuals for responding to climate change, and news of the latest research. IPCC regularly publishes extensive regional analyses of climate trends (IPCC, 2013), climate extremes (IPCC, 2012), and

Spotlighting impacts on high-profile PAs—especially World Heritage sites, such as Tadrart Acasus (Algeria)—is one way to "turn up the volume" about the perils of climate change (IUCN Photo Library / © Catherine Gras).

impacts and adaptation options (IPCC, 2014a, 2014b). Many local and regional networks also exist. Useful websites for capacity building, communication, and other climate adaptation topics are listed in the Appendix.

- **Scientists and researchers.** Universities, government scientists, NGO partners, and other research and conservation groups can help managers understand climate change and its impacts. Many ecologists and climate scientists are willing to provide briefings for managers and other decision makers. Natural and social scientists all provide insights into the many elements of climate adaptation and should be considered as resources.
- **Local stakeholders and traditional ecological knowledge.** To build more detailed information about likely changes to a particular PA, first consider what people living on the land have observed about changes in their immediate environment: seasonality, changes in populations or distribution of key species, frequency and seriousness of extreme weather events, etc. Such traditional ecological knowledge (TEK) is an important, and sometimes the only, source of local information for planners and managers (e.g. Menzies, 2006). Many researchers trained in the Western science tradition are now also usefully incorporating elements of TEK into their studies. TEK has often been undervalued or taken for granted, but it can be a valuable and unique resource for PA managers and planners, as well as extremely cost-effective (Danielsen, et al., 2014). It is always a good idea to seek multiple lines of evidence when drawing conclusions or attributing observed trends or events to climate change. Even while recognizing the importance of TEK, scientists need to be very aware of ethical issues and guidelines for engaging Indigenous communities and using their information (CTKW, 2014).

3.3 Engage partners and communities

Climate change is a shared problem that affects both ecological systems and the people that rely on them. Implementation of effective adaptation cannot be undertaken alone. The scope of the problem and solutions required are best addressed by including a broad range of people, sectors, and allies. Engagement with scientists, local communities, and others who care about and depend on PAs can lead to the development of innovative ideas and opportunities. Leveraging current partnerships can result in broader networks and connections, as well as new information and perspectives (see Case Study 3.1). Whether reaching out to the public, local stakeholders and communities, other decision-makers, or academic and NGO partners, it is important to think creatively about who should be at the table and how useful partnerships and perspectives can be cultivated.

Best Practice 3.2: Create ongoing opportunities for knowledge exchange

Effective decision making in a perpetually changing climate requires attention to processes and interactions with people, not just data and products (NRC, 2009; Moser and Ekstrom, 2010; Kingston, et al., 2015; Reed, at al., 2014). Perhaps the most important practice a PA manager can develop is to help establish and contribute to information networks that facilitate ongoing knowledge exchange between scientists, managers, community members, and other stakeholders. These are opportunities for learning and respectful relationships that provide a setting to discuss issues, questions, and approaches for jointly solving problems. Knowledge exchange and shared learning between scientists and managers is essential to ensure studies are relevant and useful.

Case Study 3.1

Community engagement for conservation in Gombe Stream National Park, Tanzania

The Jane Goodall Institute (JGI), with financial support from the Royal Norwegian Embassy and in partnership with the United Nations and technology firms, has teamed up with Gombe Stream National Park (Tanzania) and surrounding communities to address the local effects of climate change. In conjunction with REDD, ESRI, DigitalGlobe, and Google Earth Outreach, JGI is employing technology that enables park staff and community members to take a leadership role in gathering forest data in the area surrounding the park. Using high-resolution satellite images and GIS technology, specially trained community forest monitors map the forest, chimpanzee habitat, and human land use. Because of its close working relationship with communities on the ground, JGI is uniquely positioned to share the information it gathers with local communities to engage them as partners in their conservation mission.

In 1994, Dr. Goodall established what has become one of the most comprehensive conservation programs in Africa, TACARE (pronounced "take care"), which integrates traditional conservation approaches with a broad range of community development projects. TACARE approached the challenges presented by climate change by first helping local communities protect and restore the forest surrounding the park, most of which is communal and government land. The forest mitigation programs around Gombe Stream are gaining international recognition for directly linking climate change impacts to a wider climate adaptation framework centred on the principles of ecosystem-based management and community involvement. JGI and Gombe Stream National Park's community-based approach has established a valuable model for other practitioners working on long-term conservation programs.

Adult female eastern chimpanzee (*Pan troglodytes schweinfurthii*) with offspring, Gombe Stream National Park, Tanzania (Ikiwaner).

Protected areas are ideal locations to communicate about climate change and how nature and cultures can come together to find solutions for a better future. People care about and are connected to their PAs, both physically and emotionally. This offers the PA manager an extraordinary position for telling stories of the land that inform and educate visitors, not only about the changes that are occurring, but the importance of conservation for adapting to change and the actions that can be taken to build a more sustainable future.

3.4 Communicate and educate: Turn up the volume

Effective communication and education are at the heart of a strong capacity for climate change response. To be effective, materials must be targeted according to the intended audience. The WCPA Strategic Framework for Capacity Development (IUCN, 2015) identifies three priority focal groups.

1. **Protected area institutions and personnel.** These are *internal* audiences that include managers, their employees, and in some cases outside contractors.
2. **Landscape and seascape stewards.** These are *external* audiences closely linked to and often sharing goals with PAs, including NGOs, local communities, and other stakeholders and partners.
3. **Influencers.** These are *external* audiences whose policies, decisions, attitudes, political will, and activities indirectly influence capacity development and the management of PAs.

Enhancing communication capacity involves both *internal communication* to ensure all levels of management are

Sinkholes with fluctuating water levels are a normal feature of the region around Lake Cerknica (Inner Carnelia Regional Park, Slovenia), but under climate change they are increasingly drying out completely. If that happens, the fish living in them must be moved to other ponds (IUCN Photo Library / © Luka Dakskobler).

familiar with the relevant science and available options, and *external communication* to share pertinent information among stakeholders. Internal communications include interactions among various personnel and divisions with different responsibilities within a PA, as well as targeted training for specific disciplines. External communications should be designed to both engage the general public in developing necessary adaptation alternatives in the present, and to educate specific external audiences, such as young people, who will inherit the responsibility of long-term management in the future. The best engagement strategies use a wide variety of communication techniques and media, and experiment with new outlets and technologies to effectively communicate in ways that reach a range of cultures (Case Study 3.2; Moser and Dilling, 2006; Kahan, 2010; Kahan, et al., 2012).

Internal communication with staff and employees

Climate change adaptation will be most effective when there is a common understanding of the issues and a culture that encourages discussion of potential responses and solutions. Cultivating an internal culture of dialogue and learning within the ranks of PA personnel primes managers for important external dialogue with a broad array of stakeholders.

Best Practice 3.3: Increase climate literacy within the professional workforce

Because climate change will eventually affect all aspects of PA management, everyone involved should know what climate change is, what changes are most likely (in general terms), and how these changes may affect his or her area of responsibility. Management actions are most likely to be effective and enjoy broad support when personnel are well versed in the realities of climate change and are invited to discuss alternatives and options. All levels of management—and especially those in the field—will benefit from knowing what they should be looking for in terms of ecological changes and which types of impacts warrant closer monitoring. Climate change should be incorporated into existing training

Case Study 3.2

Embracing the media as a partner for climate change communications in Southeast Asia

In its focus on building coastal resilience to climate change impacts in Thailand, Cambodia, and Viet Nam, IUCN works closely with the media, raising public awareness on the issues of climate change. In Thailand, IUCN established a partnership with Thai Public Broadcasting Service (Thai PBS), the first and only public broadcaster in Thailand, operating since 2008.

The partnership involves capacity building for broadcasters, where IUCN provides training to Thai PBS reporters, editors, producers, media researchers, and trainers for them to understand the issues through interaction with academics, villagers, and authorities as well as by seeing the real situation with their own eyes. In addition, IUCN promotes citizen journalism opportunities offered by Thai PBS. This is a crucial tool empowering stakeholders, especially local communities, to tell their own stories and present them in a 3-minute video format. The videos are of broadcasting standard and get aired on national TV.

Communication on climate change is being done through other formats as well, such as animations, news reports, environment programs, and seminars. Currently, IUCN and Thai PBS are developing a 13-episode TV show featuring impacts of climate change on coastal communities in Thailand, Cambodia, and Viet Nam, and the way each community adapts to live in a changing climate.

Partnerships like this are an immense help in raising public awareness on climate change. In addition, stories aired on TV indirectly bring the issues to the attention of national policy makers.

because it affects all aspects of PA management, including resource protection, fire management, land acquisition, community engagement, interpretation, and recreation.

Site-based and online training courses on climate adaptation for conservation are now available in a variety of languages. These courses can help PA personnel develop additional skills in ecosystem restoration, vulnerability assessment, connectivity conservation, monitoring for change, climate change interpretation, and other important skills (see Case Study 3.3). These are topics presented throughout the remainder of the guide and examples of training resources are in the Appendix at the end of these guidelines.

Best Practice 3.4: Communicate nature-based solutions to climate change

Implementing an effective external communication effort can forge and maintain crucial local relationships, build capacity to engage larger audiences, and help garner public support for adaptation strategies and conservation agendas. While science literacy alone does not guarantee public action and support (e.g. Corner, 2012; Kahan, et al., 2012), outreach

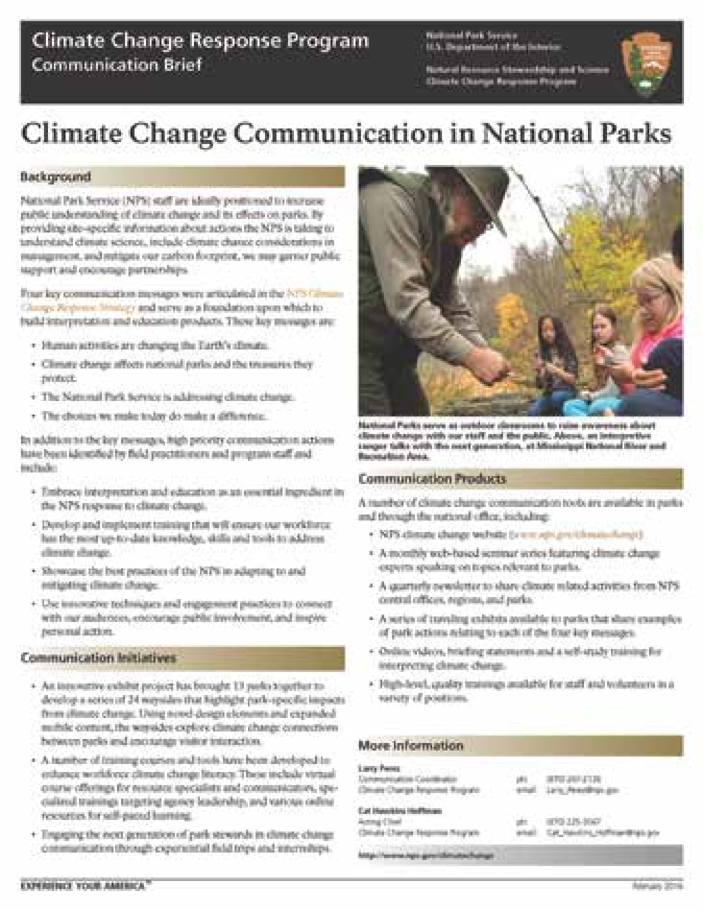
Case Study 3.3

Raising the bar on climate competency in the US national parks

Interpretive rangers in the NPS have long been required to achieve proficiency in a wide array of competencies—the unique knowledge, skills, and abilities that allow for effective communication and interpretation of park resources and values. In 2010, the NPS Climate Change Response Strategy identified the need to cultivate a better understanding of climate change among all staff and help them actively engage the public on related topics through interpretive programs and products.

In response, training leads for the NPS began developing a new training module on climate change and, for the first time, a specific science competency that included several critical resource issues being affected by climate change. The competency served as a vehicle to advance new methods of engagement—principally visitor-centred interpretation. A panel of subject-matter experts collaborated on a comprehensive pilot curriculum that included sessions on science literacy, facilitated dialogue, and civic engagement.

Twenty participants from around the USA attended the pilot course in May 2011. Since then, hundreds of individuals have attended in person or through online training. Some graduates of the course are taking the curriculum back to their parks and offering the training locally to include many seasonal interpreters and communication specialists. In addition to the regular annual course, instructors also have offered local sessions at individual parks and to partner agencies. The program has proven remarkably successful at facilitating the flow of climate change information and interpretive best practices to all levels of interpretation—ultimately benefiting park audiences and helping build adaptive capacity within the NPS management and their staffs.



Climate Change Response Program
Communication Brief

Climate Change Communication in National Parks

Background

Communication Initiatives

Communication Products

More Information

EXPERIENCE YOUR AMERICA™

The US National Park Service has published a series of briefs on various aspects of climate change, including this one aimed at intrepreters in the field.

The four-module, on-line course on interpreting climate change is now available to PAs worldwide at https://www.nps.gov/subjects/climatechange/toolkit-training.htm. This material will be included as part of a broader, national strategy for climate change interpretation and education (see: https://www.nps.gov/subjects/climatechange/nccies.htm).

efforts can play a critical role in fostering an attitude of environmental stewardship, imparting the present and future realities of climate change, and illuminating the urgent need for management actions.

Building capacity for adaptation also means having personnel look beyond traditional resource management fields to consider insights from a wider spectrum of disciplines. The social sciences have found insights into public and community values related to climate change, and identified techniques for more meaningful and productive communication, such as facilitated dialogue and public deliberation (e.g. http://cpd.colostate.edu/about-us/what-is-public-deliberation/; see Moser and Ekstrom (2010) for barriers to climate change adaptation; also see "climate change communication" in the Appendix). Facilitating the flow of climate adaptation information across the broadest spectrum of audiences will require a mixed communication strategy that uses a variety of tools and techniques. Box 3.1 offers some ideas and techniques to help PA managers that work with and engage local communities and stakeholders.

Focus on solutions

Climate change is a serious issue that can leave many people feeling overwhelmed, depressed, and powerless due to the complexity and scope of the issues. Whenever possible, messages about climate change should communicate approaches, potential solutions, and individual actions that empower and motivate people. It is especially important when communicating about mitigation and adaptation to present visions of the future that have desired outcomes and to identify pathways and actions people can take to make a difference. Audiences will identify most strongly with actions that are specific and can be integrated into their daily lives. Adaptation measures that focus on specific behaviours rather than overarching goals are more easily implemented. For example, asking an individual or community to reduce agricultural runoff into streams is too general. A better approach is to ask people to reduce fertilizer use, maintain vegetation along streams, and encourage practices that minimize bare ground and soil erosion.

Consider using a variety of approaches in communicating with different audiences. Storytelling and metaphors can be excellent ways to reflect, reference, and access positive motivations and help people feel that they can overcome the challenges presented by climate change. Empowering stories show that people have overcome obstacles before and that through innovation and perseverance, communities can work together to meet the challenges of climate change as well.

Temperate coniferous forests are an important holder of carbon stocks in these regions. (Clockwise from top): Nahuelbuta National Park, Chile (Scott Zona); Tarvagatai Nuruu National Park, Mongolia (Mongolian Ministry of Environment, Green Development, and Tourism); Manali Wildlife Sanctuary, Himachal Pradesh, India (Paul Evans).

Communicating uncertainty
Everyone routinely works with imperfect knowledge, but the inability to predict the future under climate change has frequently been used as an excuse for inaction. Too much focus on uncertainty can obscure the important messages about trends and impacts we are sure about.

When communicating about climate change, a good strategy is to start with what you know, not what you don't. On many aspects of climate change—such as increasing temperatures and whether human activities are the cause of global warming—the science is settled and we can state that clearly. For other issues, such as forecasts of short-term weather events or how certain species will respond, the science is less certain. Stating what is known in positive terms helps focus on what can be done; generalities and negative statements often create apathy. Another useful technique is to shift from "uncertainty" to "risk". Framing climate change risk makes it easier for people to weigh up the costs and benefits of inaction, rather than getting stuck in the perception that knowledge is still imperfect. These issues are explored more fully in Chapter 4.

The most important question for many climate impacts is "when", not "if". Hazards and risks are easier to ignore by focusing on "if" they will happen within a certain time frame. People are motivated to take action when they know an event will occur, even when they don't know when it will happen (Ballard and Lewandowsky, 2015). For many audiences, uncertainty in climate projections is best expressed as a range of possibilities—e.g. "a range of possible temperature increases", rather than that there is "uncertainty around average results" or as a statistical probability.

3.5 Plan and act: Become a learning organization

Climate change—often in combination with other stressors—will create new challenges that require creative solutions.

Box 3.1

Techniques for effective climate change communication

Climate change is a complex topic with which to actively engage audiences. Here we outline some useful techniques and approaches PAs can employ for engaging with outside audiences through partnerships and programmes, strategic messaging, and making climate change local, relevant, and urgent.

Highlight tangible issues and values
Climate change is often presented as an abstract or future concern that doesn't affect people in a direct way. Messages about climate adaptation will be most effective when they focus on the concerns and values that are visible and relevant. Climate change can be an issue that brings home the relevance of PAs to the humans who depend on them, increasing their awareness of climate risks and motivation to act. Climate messages can draw on connections to local plants, animals, physical elements, cultures, communities, and extreme weather events. The more immediate, concrete, and personal the stories are, the more compelling they will be to the community. For one group it may be water quality or availability, for another it could be the health of its children, and for others it may be opportunities to experience nature or view wildlife. Framing communications about climate change in terms of community concerns is crucial to building support for management actions, and facilitating changes in behaviour.


An intern with the US National Park Service Young Leaders in Climate Change Program collecting snow patch melt water samples to test for water chemistry at Gates of the Arctic National Park and Preserve, Alaska, USA (NPS).

Engage young people
Engaging youth in communication about climate change and PA conservation helps to build the next generation of environmental stewards. Through partnerships with science and educational organizations, PAs can incorporate young people's knowledge, skills, enthusiasm, and perspectives into management solutions, while helping students build connections to the places they are learning about.

An effective way to engage students is to involve them in research, monitoring, or interpretation programs. This builds a deeper connection between the college or university and the PA and helps to ensure that stewardship and conservation are a valued part of the educational experience. Such exchanges have the potential to create transformative experiences for youth as well as PA staff. Connecting specific climate change impacts to the ability of young people to contribute and take action in their own lives boosts the capacity of PAs to adapt to the future, creates a sense of empowerment, and fosters future leaders.

Organizations that promote learning will be more capable of dealing with novel and rapidly changing situations than those that rely on doing “business as usual”. Learning organizations allow people to continually expand their capacity to create the results they are aiming for, while working together for a better future (Senge, 2006). The rationale for such organizations is that in situations of rapid change, only those that are flexible and adaptive will excel. Building a learning organization involves leadership that is credible and open-minded.

For most PAs, climate change is a complex issue with many variables, and there may be no relevant history or previous experience to guide decisions. Furthermore, adaptation strategies may require prioritizing one important value over another. Alternative courses of action can involve significant trade-offs while presenting no definitive “right” answer. Thus, when dealing with the problem of climate change, PA managers will need to recognize that there is a range of thoughts and opinions on future actions, and actively work to maintain flexibility in decision making.

Best Practice 3.5: Commit to flexible and iterative management practices

Managing for climate change often involves responding to rapidly changing conditions with tools and resources that are still being developed. Being open and transparent about decisions on climate adaptation contributes to a culture of continual learning. Promoting a culture of learning is a key aspect of capacity development; this includes celebrating and replicating successes, and learning from failures. Transparency in evaluating and selecting adaptation options is part of “showing your work”—a message from Chapter 2. Flexibility is important to managing in the face of an increasingly variable and uncertain climatic future.

Two key components of flexible management are: (1) a framework that allows and encourages responsiveness and reassessment; and, even more importantly, (2) a mindset among managers, other PA personnel, and communities that recognizes and embraces that framework.

Building adaptive capacity via flexible management is basic good management for PAs but it acquires a new urgency due to rapid climate change. Adaptive management is frequently promoted as a framework for flexible management. But the term “adaptive management” is used in many contexts; here, we informally refer to it as a flexible management approach that values learning, does not penalize mistakes made in good faith, and incorporates a formal plan for responding to new information. Rigorous application of adaptive management rarely has been achieved in conservation (Fischman and Ruhl, 2016). Budget and staff constraints are barriers to rigorous adaptive management, and frequently the long-term nature of adaptive management doesn’t align well with staff turn-over and the basic responsibilities of land and water management organizations (NRC, 2009).

A more relevant approach to flexible decision making for many PAs is “deliberation with analysis” (NRC, 2008; NRC, 2009). This recognizes that many participants working together over time establish and implement management goals. As new information is received, deliberation and analysis are applied in a structured way to revisit objectives and choices.

Regardless of method, the key outcomes of flexible management are a willingness to act under uncertainty, an embrace of science and other forms of knowledge, and a willingness to trade off short-term gain for longer-term understanding and movement towards better management.

Community consultations (here, at Saadani National Park, Tanzania) are a prime opportunity to exchange knowledge, resulting in increased capacity for climate adaptation among all parties (IUCN Photo Library / © Marie Fischborn).

Flexibility can be incorporated into standard management planning. Along with specific conservation targets to be monitored, climate-smart PA planning should include monitoring of key climate-related variables, including predetermined “triggers” for action. If, for example, managers of a marine PA traditionally measured indicators such as the number of turtle nesting sites and the extent of mangroves, they might now also include mean sea level and changes in frequency of storms, identifying thresholds for each. Evidence of sea-level change might, for instance, trigger relocating young mangrove trees and/or acquiring higher land for the reserve as the coastline erodes. These climate variables would sit alongside more conventional conservation targets in guiding actions in the management plan. The plan should be re-examined periodically throughout its life to ensure its overall direction and objectives are up-to-date in light of changing environmental conditions.

3.6 Summary

Climate change adaptation is relatively new, and it is crucial that managers and practitioners communicate and share experiences, best practices, and lessons learned. Protected areas can build capacity for future leaders through new and existing networks and by training staff and reaching out to youth and young professionals. Equipping PA managers to respond to the challenges of climate change requires that they plan, manage and act in ways that differ from those of the past. PAs will build capacity to respond to climate change by:

- Starting now and working with what you have;
- Engaging partners and knowledge holders, both professional and local;
- Supporting staff development;
- Committing to ongoing knowledge development and exchange;
- Incorporating forward-looking planning;
- Being flexible and willing to alter plans;
- Thinking at broader scales; and
- Being a “learning organization”.

Chapter 4

Assessing climate change vulnerability and risk

Understanding how species, ecosystems, and ecological processes are already affected by climate change and how they will likely fare under future conditions is essential for developing adaptation strategies (Figure 4.1). Protected areas will be exposed to some combination of increased temperatures, more intense storms, altered hydrological cycles, and other climate effects that will impact ecological and cultural values, routine operations, and visitors. Because climate affects virtually all species and the ecological and evolutionary processes that sustain them, most PA managers will need to participate in climate change assessments (Glick, et al., 2011). Most assessments do not have to be done for each site, and many species- and ecosystem-based assessments can be done at regional scales. This chapter explains what a climate change vulnerability assessment (VA) is, presents best practices for designing and structuring an assessment to meet the needs of your PA, and gives guidance for getting started.

Almost all PA-based VAs are conducted as a collaboration between managers, subject-matter experts, and other stakeholders. Managers often need to identify scientists with the technical and social skills required to lead an assessment that meets a PA's needs. Investigators qualified to lead VAs are usually associated with a university, NGO, or research institution. This chapter provides background information needed to be an effective partner and to make informed decisions that *will substantially* determine the usefulness of a VA. This background includes understanding when or why to use (or not use) a particular method or technique.

4.1 What is a vulnerability assessment and why is it important?

Vulnerability to climate change is the extent to which a system is susceptible to harm from direct and indirect effects of climate change, including variability and extremes. Vulnerability assessments can be conducted for social, cultural, or natural systems. Here we focus primarily on ecological systems, which include species, ecosystems, and ecological processes.

Coastal areas are among the most vulnerable to climate change impacts: (Left): Tidewater glaciers at Glacier Bay National Park (Alaska, USA) are receding, their meltwater adding to sea level rise (NPS). (Top right): A storm off the coast of Diawling National Park, Mauritania. Storm intensity is expected to heighten as the climate warms (© IUCN / Ger Bergkamp). (Lower right): Community-built sea wall, Manus Island, Papua New Guinea. Some communities in Melanesia are blowing up coral reefs to create sea walls to protect themselves against sea level rise (James Watson).

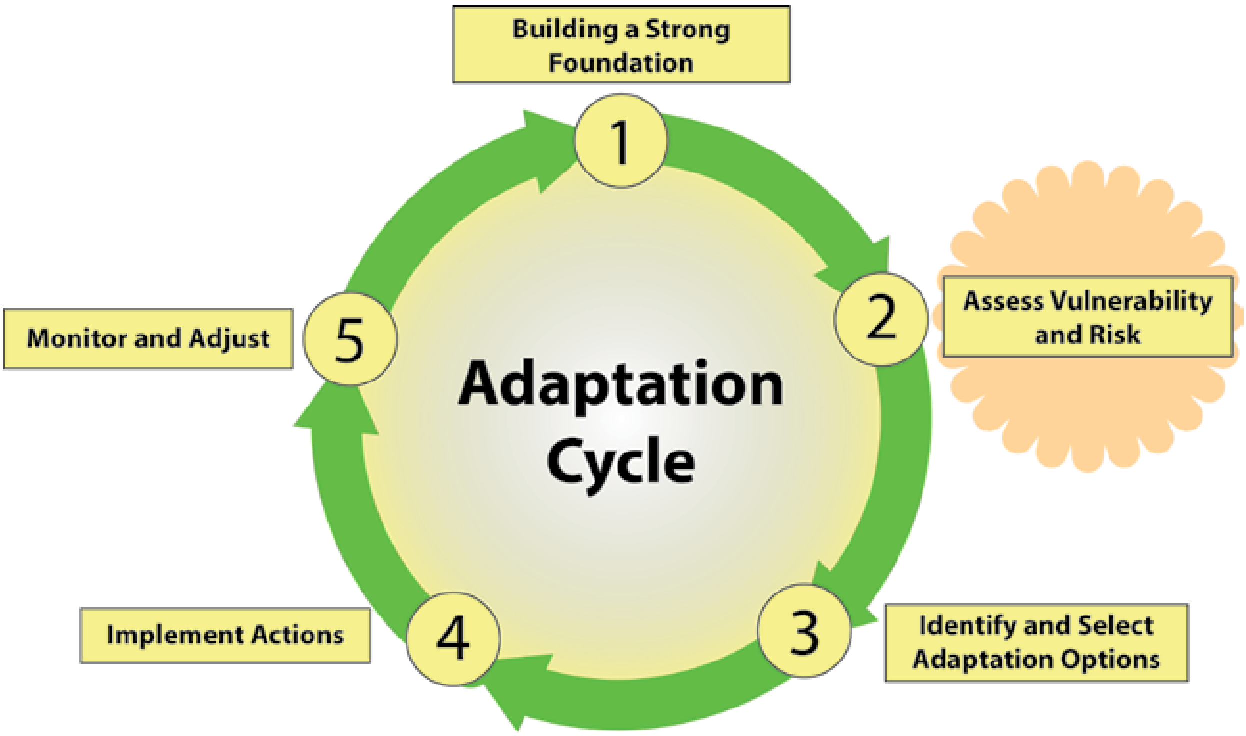


Figure 4.1. Step 2 in the generalized adaptation cycle is to assess vulnerability and risk in order to evaluate how PA values will be affected by climate change and to inform the selection of appropriate adaptation actions. Generalized cycle adapted from EEA, 2015.

Ecological VAs aim to understand:

- *Which* species, systems, or other conservation targets are most vulnerable to climate change;
- *Why* they are vulnerable;
- *Where* they are vulnerable within a given area; and
- *When* they may be affected.

Vulnerability has three underlying components: exposure, sensitivity, and adaptive capacity (Box 4.1). Impact from climate change is measured as a combination of how exposed the feature (e.g. species, ecosystem, site) is to climate change and how sensitive it is to that exposure. Vulnerability is then assessed based on potential impact (estimated from exposure and sensitivity) combined with the ability of a system to adjust to the impact caused by climate change—its adaptive capacity. By understanding these components of vulnerability, a practitioner can estimate risk, which is the combination of the likelihood that a future event actually happens and the magnitude of the impact from that event.

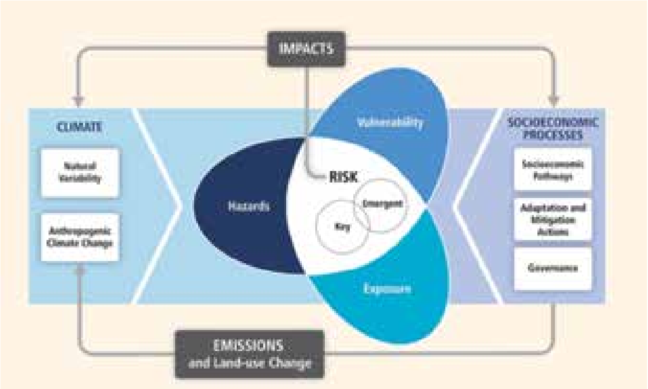


Figure 4.2. Risk of climate-related impacts results from the interaction of hazards (including events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socio-economic processes, including adaptation and mitigation (right), are drivers of hazards, exposure, and vulnerability (IPCC, 2014a).

Using vulnerability assessments to evaluate risk
Decisions on climate adaptation must rely on understanding climate-related risks. Risk assessments identify resources and values of concern and hazards that can affect them. Risk is estimated as the likelihood (probability) that a hazard will occur and the seriousness of the impact (consequence). Key risks are those with potentially severe adverse consequences for humans and social–ecological systems. Emergent risks arise from indirect or long-distance impacts and can include unintended consequences of human responses to climate change. Vulnerability assessments provide important information that helps planners identify the kinds of interventions that can effectively reduce risks. Figure 4.2 illustrates the relationships between factors that contribute to risk and vulnerability.

Vulnerability assessments that help assess risk should be initiated early in adaptation planning (Figure 4.1) so results can be used to identify and evaluate adaptation activities. Results from VAs are often presented as a categorized list or ranking of the relative vulnerability of the conservation targets (Case Study 4.1). These types of rankings can be important because they help identify key vulnerabilities, and this information can then inform priorities for action. VAs also identify why the

Box 4.1

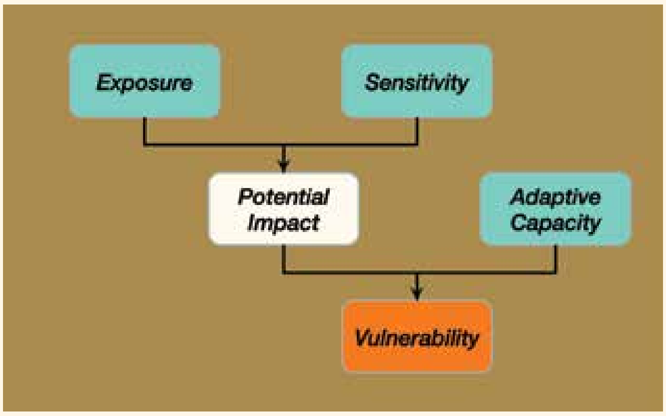
Components of climate change vulnerability

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and the variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Exposure is the degree to which a system is exposed to significant climate variations. Exposure is usually measured by factors external to the target, such as the rate and magnitude of changes in temperature, precipitation, sea level rise, flood frequency, and other physical factors. Evaluations of exposure are almost always based on projections from climate models.

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise). Sensitivity depends on a variety of factors, including ecophysiology, life history, and microhabitat preferences. These can be assessed by empirical, observational, and modelling studies.

Adaptive capacity refers to the ability of a system to adjust to climate change (including climate variability and extremes), moderate potential damages, take advantage of opportunities, or cope with the consequences. Traits that confer adaptive capacity may be intrinsic or extrinsic to the conservation target, and they include ability to move to more suitable local microhabitats or to migrate to more suitable regions, plasticity in phenology (the ability to adjust the timing of seasonal events such as flowering, migration, or hibernation), genetic and functional diversity, and plasticity in ecological processes (e.g. sediment-related accretion in marshes). Like sensitivity, these can be assessed by empirical,observational, and modelling studies.



Three components of vulnerability, illustrating that the potential impact is determined by exposure and sensitivity, and that overall vulnerability may be moderated by adaptive capacity.

conservation target is vulnerable. This information is used to identify which adaptation actions are appropriate (or not), and to design strategies to address vulnerabilities and risks.

4.2 Types of vulnerability assessment

All VAs apply to a specific area, and some produce maps with the locations of ecosystems, regions, or parts of a species range that are more or less vulnerable to current and future climate change (e.g. Watson, et al., 2013; Ponce-Reyes, et al., 2012; Case Study 4.1).

Vulnerability assessments have different scopes and can be conducted on a wide variety of scales. Some are largely qualitative and may be initiated by holding a multi-day workshop where conservation targets are evaluated by a knowledgeable team using established criteria (Figure 4.3). Other VAs are highly quantitative and rely on complex models of climate, vegetation, and species population dynamics. The design of an assessment needs to reflect the purpose, available data, and information needs and capacity of the audience.

The specific resource targets of a VA can be species, vegetation communities, a site, an entire PA, or any combination of features that are of conservation interest. Johnson (2014) summarized a large number of VAs that cover the full range of conservation targets, methods, and levels of detail.

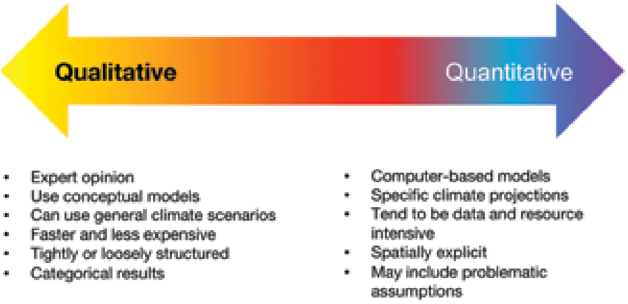


Figure 4.3. The spectrum of climate vulnerability assessments and characteristics typically associated with more qualitative or quantitative approaches.

Regardless of the approach or level of detail, most VAs include:

- Evaluation of exposure, sensitivity, and adaptive capacity of the species, ecosystem, or ecological process. Sensitivity and adaptive capacity are sometimes evaluated together.
- Analyses of observed (historical) and projected (future) climate, land use, demography, and other important climate and non-climate factors.
- Evaluation of changes that have already occurred in the species, ecosystem, or ecological process of interest. Where possible, changes are determined to be caused by either climate or non-climate drivers.
- An objective scoring method to evaluate the relative vulnerabilities of species, areas, or processes of interest.
- Estimation of uncertainties of projected changes in both climate and non-climate drivers of change as well as the species or ecosystem response. Uncertainty can be estimated using expert knowledge or statistical variation.
- An analysis of spatial information available for the potentially vulnerable areas, including an evaluation of potential climate refugia (i.e. areas of low exposure to climate change).
- Narratives that describe key information sources, relevant ecological and geographical contexts, and justifications for rankings.

4.3 Designing an assessment

Best Practice 4.1: Design the vulnerability assessment to match the protected area and conservation needs

Early in the design stage, each assessment team must make a series of decisions that will strongly affect the cost and complexity of the process, and the way the results can be used. When designing a VA, it is important to design the assessment so that it fits the needs and capabilities of the PA and assessment team. Key decisions are the geographical area to evaluate, level of detail of the study, the period over which to evaluate change, the number and specific types of conservation targets to be assessed (e.g. species, ecosystem type, or area), and the methods and data to be used in the assessment. This section introduces topics that are described elsewhere in much more detail (Glick, et al., 2011).

Consider scale: geography and period of assessment

Vulnerability assessments can be conducted at any scale from local to global. Climate change requires thinking and planning at landscape and broader scales, even when management decisions are focused on local or site-based goals. The need for broader thinking is especially true when important conservation targets are migratory or widely ranging species, or when range shifts in response to climate change may have important consequences (such as a species moving into or outside of an existing PA boundary).

Savanna elephant (*Loxodonta africana*), Tanzania. Wetlands are important for many savanna species and a warming climate is affecting both around the world (Liana Joseph).

Case Study 4.1

Mapping causes of climate vulnerability for Australia's threatened species

Most climate VAs have focused on one or a group of species, or on a specific regions or site such as a PA. Now that species-based assessment methods are widely used, it is possible to evaluate the causes of vulnerability of large groups of species, evaluate the spatial distribution of the causes of vulnerability (Watson, et al., 2014; Lee, et al., 2015), and the kinds of on-the-ground actions that may be needed.

Lee, et al. (2015) used this approach to conduct species-level climate VAs for 213 threatened species in Australia, including birds, mammals, amphibians, reptiles, and plants. Vulnerability of species was estimated using the NatureServe Climate Change Vulnerability Index (CCVI; Young, et al., 2011; http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index). The CCVI estimates vulnerability using a set of 18 factors that include climate exposure (e.g. temperature, moisture, sea level rise), species traits that reflect sensitivity to the environment (e.g. reliance on cool temperatures), the behavioural ability of the species to respond (e.g. dispersal ability, reliance on specific habitats), and natural and anthropogenic barriers to movement. The CCVI did not include geographic range or anthropogenic threats that may contribute to climate vulnerability.

Results of the CCVI showed that vulnerability of species varied from those at very high risk (e.g. mountain pygmy possum) to others that are expected to benefit from climate changes (e.g. western quoll). Species with a vulnerability index of 4.0 or above were considered moderately to highly vulnerable, and 96 of 213 species (42%) were in this category.

English name	Scientific name	Vulnerability Index
Mountain pygmy possum	*Burramys parvus*	11.3
Chiddarcooping myriophyllum	*Myriophyllum lapidicola*	11.0
Bog willow-herb	*Epilobium brunnescens beaugleholei*	10.9
Anemone buttercup	*Ranunculus anemoneus*	10.9
Euphrasia bowdeniae	*Euphrasia bowdeniae*	10.7
…	…	…
Regent honeyeater	*Xanthomyza phrygia*	–1.9
Superb parrot	*Polytelis swainsonii*	–2.1
Slender-billed thornbill	*Acanthiza iredalei iredalei*	–2.1
Red-lored whistler	*Pachycephala rufogularis*	–2.8
Western quoll	*Dasyurus geoffroii*	–5.0

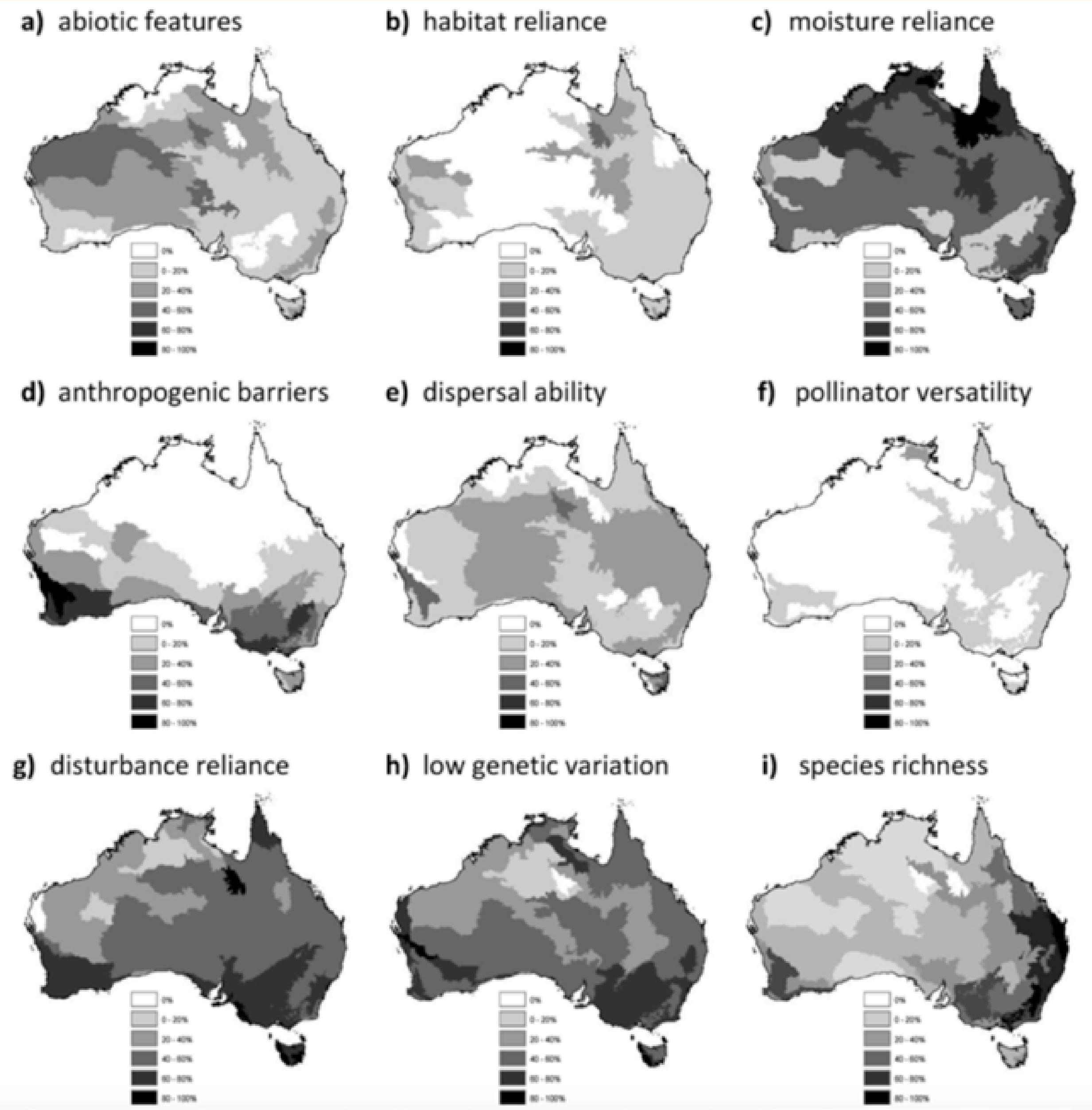
Climate change vulnerability index for the five most and least vulnerable of 213 threatened species (modified from Lee, et al., 2015).

Overall, disturbance regime, reliance on a particular moisture regime or habitat, and genetic variation were most important factors in determining vulnerability (Lee, et al., 2015). The importance of vulnerability factors varied by taxonomic group and geographically, as shown in the figure.

Two messages emerge: Vulnerability to climate varies enormously, even among species already identified as threatened. And among those species vulnerable to climate changes, there are very large differences and discontinuities in the distribution of factors that account for vulnerability. Results from species-level assessment (i.e. index scores) and the geography of the causes of vulnerability can inform conservation plans for species and for management of biodiversity at site to regional scales.

(Left to right): Mountain pygmy possum, Chiddarcooping myriophyllum, bog willow-herb, anemone buttercup, *Euphrasia bowdeniae*.

Case Study 4.1 (continued)



The proportion of species affected by the eight most common causes of climate vulnerability (a–h), and the distribution of threatened species (i). Darker shades represent a greater percentage of threatened species (from Lee, et al., 2015).

For assessments focused on a particular PA, a first consideration is to identify the area required to support existing biodiversity and key ecological functions (Hansen, et al., 2011). For example, if a particular species is the target of the VA, processes that occur outside the PA (e.g. seasonal migrations, or natural disturbances such as fire, floods, and human activities) may affect its population within the PA boundaries, so a larger area needs to be considered. If no guidance is available, a good starting point for larger PAs is to consider an area that extends 25 km around the protected area (Hansen, et al., 2011). This 25-km buffer accounts for natural disturbances that flow into PAs (e.g. fire, runoff) and the most impactful land uses around a park. The "best" buffer size will vary with the size, shape, and geographical context of a specific PA, but in all cases it is important to consider the importance of the surrounding area.

The period of an assessment must match time scales of management plans and adaptation goals. However, it is useful to consider the longer view as well. Most planning horizons for management decisions are on the order of 5 to 20 years, with the latter considered a long-term plan. However, because climate change is continuous, longer time frames are important. A good approach is to evaluate vulnerability for multiple periods. A VA that considers a period 10–20 years in the future as well as mid-century (2050–2060) will support a broad range of decisions. Using both time frames can inform on-the-ground management decisions, and identify conservation goals that may be practical in the near term, but that are not achievable under future climate conditions.

Developing scenarios

Scenarios are an increasingly important tool for climate adaptation because they help planning when the future is both unknown and likely to be very different than the present. Scenarios are plausible characterizations of the future (Box 4.2). They differ from forecasts and predictions because they are not associated with probabilities, but they are based on scientific evidence and must be plausible. Scenarios are particularly useful in climate adaptation to identify the range of future conditions to be considered by vulnerability assessments, and to identify and evaluate potential adaption actions.

Once the period of interest is determined, scenarios of future change can be developed for the assessment (Rowland, et al., 2014). Time frames and methods for scenario development vary, but the time frame should be compatible with the VA. At this stage in the adaptation process, the main inputs from scenarios will likely be climate variables, although other factors included in the scenarios (e.g. fire, floods) can certainly contribute to evaluating vulnerability. Box 4.3 describes approaches that can be used to create plausible climate scenarios, and Chapter 5 describes scenarios and their uses in more detail.

Common approaches to vulnerability assessment

Ecological systems are organized at various levels, each of which has unique properties and vulnerabilities to climate change (Table 4.1). Assessments can vary widely in scales of space and time, and they can focus on different levels of ecological organization. In this section, we describe only a few common approaches.

Species-based approaches

Species are of direct interest both as a key level of biodiversity and because of their value to humans. Species respond to climate change based on their tolerances to environmental conditions. Thus, species represent the fundamental level of organization to climate change response. An increasing number of extensive data sets are available for quantifying species abundance and distributions and how these may interact with climate change (Lawler, et al., 2010; Foden, et al., 2013).

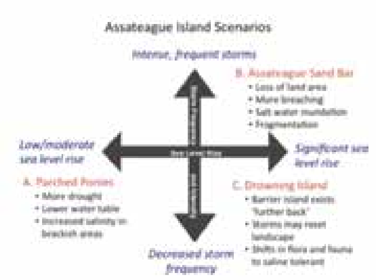
Species-level assessments typically focus on vertebrates and vascular plants, with lesser-known taxonomic groups being considered mostly through habitat and ecosystem assessments. The IUCN Species Survival Commission's Climate Change Specialist Group has developed best practice guidelines on species VA (Foden and Young, 2016). Here, we summarize a few common approaches that PA managers will likely encounter.

The first approach is to develop a *species distribution model* based on statistical relationships between the current distribution of a species and important habitat characteristics. These characteristics may include seasonal or annual precipitation, average minimum or maximum annual or seasonal temperature, climate extremes, or other

Box 4.2

Scenarios for climate adaptation

Scenarios are descriptions of possible events or actions in the future. Scenarios to explore climate change span a range from qualitative narratives to quantitative model outcomes. Qualitative methods to construct scenarios tend to be based on participatory exercises with diverse expert groups, while quantitative methods use climate and ecosystem models that incorporate known factors and processes with associated uncertainties. The IPCC CO2 emissions scenarios are quantitative, based on model forecasts of factors like fossil fuel use and economic development. Processes for creating climate change scenarios are highly structured regardless of the methodology.



Both quantitative and qualitative information were used to construct climate change scenarios for Assateague Island National Seashore, a barrier island on the northeast coast of North America Rather than being presented as a range of conditions, scenarios in this case are depicted in quadrants based on the intersection of two axes, the ends of which represent very different drivers (i.e. sea-level rise and the frequency and intensity of storms). Use of a four-quadrant diagram is a common qualitative method used to construct scenarios for participatory scenario planning process (see Chapter 5).

A similar participatory scenario planning process, also using a two-axis, four-quadrant approach, was employed to engage stakeholders and explore climate change adaptation in biosphere reserves in Mexico and Bolivia, where Indigenous community rights and land access were important issues (Ruiz-Mallén, et al., 2015). Scenarios were developed collaboratively with community members, and they included climate and socioeconomic changes important to the biosphere reserve and community. Key drivers (i.e., axes) for the scenarios developed for Mexico and Bolivia differed, but participants consistently identified constraints to adaptation imposed by access to land and natural resources.

Level of Organization	Relevance to conservation	Response to climate change	Key vulnerabilities	Types of metrics typically assessed	Examples
Species	• Direct value to humans • Recognizable level of biodiversity	• Modification of population size and distribution based on tolerances to environmental conditions	• Risk of extinction • Change in abundance • Shifts in distribution	• Physiological • Demographic • Life history • Habitat use and distribution	• Foden, et al., 2013 • Summers, et al., 2012 • Thuiller, et al., 2005
Habitats	• Habitats can be surrogates for species and their resource use	• Largely via recognized responses of dominant species	• Structural complexity • Food and other resource provisioning	• Location • Areal extent • Spatial configuration • Connectivity	• Comer, et al., 2012 • Manomet Center for Conservation Sciences and National Wildlife Federation, 2012
Ecosystems	• Influence resources and conditions for species • Provide ecosystem services to humans	• Emergent properties such as productivity reflect integrated responses of species to environmental conditions	• Change in disturbance regimes • Loss of resilience • Reduction in ecosystem services	• Productivity • Hydrology • Disturbance • Carbon budget • Areal extent • Spatial configuration	• Schröter, et al., 2005 • Teck, et al., 2010
Biomes or plant functional types	• Broad-scale units define vegetation life form and function and provide a coarse filter for potential responses of lower organizational levels • Provide feedbacks to the climate system	• Emergent properties reflect integrated responses of species functional types environmental conditions	• Loss of area • Change in location and distribution • Albedo	• Areal extent • Location	• Neilson, et al., 2005 • Gonzalez, et al., 2010 • Rehfeldt, et al., 2012

Table 4.1. Levels of organization of ecological systems that are often considered in VAs.

combinations of climatic variables that are important to determining habitat suitability. Using projected changes in the climate variables, a map of the new suitable habitat is created for the species. This is often referred to as *climate envelope modelling.* In relatively simple applications, this kind of approach has the advantage of being based on actual geographic information that is widely available (Franklin, 2009) and can be applied to a very wide range of species and at various spatial scales. The disadvantage is it generally does not account for behaviour, species-specific traits, or interactions (e.g. competition, predation), which can be important (Ockendon, et al., 2014).

A second approach is to construct a *mechanistic computer model* that incorporates projected species-specific behaviours, life history, and/or other ecological and physiological responses to climate change. While both statistical and mechanistic approaches can be used to create spatial maps of projected species distribution under climate change, mechanistic approaches are generally more sophisticated and take more resources to produce because they require detailed knowledge of species tolerance to physical change and how populations may

Baby green turtle (*Chelonia mydas*), Bundaberg, Queensland, Australia. Climate change is thought to endanger all turtles due to rising sea levels and increased temperatures in the sands where eggs are laid (Liana Joseph).

Box 4.3

Creating climate scenarios

Temperature and precipitation projections are now readily available for every country. They include trends, which can be enhanced with information about extreme weather events (IPCC, 2012, 2013). While more specific and detailed climate analyses are available for many regions, the readily available climate information described below can be used to create scenarios that can help many PAs consider climate impacts.

The complexity of scenario development should match the ability of the PA to use the information, as well as the needs of decisions the scenarios are meant to inform (see also Box 5.2 about scenario planning). Coarse-scale data are sufficient for most PA assessments, but finer-scale projections may be warranted for areas with strong local effects on climate, such as coastal upwelling zones or complex mountain terrain. It will sometimes be sufficient to develop scenarios based on projections of two or three highly influential climate variables, while other situations will require detailed information about many variables. For PA managers not familiar with climate data, Daniels et al. (2012) is a general guide to climate projections for land managers, and Snover et al. (2013) provide guidelines for selecting climate data based on assessment needs.

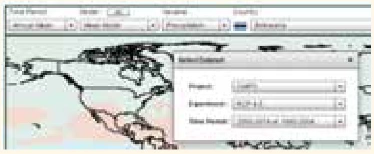
We describe two methods for developing climate scenarios. The first method requires no special expertise and can provide a starting point for most PAs. The second method is more quantitative and most PAs will need a collaborator with suitable expertise to acquire and summarize the climate data. Internet-accessible climate data and associated tools are proliferating, and in the future many PAs will likely be able to use the second method or something similar without assistance. Already, the Climate Change Knowledge Portal (http://climatewizard.ciat.cgiar.org/index1.html) evaluates a broad set of variables suitable for creating climate scenarios and provides instructions for using their web tools.

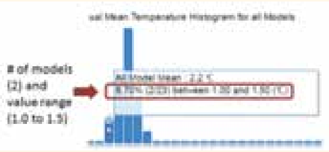
A simple method to create qualitative climate scenarios
This approach uses internet tools to create climate scenarios from average temperature and precipitation changes. Climate projections from the most recent IPCC (CMIP5) climate models and emissions scenarios are obtained from the Global Climate Change Viewer (GCCV; Adler, et al., 2013; Adler and Hostetler, 2013). Because results from GCCV are country-wide averages, PAs in large countries should examine maps of geographical variation (produced on the website) and adjust results when a PA is located where projected changes differ substantially from the countrywide average. Geographical variation can be very important, particularly where there are large gradients in precipitation due to topography or regional atmospheric dynamics, such as monsoonal rains. This method will generate plausible scenarios for most PAs, but there will surely be situations where geographical variation is too great, or data too sparse. All results should be critically evaluated for plausibility.

The following instructions were used to generate the two climate scenarios in the table below. Climate projections differ depending on the rate of future GHG emissions. Emissions scenarios are called representative concentration pathways, or RCPs. RCP 4.5 can be considered a low-emissions scenario, consistent with aggressive actions having been taken by mid-century to stabilize GHG emissions. RCP 8.5 represents a high “business as usual” scenario with greenhouse gas emissions increasing throughout the century (Moss, et al., 2010). In some situations, it will be useful to create more than two scenarios in order to represent a broader range of temperature–precipitation combinations.

You begin by obtaining temperature and precipitation projections from the GCCV website (http://regclim.coas.oregonstate.edu/visualization/gccv/cmip5-global-climate-change-viewer/index.html) by using menus to select relevant parameters, as follows:

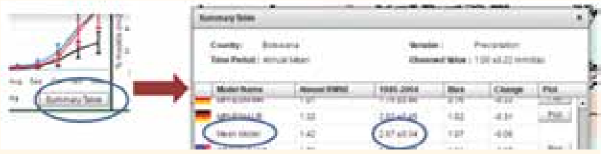
1. Open the website and select these variables: Time period = ‘Annual Mean’, Model = ‘Mean Model’, Variable = ‘Temperature’, and the ‘Country’ (in this case, Botswana).
2. Click on ‘Select Dataset’ and select Project = ‘CMIP5’, Experiment = ‘RCP 4.5’, and Time Period = ‘2050–2074 vs 1980–2004’.
3. To obtain a plausible minimum temperature change, move the mouse cursor over the left-most bar in the vertical bar chart that represents a result (i.e. a bar where ‘% of models’ is greater than 0). With the cursor over this vertical bar, a pop-up box will be displayed with the number of models and the range of values the bar represents. For example, ‘8.70% (2/23) between 1.00 and 1.50 (°C)’ means two of 23 models had values with a temperature increase of 1.00 to 1.50 degrees. A reasonable rule for deciding which value to use is to select a value obtained by two or more models. Record the mid-point of the bar representing the low value in the table (e.g. 1.25 °C for Botswana).





Box 4.3 (continued)

4. Repeat step 2, using Select Dataset to select Experiment = RCP 8.5.
5. Now record the maximum temperature change. Move the cursor over the right-most bar that represents 2 or more models and record the mid-point as in step 3. For Botswana, this value is 4.25.
6. Change the Variable to ‘Precipitation’, leaving other selections as above.
7. Record a high and low value for RCP 4.5 and for RCP 8.5 (a total of 4 values), following the procedure from step 3.
8. Set Experiment = RCP 4.5, then click on ‘Summary Table’ in the line plot panel. In the Model Name column, use the right scroll bar (if necessary) to find the result for ‘Mean Model’ and record the 1980–2004 value (2.07 for Botswana). Using Select Dataset, set Experiment = 8.5 and repeat. Mean Model values can be the same or different.



9. Divide the high and low precipitation change for each RCP by the Mean Model value for that RCP, then multiply to 100 to calculate the percent change. For Botswana, RCP 4.5, (–0.25/2.07) * 100 = –12%.
10. Determine which precipitation values will be used in the scenario table. Precipitation projections usually span a broad range, often including both increases and decreases in precipitation. If precipitation projections for RCP 4.5 and 8.5 differ substantially, scenarios should match changes in precipitation and with change in temperature for the same RCP. If range of changes in precipitation for RCP 4.5 and 8.5 are similar, use the lowest and highest value to create the most divergent scenarios and discard the other values.
11. Now create scenarios using changes in temperature and precipitation. For planning purposes, create the most divergent, plausible scenarios. For arid regions this is usually accomplished by defining one scenario with the higher precipitation value (greatest increase, or least decline) matched with the lowest temperature increase, and another scenario with the lowest precipitation (greatest decline or smallest increase) matched with the greatest temperature increase. These scenarios are represented by the lower left and upper right quadrants in the accompanying figure. For wet regions, the most divergent scenarios may be created by combining the higher precipitation rate with the largest temperature increase.

	Emissions scenario	
	Low (RCP 4.5)	***High (RCP 8.5)***
Temperature increase (ºC)	1.25	4.25
Precipitation (change from historical)	+12%	–12%
Daily maximum temperature (return interval; historical occurrence of once per 20 years)	Every 2 to 3 years	Almost every year
Dryness	Slight increase	Large areas of drought
Heavy rainfall	Same	Slight increase

Climate scenarios for Botswana for circa 2060, created using the first method (see text). Climate projections derived from the GCCV are for a low greenhouse gas emissions scenario (RCP 4.5) and a high emissions scenario (RCP 8.5). Information on changes in climate extremes was derived from IPCC (2012).

The usefulness of scenarios is enhanced by additional information on climate extremes. The most comprehensive and accessible synthesis of extremes is the IPCC special report (IPCC, 2012; http://ipcc-wg2.gov/SREX/). Because the IPCC report is based on earlier climate models than those used by GCCV, and because the reporting periods differ, some interpretation is needed to combine results. Results in IPCC (2012) for emissions scenario B1 are most similar to RCP 4.5; scenario A1B is somewhat warmer than RCP 4.5, and emissions scenario A2 is roughly comparable to RCP 8.5 (Rogelj, et al., 2012). Regional projected changes in maximum and minimum temperatures, heat waves, heavy precipitation, and dryness are summarized in IPCC (2012; their table 3-3). Specific projections of climate extremes that are most easily included in qualitative scenarios are presented in IPCC (2012) figures 3-5b and 3-7a. Chapter 3 in the IPCC report discusses historical occurrence and projections of a broad range of climate extremes and disturbances that may be of particular interest to a PA. Table 5.1 includes many additional climate variables used to create scenarios.

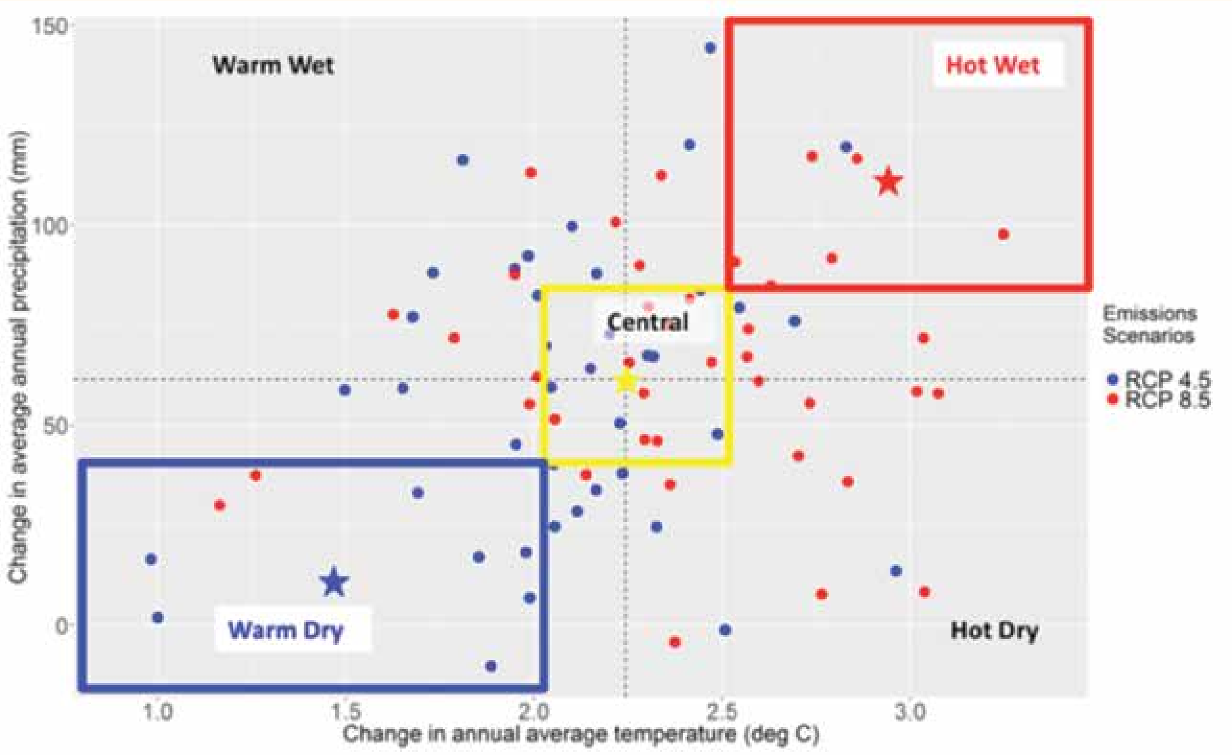
Sea-level rise is important for many PAs, and it thus may be an important variable to include in climate scenarios. The IPCC Working Group 1 report (2013, Chapter 13) includes regional-scale sea-level rise projections. Some recent analyses have estimated greater rates of sea-level rise than those reported by IPCC, particularly studies with new

Box 4.3 (continued)

information on ice sheet dynamics (DeConto and Polllard, 2016). Both high and low estimates can be used in scenarios to represent the range of projections for sea-level increases.

A more detailed approach

If a PA can acquire and process results from individual climate models, a simple technique for identifying potential climate futures is to plot results from each individual model and define scenarios by quadrants in the resulting plot (coloured boxes in the accompanying figure). Each quadrant of the plot represents a future climate scenario that can be used to assess ecological impacts and adaptation options. The three climate scenarios outlined in the figure are defined by the 25th percentiles of changes in precipitation and temperature, but other methods or cut-points can be used to define climate futures. In the figure, the Warm Dry scenario could also be described as a "least-change" scenario, in which case it is very important to acknowledge that the "least-change" scenario is not the "most likely". After the models (GCMs) that contribute to each scenario are identified, results from them can be further summarized by additional variables of interest, such as the number of hot days (above some threshold), days below freezing, days with heavy precipitation, growing degree days, etc.



A scatter plot of climate model projections, illustrating potential climate futures in the coloured boxes. The stars are average values for the results in each box.

respond. Sufficiently detailed data are unavailable for most species, but mechanistic models are often constructed and used to support management of species that are of special conservation or economic importance.

An increasingly common approach is to use species' innate biological traits as predictors of vulnerability to climate change. Traits that are selected for analysis typically involve known sensitivities to change, such as specialized relationships to other species (i.e. ecological specialization or inter-specific interactions). Other traits useful in these kinds of assessments are responses that can be used to measure species adaptive capacity, such as the ability to move or migrate, or to change form or behaviours (e.g. colour change or shift in primary food source). Trait-based VAs are often used by conservation organizations and management agencies because they permit a relatively rapid assessment for multiple species. Results are readily used to prioritize conservation action and implementation of adaptation schemes. The NatureServe Climate Change Vulnerability Index (CCVI; Young, et al., 2015; Case Study 4.1) is a widely used trait-based index of climate vulnerability.

Ecological communities to landscapes

In cases where circumstances prevent a focus on species, or when the area of concern is very broad, habitats or vegetation communities may be used as the basis for a VA. Local communities may play a role in defining the scale and focus by identifying specific parts of the landscape where social or ecological values may be vulnerable (e.g. summer grazing or spring nesting areas). When ecological communities are being assessed, the evaluation is often based on responses of the dominant or other important species. To the extent that species are dependent on habitats, VAs at this level provide a coarse filter that can be a cost-effective means to identify areas and species that may require more detailed assessment.

Ecosystem-level VAs may look at how stable the overall ecosystems are likely to be when considering future climate change, or how the processes that sustain these ecosystems will be affected (Watson, et al., 2013).

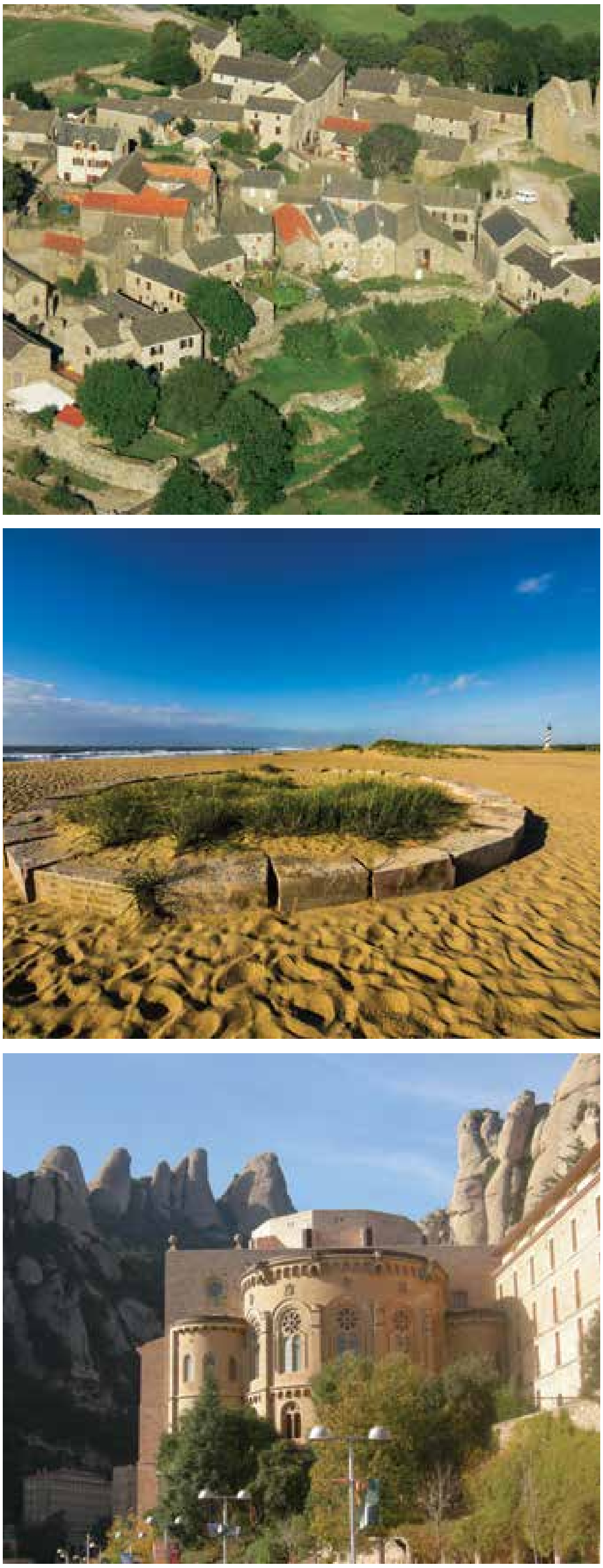
Recently, ecosystem services—which include provisioning of physical resources such as water, regulating services such as carbon storage, and cultural services such as the protection of aesthetic beauty—have become an important part of the assessment framework (Ingram, et al., 2014). Vulnerability assessments that focus on these services often seek to understand how climate change affects the resilience of ecosystems to disturbance. Because of the spatial scales at which this kind of VA is conducted, simulation modelling is often the most feasible method of assessing potential ecosystem responses to climate change. While possible, it is unlikely that most PAs would undertake simulation modelling on their own, but this could be a very useful tool for the purpose of planning and management at landscape scales that go beyond the boundaries of an individual PA. Modelling ecosystem responses and recovery to disturbance is especially important in highly dynamic environments that frequently experience extreme events (e.g. coastal zones or areas prone to flooding or fires).

Biomes or plant functional types (e.g. temperate needleleaf evergreen, or tropical herbaceous forest) are typically the coarsest organizational level considered in VAs, often for continental to global analyses (Gonzalez, et al., 2010; Rehfeldt, et al., 2012; Watson, et al., 2013). Vulnerability assessments at this level of organization reveal broad-scale trends and potential for major shifts, such as forests changing to grass- or shrublands. While assessments at the continental or global scale are often not useful for decision making at a specific site, it is useful to be aware of biome-level assessments and whether your PA is forecast to experience transformational changes.

The selection of organizational levels for a VA depends on the conservation targets, data availability, available resources, and spatial and temporal scales of interest. Many VAs consider two or more organizational levels—usually species and communities or habitats—because of the complementary information they provide (e.g. Amberg, et al., 2012; Ponce-Reyes, et al., 2012).

4.4 Defining your approach and engaging a team

In most cases PA managers will contribute to the design of a VA, but the research, evaluation, and reporting are usually done by outside experts. The most useful and economical



Climate change will impact historic structures that are a vital part of many PAs. Top: La Garde Guérin, a medieval village in Cévennes National Park, France (IUCN Photo Library / © Pierre Goeldlin). Middle: Managers at Cape Hatteras National Seashore (North Carolina, USA) were forced to move the park's iconic namesake lighthouse from its original location at the edge of the ocean (foreground) 880 m inland because of accelrating shore erosion (GEDApix/ GEDavis & Associates). Bottom: A monastery in Montserrat National Park, Spain (© IUCN / Gonzalo Oviedo). In all these examples, the fabric and structure of the buildings themselves could be damaged by climate-driven changes in precipitation regimes and air quality.

American alligator (*Alligator mississippiensis*). The US Department of Agriculture notes that climate change concerns for turtles and crocodilians are three-fold. “First, these mostly aquatic species may encounter altered habitats and increased habitat fragmentation with altered climate. In this regard they share many concerns with amphibians, such as sensitivity to changes in water availability and its thermal properties. Second, turtles and alligators have temperature-sensitive sex determination: cooler temperatures may produce nests of only males; warmer temperatures may produce nests of only females. Temperature changes in a local area may have the effect of altering the sex ratios of populations—potentially affecting future reproduction and over time compromising their evolutionary fitness. Third, coastal species such as the American alligator and crocodile are susceptible to an increasing frequency or intensity of storms caused by increases in ocean temperatures. Storm surges can displace or drown animals, and dehydrate them by salt water intrusion into freshwater habitats” (GEDApix/GEDavis and Associates).

VAs will be designed to directly inform specific management planning processes for the conservation targets. Key decisions when designing a VA will focus on the explicit conservation targets, size of the area of analysis, degree of detail (see below), period, and uncertainty.

Best Practice 4.2. Use a structured process to conduct the assessment

While every PA is unique, there are steps and principles that are common to designing and conducting most VAs. These can be categorized into four general stages as outlined in Table 4.2 and briefly described below.

Stage 1. Define purpose, audience, and decisions to inform

It is particularly important to be very clear on the purpose, audience, and intended use of the results of the assessment. If the purpose is to communicate general threats to broad-scale habitats, it may be sufficient to use global-scale projections of temperature and precipitation and results from generalized models of ecosystem or biome changes. If the purpose is to inform site- and species-specific management plans, it may be necessary to use downscaled climate projections and sophisticated population models. This is the time to ensure the assessment is designed to meet information needs. At the end of Stage 1, the project leader should have a coherent and complete plan, including a time schedule and cost estimate.

Stage 2. Gather and evaluate information

This constitutes the bulk of work for most assessments. Regular engagement of stakeholders during this stage can achieve two goals:

1. **Educate stakeholders.** Most recipients of the results will need repeated exposure to the data sources, vulnerability rankings or indices, methods, and final products before they understand what is being done. Without an understanding of the process, results of the assessment are not likely to be fully used.
2. **Correct the process as needed.** Problems applying methods decided on in Stage 1 may not be apparent until the analyses are underway. These may relate to data availability or quality, spatial context, or conservation targets. Methods frequently must be modified to best meet the desired information needs.

Stage 1. Define purpose, audience, and decisions to inform. These tasks establish the high-level bounds of the study.

- Identify and engage key contributors and end-users (internal and external stakeholders).
- Articulate and agree on overall goals and objectives. What decisions will be informed by the assessment, and what information is needed for the decisions?
- Identify conservation targets.
- Agree on spatial scale and time frames.
- Agree on climate projections to be used.
- Select assessment approach based on targets, user needs, data, and resources.
- Define format and content of assessment products (rankings, tables, reports, narratives, etc.).

Stage 2. Gather and evaluate information. Data gathering and assessment are sometimes separated, but in practice there is virtually always some overlap.

- Review literature on observed trends, patterns, and relationships.
- Seek or construct conceptual (causal) models of key drivers and responses.
- Engage subject-matter experts.
- Acquire projections of relevant climate variables.
- Evaluate components of vulnerability (exposure, sensitivity, adaptive capacity).
- Present methods, preliminary results, challenges, and issues to stakeholders, and then discuss with them. Adapt process as needed. *This is a very important step.*

Stage 3. Identify patterns, implications, and potential adaptation actions. Expertise obtained from conducting the VA can lead to important insights on potential actions.

- Summarize key or common causes of vulnerability.
- Identify patterns of vulnerability (groups of species, functional traits, spatial patterns, etc.).
- Highlight insightful results, including highly consequential factors and potential management actions.
- Consider effects of management actions and climate futures on vulnerable species.
- Identify strengths, gaps, weaknesses and high-priority future needs.

Stage 4. Report and communicate results. Carrying out a formal communication plan may add great value to projects.

- Draft report for review by stakeholders.
- Share methods, results, and implications with stakeholders and decision makers.
- Revise and submit final products.

Table 4.2. General stages in designing and conducting a comprehensive climate change vulnerability assessment. Feedbacks between processes are not indicated.

At the end of Stage 2, most assessments will have scores for each conservation target that identify those elements most at risk, and provide indications of the cause of vulnerability.

Stage 3. Identify patterns, implications, and potential adaptation actions

A substantial effort may be required to make sense of the results and create effective graphics, tables, and other products to communicate key messages. Millsap, et al. (1990) provide a model for very effectively using a species-based conservation assessment to identify needs for resource protection, further research, or direct intervention (e.g. habitat improvement, enhanced protection of species, changes to harvest practices, etc.).

Vulnerability assessments are not intended to comprehensively identify and evaluate adaptation options. But in practice the assessment team is likely to have thoughtfully identified sources of threats and adaptation responses. Reporting these insights can greatly increase the value of the assessment.

Stage 4. Reporting and communication

Reports of most VAs will include descriptions of the study area and methods, and results that frequently include maps and tables with rankings or categories of vulnerability. These are generally accompanied by narratives that summarize information on the conservation targets and that explain and justify the assessment results. Narratives and literature syntheses are important components of VAs.

Short summaries, videos, and stories can very effectively engage and inform PA visitors, staff, and community members. Summaries that highlight "key vulnerabilities" (explained below) can be particularly important to increase the likelihood that results will be accepted and used by managers and other stakeholders.

4.5 Identifying the most important links to actions

A VA is intended to provide a basis for linking adaptation actions to projected climate impacts. Within the context of climate-informed goals, results from a VA help determine priorities. To do so, it is necessary to evaluate the full spectrum of results from the assessment, and identify those vulnerabilities that provide a critical link between conservation goals and adaptation actions. Key vulnerabilities are those that pose the greatest obstacles to achieving agreed-upon conservation goals and objectives (Gross, et al., 2014).

Best Practice 4.3: Focus on key vulnerabilities

The specific process and criteria used to identify key vulnerabilities will vary with the goals of a PA or planning process. Each team will need to use criteria that are most relevant to its particular situation. The following criteria to identify key vulnerabilities (from Gross, et al., 2014) will apply to many situations:

- **Impact on ability to achieve conservation goals.** This is implicit to defining a key vulnerability, and it should always be an important consideration.
- **Implications for other relevant societal values.** Many PA decisions need to consider effects of management

A local market near Tarangire National Park, Tanzania. The vulnerabilities associated with food security are a major concern in adapting to climate change (IUCN Photo Library / © Alicia Wirz).

actions on social and economic values, such as mitigation of climate risks to human communities, or maintaining traditional practices or cultural sites.

- **Ecological significance.** A higher priority may be assigned to vulnerable species or systems that are listed as threatened or endangered, or to keystone species or ecosystem engineers (i.e. organisms that create, significantly modify, maintain, or destroy habitat).
- **Magnitude of impacts.** Will the scale and intensity of the impact be highly consequential and especially harmful (e.g. by affecting predator–prey interactions)? Would the impact affect an extended geographical area or large number of species?
- **Likelihood of impacts.** Are the impacts already being observed at the PA or elsewhere? Are they projected to occur with high certainty, or are they based on more uncertain projections?
- **Reversibility of impacts.** Are the potential impacts likely to be persistent and irreversible (e.g. by resulting in species extinction or system collapse)? Are there effective actions that can be taken after the impact occurs?
- **Timing of impacts.** Are the impacts already occurring or likely to occur in the near term, or are they projected to occur far in the future? Even where impacts may be far in the future, opportunity costs might be incurred by failure to act in the near term.
- **Potential for successful adaptation.** At this stage the full range of adaptation options will not have been identified, but there may be obvious adaptation opportunities with a high likelihood of success. This may be a useful consideration for overall adaptation planning.

4.6 Summary

Protected areas will be exposed to some combination of increased temperatures, more intense storms, and altered hydrological cycles. These climate effects will impact ecological and cultural values, routine operations, and visitors, and it is important to understand how vulnerable they are. Because climate affects virtually all species and the ecological and evolutionary processes that sustain them, most PA managers will need to participate in climate change assessments.

There are various ways VAs are conducted, but most formal assessment techniques evaluate exposure, sensitivity, and adaptive capacity of the species, ecosystem, or ecological process, and involve analyses of observed (historical) and projected (future) climate, land use, demography, and other important climate and non-climate factors. While there is a variety of different methods, good VAs will:

- Use a design that matches the PA and conservation needs.
- Use a structured process to conduct the assessment.
- Clearly identify and describe key vulnerabilities.

Chapter 5

Moving to action:
Options for climate adaptation

We are now in an era of managing for change, as much as managing for persistence or historical conditions. First and foremost, it is important to recognize that every PA can begin climate adaptation now. This chapter presents a range of adaptation options, while Chapter 6 advises on prioritizing them and selecting an adaptation strategy.

Developing a list of potential adaptation strategies is Step 3 in the adaptation cycle (Figure 5.1). It requires creative thinking to consider the challenges of new combinations of species, different patterns of fire or flooding, or alterations to established ecological processes such as the timing of spring green-up, water runoff, or outbreaks of pests. In some cases, conventional management practices will no longer be adequate, and managers, scientists, and communities will need to work together to consider new practices, or make significant adjustment to existing ones. This chapter describes how to identify the broadest range of options, without regard to whether they are currently considered "practical" or even "possible". Some climate adaptation practices considered unrealistic a short time ago are now being implemented.

Once a VA is prepared (Chapter 4), PA managers should work with scientists, communities, and stakeholders to consider how the assessment might affect conservation goals (Chapter 2). Well-considered goals are the basis for wise adaptation. Each important conservation goal should be revisited and, if necessary, revised to ensure it is still realistic, achievable, and robust to projected climate changes. This process can be informed by key vulnerabilities and threats identified from VAs (Chapter 4), literature reviews, and management plans. Information from park staff, stakeholders, community members, and outside experts can help focus adaptation efforts where they will make the most difference.

5.1 General adaptation strategies for protected areas

Adaptation responses can be very local (e.g. installing a larger culvert to accommodate more intense rains) to broad and visionary (e.g. designing a system of well-connected PAs). Adaptation options must consider factors outside PAs that contribute to their integrity and sustainability, including protecting habitats critical to species of concern (e.g. seasonal needs of wildlife), uplands that protect water quality or quantity, buffers from disturbances, and habitats that connect the PA to other natural areas.

Adaptation actions may be *anticipatory,* preparing for known or potential future impacts, or *reactive,* responding to impacts already apparent. Most managers will eventually need to carry out reactive adaptation to contend with unanticipated events, but *anticipatory adaptation is preferable.* A decision to relocate a facility or road from a floodplain following a major flood constitutes a reactive adaptation action. An anticipatory action would be a decision to avoid building there in the first place, or recognizing that flooding of an existing road is inevitable and moving it in advance. A reactive action is controlling an invasive species after it has colonized a new area as a result of climate changes. The anticipatory action might focus instead on identifying invasive species likely to expand their ranges in response to climate change, and establishing early-detection and rapid-response protocols to prevent invasion of sensitive areas.

Best Practice 5.1: Consider alternative climate futures when identifying options
It is impossible to predict the exact rate and magnitude of

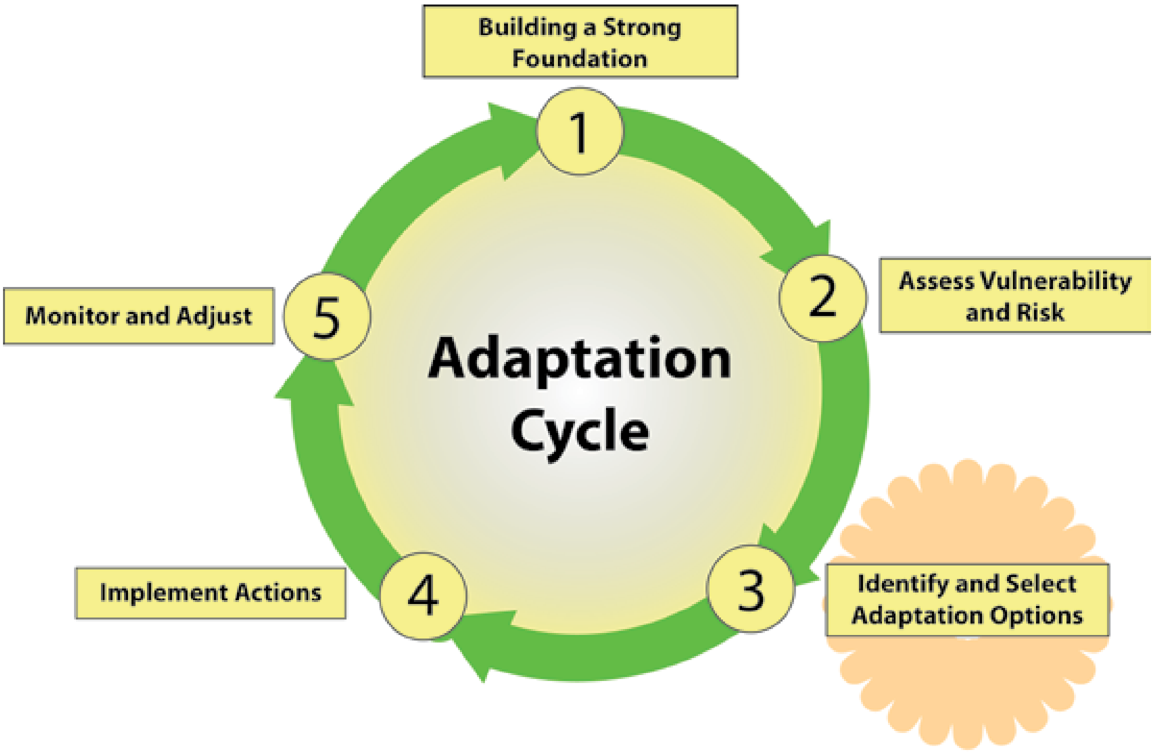


Figure 5.1. Step 3 in the adaptation cycle links results from the vulnerability assessment to adaptation options and selection of actions to be implemented. Best practices related to this step are in Chapters 5 and 6. Generalized cycle adapted from EEA, 2015.

Guided by a philosophy of anticipatory adaptation, managers at Assateague Island National Seashore (Maryland/Virginia, USA) are designing new park structures—such as lightweight changing rooms, passive-solar vault toilets, and a solar-powered shower—so they can be moved if needed as storms intensify and sea level rises (US Department of Energy).

Young silvertrees (*Leucadendron argenteum*) returning to the slopes of Table Mountain, Cape Town, South Africa, after the removal of invasive pine plantations. Reactive adaptation, such as removing invasive species after they have become established, is less preferable than anticipatory action, but most PA managers will find it necessary to respond reactively sooner or later (Abu Shawka).

climate changes, nor the precise response of ecological systems to changes in temperature, precipitation, and climate variability. Because of this uncertainty, a best-practice approach is to identify potential adaptation options for a range of future conditions. Because the magnitude and extent of changes will increase over time, planning processes should consider changes at both shorter and longer terms. Ideally, evaluations of climate trends from a VA will be used to identify adaptation options. Otherwise, climate projections to 2040 and to 2090 are suitable for many conservation planning purposes. For most planning purposes the climate for a year of interest (e.g. 2040 or 2100) should be estimated from projections for a surrounding 20- or 30-year period. For example, the "average" climate for 2040 would be estimated from model results for 2031–2050 (a 20-year period) or 2026–2055 (a 30-year period). Box 4.2 describes two approaches to developing alternative climate scenarios, but the approach that a PA uses will usually be strongly influenced by availability of climate expertise and information. Table 5.1 is an example of detailed climate scenarios for Isle Royale National Park, USA, that were developed by a team of PA managers, climate adaptation specialists, and climate experts.

Information on key vulnerabilities and future climates provides a solid foundation for identifying potential adaptation options. There are many planning techniques that can be used at this stage to identify options, and the choice of method will depend on the local situation and available resources. A very common approach is to convene a workshop with managers and subject-matter experts to exchange information and identify potential adaptation options.

Best Practice 5.2: Identify a range of options at both site and system scales

Climate change is a global phenomenon, but on-the-ground actions must be tailored to situations that are often site-specific. Thus a particularly challenging aspect of climate change is the need to simultaneously consider impacts and responses at very broad as well as very local scales (Case Study 5.1). Correspondingly, there are well-established

High-latitude PAs, such as Torres del Paine National Park in Chile, are expected to feel the effects of climate change quickly (IUCN Photo Library / © Sue Mainka).

Climate Driver	**Scenario**			
	Least Change	**Summer Drought, Wind, and Fire**	**Warmer than Duluth**	**Isle Savanna**
Mean annual temperature	**increase 3.4 °F**	same as Least Change	**increase 6.5 °F**	increase 5 °F
Cold days (< 32° F)	**15 fewer days**	same as Least Change	**up to 30 fewer days**	**up to 30 fewer days**
Hot days (> 95 °F)	increase of < 5 days	same as Least Change	increase of 5 days	same as Least Change
Growing season	**2 weeks longer**	same as Least Change	**4 weeks longer**	3 weeks longer
Annual precipitation	+5% (up Winter, down Summer)	same total as Least Change	same as Least Change	10-15% increase
Intense precipitation	20% increase in number of days with >1 inch precip	same as Least Change	same as Least Change	**summer: sporadic extreme events, 30% increase in > 1" events**
Snow	snow days -25%	same as Least Change	**snow days -50%**	**snow days -40%**
Wind	20th century conditions	**Increased probability of large wind events (derechos)**	same as Least Change	same as Least Change
Lake levels	20th century conditions	same as Least Change	same as Least Change	same as Least Change
Lake temperature	+3.6 °F in warm season temp, >50 °F water temp for 25 more days	same as Least Change	+8.3 °F in warm season temp, >50 °F water temp for 60 more days	+6.0 °F in warm season temp, >50 °F water temp for 45 more days
Lake ice cover	12 fewer days	same as Least Change	45 fewer days	30-40 fewer days
Climate variability	20th century conditions	**Punctuated dry summer periods**	**Greater variability in seasonal and annual temperature**	**Greater variability in seasonal and annual precipitation**
Arctic Oscillation	20th century conditions	same as Least Change	same as Least Change	**Predominance of positive phase (7 out of every 10 years)**

Table 5.1. Summary of projected climate changes for a range of climate scenarios for Isle Royale National Park, Michigan, USA (Fisichelli, et al., 2013). Conditions in bold denote significant drivers causing divergent scenarios. The 'Least Change' scenario, which acts as the base model, uses the lower bounds of climate projections for 2050. In this scenario, warming of the past several decades will continue, resulting in 15 fewer days with temperatures below 0°C in winter; a warmer, longer growing season; increased winter precipitation and less summer rainfall; and lower overall snowpack and Lake Superior ice cover. In the 'Summer Drought, Wind, and Fire' scenario, climatic conditions are very similar to those of the 'Least Change' scenario with the addition of large disturbance events (such as wind storms and wildfires) and punctuated dry summer periods, which further accelerate ecosystem changes. In the 'Warmer than Duluth' scenario, the climate changes at a rate near the upper end of projections. Ecosystem changes progress at a faster rate than in the 'Least Change' scenario with a messy transition from boreal to temperate forest, changes in phenology, and extra stresses on the park's iconic moose and wolf populations. In the 'Isle Savanna' scenario, climate change is both more severe and more variable than in 'Least Change.' Temperatures warm 2.8°C by 2050 and although mean annual precipitation increases, extreme variability causes cycles of drought punctuated by heavy rains, accompanied by warmer and drier winters. Cascading events prove to be a major tipping point for the vegetation of the park, which by fits and starts slowly converts to a more savanna-like ecosystem. All scenarios projected a loss of ecosystem resiliency and an inevitable shift in vegetation from cool-adapted boreal to warm-adapted temperate species. Based on commonalities among scenarios, workshop participants identified several 'no-regrets' and 'no-gainer' strategies.

Case Study 5.1

Adaptation programme in the Central Region of the Sierra Madre Oriental

Climate change poses a growing threat to Mexico's ecosystems and communities. Regional and local planning tools are therefore required to implement climate change adaptation and mitigation strategies.

In the Central Region of the Sierra Madre Oriental (RCSMO, for its initials in Spanish), climate change is likely to impact biodiversity-rich ecosystems and local communities, increasing their vulnerability because their livelihoods depend primarily on the area's natural resources.

In line with the Climate Change Strategy for Protected Areas 2010 (ECCAP), CONANP, in cooperation with GIZ, designed the Climate Change Adaptation Programme for the Central Region of the Sierra Madre Oriental (PACC-RCSMO).

The area of intervention is approximately 2.15 million hectares, covering parts of five states (Tamaulipas, San Luis Potosí, Hidalgo, Puebla, and Veracruz) and portions of three major river basins that drain into the Gulf of Mexico (Pánuco, San Fernando-Soto la Marina, and northern Veracruz). Four PAs are established in the RCSMO region; three of them are federal PAs and the fourth is set to be declared.

The main objective of the programme is to propose strategies that serve as a reference to guide action. The information used in the programme is largely based on a multi-level vulnerability analysis of the dangers of climate change to the livelihoods of the local population and the area's ecosystem processes.

Socio-environmental interactions can determine the type of response to climate events or other factors, such as changes in land use and natural resource management. Some communities, for example, have developed activities such as extensive livestock farming, which intensifies the use of natural resources and results in deforestation and the slow regeneration of forest ecosystems. There are, however, also examples of communities that have contributed to conserving ecosystems through agro-ecological practices, such as the production of shade-grown coffee.

(Above): Central Region of Sierra Madre Oriental, Mexico. (Below): Process to identify adaptation measures.

The PACC-RCSMO incorporates the concept of EbA, which involves improving the adaptive capacity of communities and ecosystems through the sustainable use of available environmental resources.

One result from the PACC-RCSMO was a toolkit to analyze the vulnerability of ecosystems and local communities

Case Study 5.1 (continued)

throughout Mexico's PAs. The toolkit fosters a participatory process for designing adaptation, mitigation, and monitoring strategies and actions. As a result, PACC-RCSMO information could be generated and used in combination with available scientific and local knowledge to ensure the coherence of the region's social, environmental, cultural and economic context and the actions to be implemented by CONANP and other institutions. The adaptation, mitigation, and monitoring strategies developed by the PACC-RCSMO include sustainable natural resource management, ecosystem conservation and restoration, diversification of economic activities, promotion of social organization, and capacity building for pest prevention and control. These activities are part of a general climate change adaptation approach focusing on the many social, economic and cultural benefits for local communities. The strategies also address issues such as the availability of information about ecosystems and communities, the creation of knowledge networks, and stakeholder training.

The strategies developed by PACC-RCSMO are applicable to other parts of Mexico as they focus on priority vegetation types, such as cloud forest, low deciduous forest and temperate forests. Similarly, the participatory approach can be used across Mexico's PA system.

Text and figures (with permission) from: Comisión Nacional de Áreas Naturales Protegidas (CONANP) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2013, Programa de Adaptación al Cambio Climático Región Central de la Sierra Madre Oriental. CONANP, GIZ. México. For more information, see: http://cambioclimatico.conanp.gob.mx/.

Planting seedlings for mangrove restoration at the mouth of the Limpopo river, Mozambique. Restoring ecosystem processes and functions helps build resilience to the effects of climate change (IUCN Photo Library / © Daniel Shaw).

principles of adaptation that apply to many situations, but the details of how these are applied will vary with site-specific circumstances.

A good starting place is to consider the general adaptation principles for PAs in Table 5.2. They are founded on general ecological principles that are applicable to most PAs. West and Julius (2014a) provide examples of the application of these principles when designing adaptation strategies for PAs in coastal salt marsh, for a network of PAs to support migratory waterfowl, and for a wildlife refuge consisting of forests and wetlands.

Many PAs already manage non-climate stressors. Good management along these lines is an essential first step in climate change adaptation. However merely continuing with 'business as usual' management of stressors does not constitute climate adaptation. Reducing existing threats that exacerbate climate change means focusing on those threats and stressors that most directly influence key vulnerabilities. Table 5.3 lists examples of threats that may already be a high priority in a PA and that can amplify (or be amplified by) the effects of climate changes. The difference between routine park management and climate adaptation is that the latter focuses on threats that have an identified, direct link to a climate change. The link to climate can affect the location, timing, or specific on-the-ground action that is taken.

Even without climate change, a landscape perspective is important for conserving biodiversity. With climate change, it is an imperative. Species distributions are already changing in response to climate change. Table 5.4 lists principles that can help guide working with partners to identify and implement broad-scale adaptations in PAs and the lands that surround and connect them.

Principle	Description	Adaptation options
Reduce stressors that amplify climate impacts	The vigour and ability of species and ecosystems to adapt are greatest in the absence of stressors. Climate can act as a threat multiplier and interact with other stressors to increase susceptibility to disease and drought, and reduce competitive abilities of native plants and animals.	• Control nutrient runoff • Control disease • Increase connectivity • Reduce water diversions • Control invasive species • Reduce disturbances
Sustain or restore ecosystem process and function to promote resilience	Preserve fundamental ecosystem properties such as plant growth (biomass production), decomposition, wetland filtration of nutrients and sediments, and nutrient cycling. These processes contribute to ecological integrity even when species composition and ecosystem structure changes.	• Restore degraded vegetation, especially in wetlands and riparian zones • Remove dams and diversions • Restore beavers and natural ponds and pools • Ensure sediment delivery to estuaries and deltas
Protect intact, connected ecosystems	Intact and fully functioning ecosystems are more resilient to climate change than degraded systems. Intact systems facilitate the ability of species to adapt to current and future changes.	• Restore vegetation along streams • Remove dams and waterway impediments • Avoid/remove developments that bisect corridors • Establish hedgerows in agricultural lands
Protect areas that provide future habitat for displaced species	Using species distribution and other models, identify, map, and protect areas that will support shifts in vegetation and animal distributions, and those species displaced by climate change, land use change, sea-level rise, and the interaction of stressors. These areas will facilitate increased adaptive capacity.	• Use species distribution models to anticipate range shifts • Nurture partnerships to protect critical habitats outside the PA • Reduce barriers to low-lying coastal habitats to move inland
Identify and protect climate refugia	Climate refugia are local areas that have experienced less climate change than the broader surrounding area and are likely to continue to do so in the future. These areas preserve existing populations of species that are more likely to be resilient to climate change and may be a destination for future climate-sensitive migrants (see Box 5.2).	• Identify potential refugia (Box 5.2) • Suppress fires near forest refugia • Protect cold-water springs and seeps • Reduce human use and disturbance in refugia • Include areas with high topography diversity in PA and PA networks

Table 5.2. General ecological principles to help identify adaption options for terrestrial, freshwater, coastal, and marine environments, primarily at the level of an individual PA or the landscape or seascape that supports a PA.

Animal species that come together in colonies for at least part of their life cycle are susceptible to chance events associated with climate change: Cape Cross Seal Reserve, Namibia (IUCN Photo Library / © Jim Thorsell).

Threat	Interactions	Responses
Destructive fishing, sedimentation, nutrient enrichment, pollution (from herbicides, pesticides, heavy metals), herbivore decline	**For coral reefs:** These stressors increase sensitivity to high temperatures, algal growth, and reduce growth and recovery from disturbance.	• Increase incentives for use of non-destructive fishing methods, reducing runoff, and improved management of nearby agricultural lands and sewage.
Nutrient runoff, pollutants, water diversion	**For freshwater systems:** With increased temperatures there is more likelihood of algal blooms and reduced oxygen levels, especially when flows are low.	• Improve nearby and upstream agricultural management, establish vegetated buffers along waterways, use wetlands to filter agricultural runoff, improve sewage treatment.
Forest fragmentation	**For forests:** Edges are hotter and drier than interiors, and can be more prone to drought stress. Fragmentation inhibits ability of plants and animals to shift ranges, and forest edges are prone to plant invasions.	• Reduce forest clearing, maintain or establish forested corridors between forested PAs. Control invasive species. Fragmentation interacts with climate to reduce populations.
Invasive species	**All ecosystems:** Invasive species can out-compete native species and alter structure and composition of native communities. Invasive plant species may be less palatable or nutritious and reduce vigour of native herbivores; can lead to altered fire pattern and complete vegetation shift.	• Control using methods that are appropriate for the system and species. Maintain natural fire patterns, monitor for and control incipient populations of invasive species, and require use of weed-free fodder.
Increased bare ground	**Terrestrial ecosystems:** Increased drought and more intense storms can result in increased erosion, reduced regulation of water flow and increased runoff, flooding, and more sediment in waterways.	• Manage grazing levels by domestic livestock. Prioritize restoration and revegetation in watersheds and riparian areas. Control recreation in sensitive areas.

Table 5.3. Common non-climate stressors that are often amplified by climate changes, and examples of possible responses.

Principle	Description	Key references
Conserve key ecological features	Focus management on underlying features (e.g. land forms, geology, elevational gradients), structures, organisms, and areas that are the foundations of communities and ecosystem properties. These include riparian corridors, freshwater systems (springs, lakes, etc.), and critical habitat for keystone species.	• Anderson and Ferree, 2010 • Groves, et al., 2012 • Beier, et al., 2015 • Lawler, et al., 2015
Preserve and enhance connectivity	Connectivity operates on several levels. Provide opportunities for species and communities to respond to climate changes by shifting their distributions. Facilitate the movement of water, nutrients, energy, and organisms between resources and habitats. Connectivity is often considered to enhance system resiliency.	• Aune, et al., 2011 • Eros, et al., 2012 • Green, et al., 2014
Translocate species (relocation)	It may be appropriate to actively move organisms and assist in their establishment at locations where they currently don't exist or never previously did. Translocations are highly controversial as a climate adaptation strategy, but relocations, introductions, and reintroductions have been routine practices in conservation, wildlife management, and agriculture for centuries.	• Hoegh-Guldberg, et al., 2008 • Schwartz, et al., 2012 • Batson, et al., 2015

Table 5.4. Ecological principles and adaptation options that are typically more suitable for adaptation at the scale of a large PA or a network of PAs (see also Chapter 8 on Managing Protected Area Networks).

5.2 Methods for identifying options

It is important at this stage to identify a full suite of potential options, including options that currently seem impractical. To achieve this, the method used to brainstorm options must provide an environment where participants can express opinions freely and explore options that are novel and challenging, and potentially at odds with current practices. The process of brainstorming options will benefit from engagement of a range of stakeholders and a mix of subject-matter experts (climate scientists, ecologists, hydrologists), PA resource managers, PA decision makers (e.g. superintendents or directors), and citizens and others with local and/or traditional knowledge.

Many brainstorming methods are suitable for identifying adaptation options. Common techniques include scenario planning (Box 5.1), literature review and case studies, expert interviews and expert judgement via facilitated workshops, focus groups, and Delphi (a structured process for groups to reach agreement; see below). The most suitable technique will depend on factors such as availability of human and financial resources, expertise needed to organize the process, and cultural practices (see West and Julius, 2014b).

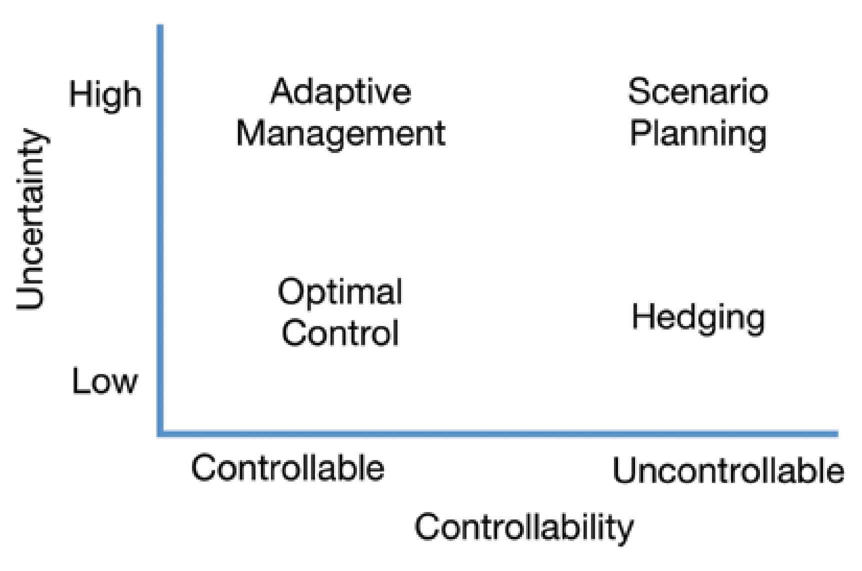
For example, Lemieux and Scott (2011) effectively used a Policy Delphi technique to identify and evaluate policy options for PAs in the Ontario (Canada) Provincial Parks system. This process differs from traditional Delpi by intentionally generating strongly opposing views on potential ways to resolve policy issues. A diverse group of participants, who can participate from many dispersed locations, anonymously and independently suggest, evaluate, and challenge potential options and solutions. While a conventional Delphi process seeks consensus, the Policy Delphi is designed to seek both consensus and disagreements on the issues. The Policy Delphi can be particularly useful where stakeholders are broadly dispersed and opportunities for face-to-face workshops are limited, or where anonymous participation enhances the ability to express ideas that are controversial or at odds with current policy.

Climate refugia are places naturally resistent to at least some of effects of climate change. Examples include areas near large, deep lakes that will warm more slowly, such as (above) this bay of Lake Baikal in Zabaykalsky National Park, Russia (Arkady Zarubin); and places with complex terrain, which promotes the retention of varied microclimates that are more resistent to climatic changes, such as at (bottom) Mount Rainier National Park, Washington, USA (GEDApix/GEDavis & Associates).

Box 5.1

What is scenario planning?

Scenario planning is a collaborative process undertaken to identify alternative scenarios (defined in Box 4.2), consider their implications, and explore actions or decisions that are most effective in preparing for and responding to changing conditions. Defence and disaster risk management organizations have long used scenario planning as a preparedness tool. Scenarios are extremely useful when organizations must evaluate challenging choices or make difficult short- and long-term strategic decisions under conditions of high uncertainty and low control over key variables.



Scenario planning is most appropriate for conservation planning when uncertainties about forces affecting the future are high and the ability of decision makers to control them is low (Peterson, et al., 2003).

Why do scenario planning?
The primary goal of scenario planning is to stretch thinking beyond current conditions to evaluate the most appropriate actions and preparations to take now. Scenarios enable PA managers and other decision makers to consider climate trends, account for surprises in their planning, and empower them to act. Scenario planning helps to identify specific strategies that address recent and anticipated changes. Some objectives in participatory scenario planning are to:

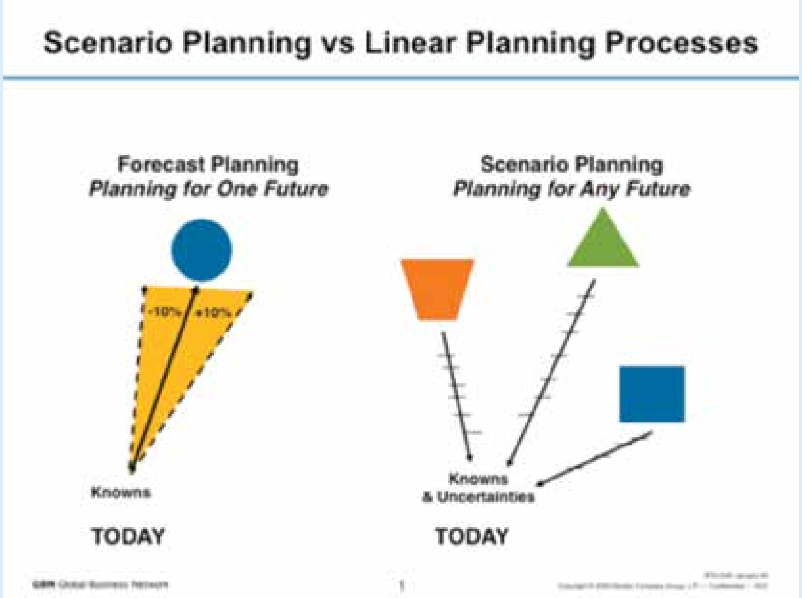
- *Facilitate conversation* to increase awareness and understanding of climate change impacts on PAs;
- *Stretch thinking* and promote long-range decision making—an alternative to linear planning processes;
- *Provide a structured process* for accessing the most relevant science, including what is known and what is uncertain;
- *Rehearse options* so that managers begin to be proactive instead of reactive; and
- *Train others* in techniques to build a more informed workforce that is knowledgeable about climate change.

Protected area managers can use scenario planning to focus on specific areas of concern and evaluate strategic choices or management actions with such questions as: Will we need to manage differently if future trends in rainfall patterns and drought result in a new fire regime? What management strategies will be needed if rising temperatures and increasing drought facilitate a more rapid spread of invasive species? What do we need to plan for if sea-level rise and storm surges significantly damage our resources and infrastructure, or permanently inundate portions of our PA when funding is limited?

Scenario planning is most effective with considerable up-front planning and workshop preparation. Scenario planning may not be appropriate when the management questions are vague or very broad, and/or when there is insufficient expertise available to construct a set of plausible and divergent alternative futures.

How does scenario planning work?
Scenario planning is structured to be a flexible process. In participatory approaches to scenario planning,

Box 5.1 (continued)



Scenario Planning vs Linear Planning Processes

Forecast Planning
Planning for One Future

-10%
+10%

Knowns

TODAY

Scenario Planning
Planning for Any Future

Knowns
& Uncertainties

TODAY

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1

interdisciplinary teams involve managers, planners, scientists, community members, and other PA stakeholders (NPS, 2013). The team considers the scientific input, which includes vulnerability and risk assessments, model forecasts, TEK, and other pertinent information. This team approach is an excellent tool for organizing diverse information and bringing it to bear on a complex problem in a transparent way. The resulting scenarios can be constructed as narrative storylines and/or quantitative expressions of future conditions, depending on the outputs needed. This sort of participatory scenario planning is now routinely used in many parts of the world to address climate change and natural resource management (e.g. NPS 2013; Oteros-Rozas, et al., 2015; Ruiz-Mallen, et al., 2015).

Scenario planning is an excellent way to engage a broad community of managers and others to explore plausible future conditions for a PA and its surroundings. Outcomes of scenario planning can include assessments of the vulnerability of resources and communities, evaluation of consequences of management alternatives, and identification of important future decision points. In some cases, the results from an initial exploratory exercise can provide inputs for subsequent planning and decision-focused efforts, helping to frame issues and suggest management alternatives. Scenario planning can be used in complementary ways with other methods and tools, including adaptive management, structured decision making, and iterative risk management (Rowland, et al., 2014).

What are the results?
A common product across all approaches is a finite "set of scenarios" that can be further refined, validated, and applied in various ways. Effective scenario sets must be plausible, relevant, challenging, and distinctive. Specific outputs from a scenario planning effort might include:

- Robust "no regrets" strategies that make sense for all the plausible climate scenarios.
- Strategy testing (sometimes called "wind-tunnelling") to evaluate what actions, approaches, or strategies will work or fail under various conditions.
- Evaluation of existing conservation goals and objectives and/or development of new or revised ones.
- Identification of existing actions that are ineffective, or even counterproductive, under some, most, or all plausible scenarios.
- Indicators of climate variables or impacts, or other key attributes, that may need to be monitored (see Chapter 7). Completing the process by articulating monitoring indicators helps to recognize future decision points, and develop indicators to determine when decisions should be made.

The outcome of scenario planning is an improved capacity to deal with a range of plausible future conditions and more effective decisions that take climate change into account. Scenarios developed by participatory processes achieve buy-in from the participants who create them and, if well-planned, the organizations and communities they represent. The results are then useful as entry points into further conversations and, in some cases, allow groups with divergent views to move past previous obstacles to conservation decisions. Regardless of the approach, scenarios provide an excellent tool for organizing information and exploring the future and the risks it poses to current decisions.

Box 5.2

Climate refugia

What are climate refugia?
Climate refugia are areas that promote the persistence of species and ecological processes during long-term climatic changes by continuing to support climate conditions that have been or are being lost due to climate changes. Biogeographical studies provide strong evidence that climate refugia have acted as safe havens from regionally adverse climates during glacial advances and retreats, and as sources of recolonization during more favourable climate periods. The concept of refugia is now being applied to challenges of contemporary climate change and broadened to consider their role in protecting populations from climate-driven disturbances such as fire (Mackey, et al., 2012).

Where are climate refugia?
The location of climate refugia will vary from species to species based on their life-history strategies, resource needs, and the rate of regional change. Nevertheless, climate refugia are likely to share common traits, including environmental stability, topographic complexity, and accessibility (Keppel, et al., 2015). The rate of climate change varies at local to regional scales. Climate data can be used to identify climatically stable regions; however, in practice, many gridded datasets lack the mechanistic detail or are too coarse for identifying refugia. In the absence of detailed climate data, areas of high topographic complexity can provide a reasonable approximation of locations with strong climatic gradients that may allow organisms to ameliorate climate changes through short-distance dispersal. Areas with persistent cold air pools or inland penetration of coastal fog, riparian corridors, seeps and springs, persistent snow fields, rock glaciers, talus slopes, areas of cold water upwelling (in marine environments), and sites of groundwater inputs to streams all create strong local gradients in thermal and moisture regimes and may act as potential refugia (for methods to identify refugia, see Dobrowski 2011; Keppel, et al., 2015; Mackey, et al., 2012). Further, metrics such as climate change velocity are being developed that characterize both climatic stability and topo-climatic heterogeneity. Although examples of marine climate refugia exist (e.g. coral reefs thermally buffered from regional ocean temperatures due to upwelling or turbidity), methods for identifying marine refugia are not well established. This may change as data on ocean temperatures and stressors improve (Cacciapaglia and van Woesik, 2016). In practice, identifying refugia based solely on abiotic conditions can be challenging; often, several lines of evidence are needed.


Deep snow drifts insulate the surface below and provide water later in the season: Yellowstone National Park, Wyoming, USA (NPS).

In addition to abiotic conditions, refugia can be assessed by identifying relict populations of species that were once more widely distributed. Disjunct and isolated populations of cold-adapted or heat-adapted taxa are often found in unique climatic settings. For instance, the presence of cold-adapted fish such as salmonids in warm regions may indicate freshwater refugia—stream or river reaches where groundwater inputs decouple water temperature from air temperature. Such settings are recognized as important habitat for cold-water fish populations (Isaak, et al., 2015). The presence of these populations provides direct evidence of refugia. However, the absence of such populations in potential refugia does not necessarily suggest unsuitable environmental conditions, but instead may reflect dispersal constraints created by barriers to movement (e.g. dams). More generally, the capacity of organisms to take advantage of potential refugia depends on the rate of regional climate change, the ability of organisms to move and colonize new areas, and the spatial distribution of refugia with respect to existing populations of threatened species. Landscape connectivity is indeed an important consideration for the effective use of climate refugia.

5.3 Summary

After evaluating the vulnerability of PA values, the next task is to revisit conservation goals to ensure they are still realistic. These goals are then used to identify adaptation options. Managers need to consider a range of possible futures that have different climates (wetter, drier, etc.; see figure in Box 4.2) and other stressors. Scenario planning (Box 5.1) is a technique that can help managers and stakeholders think about possible climate-change futures. Protected areas can use scenario planning, more traditional workshops, community meetings, or another process to identify options—an important outcome is to think creatively and consider a broad range of possibilities.

Adaptation options must be well suited for local conditions, while also considering the broader landscape context. This chapter describes general principles and adaptation options that are effective in many ecosystem types, at local to regional scales, and in response to a variety of climate and non-climate stressors. These principles and options are a good starting point for identifying options for a specific PA or conservation landscape. Climate change often acts as a threat multiplier, and many adaptation options will address existing threats, using existing practices at different times, in new locations, or in new combinations with other management practices.

Chapter 6

Selecting and implementing adaptation strategies

Chapter 5 identified a broad range of potential adaptation options that address key vulnerabilities. This chapter addresses the need to select, prioritize, and implement the best options for adaptation.

Climate changes are occurring at regional to national scales, while most near-term adaptation actions are local. Adaptation actions must therefore be appropriate for an individual PA, but still account for the landscape context within which the PA exists. To emphasize this critical point, we begin the chapter by orienting PA management decisions at the broader scale of a network. Once the scale of change is established, we then address the evaluation of options for a particular PA (identified using steps explained in Chapter 5). Selection criteria are established to help prioritize which adaptation strategies and options to carry out. We describe a continuum of strategies that can be used, depending on the magnitude of climate impacts expected or experienced, and how much active management is required. A final section addresses project implementation.

Decisions discussed in this chapter will be challenging for most PAs. Selection of adaptation actions will depend on answers to important questions: Which management actions will still be effective? How will species and ecological processes respond to changes? Which conservation goals might still be achieved? What revisions to goals are needed? What new actions or approaches should be considered? Creative thinking by managers and stakeholders will be required to evaluate options and strategies for effective adaptation.

These guidelines document describe a *process* for selecting adaptation options, not an exact recipe for how to do it.

6.1 Think and plan big

A distinguishing characteristic of a PA is its being “a clearly defined geographical space” (Dudley, 2013), but all PAs are influenced by factors outside their borders. This is especially true with respect to climate impacts, which will affect ecological values at local to global scales. As a result, adaptation will also need to be effective across a broad range of scales. In practice, most adaptation planning tends to be at a very broad scale that considers networks of PAs and how the aggregate area conserves nature, or on actions that are implemented at the scale of a single PA and areas adjacent to it. Adaptation practices for conservation systems (which include PAs and surrounding lands managed as a connected system) are introduced below and discussed in more detail in Chapter 8 on Networks. The main focus of this chapter is on selecting adaptation actions that best meet the local needs of a PA.

Best practice 6.1: Plan for climate change adaptation options at the level of protected area systems
Overall, PA managers must plan for a conservation *network* or *system,* which includes PAs and well-managed landscapes and seascapes, that are resilient and adaptive to climate change. Below are guidelines that will help design such a system:

Connectivity conservation projects are now well established around the world. (Left): Jeep track in Shuklaphanta Wildlife Reserve, Nepal, part of the Terai Arc Landscape project, which spans over 5 million hectares in India and Nepal (Ganesh Paudel). (Right): Waterfall in the Paratiisikuru valley, Urho Kekkonen National Park, Finland. The park is part of the European Green Belt Initiative, which roughly follows the line of the old Iron Curtain (Matti Paavola).

1. Consider an individual PA in the context of a well-planned conservation system that will have intact, functioning landscapes and seascapes composed of large protected core areas, smaller protected sites, and measures that maintain or enhance ecological connectivity in the areas between sites (see Chapter 8). The CBD's Aichi Target 11 (http://www.cbd.int/sp/targets/) calls for expansion of PA systems, more effective management, better planning to conserve biodiversity and ecosystem services, and measures to ensure ecological networks. This provides an opportunity for planners to add to existing PAs to make them more adaptive to climate change. It also provides an opportunity to develop ecological connectivity by maintaining or restoring linkages.
2. Plan for a mix of PA sizes in the system, but prioritize for very large representative units. Large, intact PAs will generally have larger populations of any given species, with resulting increases in adaptive resilience that are inherent in larger, more genetically diverse populations. Large PAs generally have more scope to allow species to move across landscapes in order to track suitable climate conditions (Watson, et al. 2011).
3. Where possible, plan PA units that represent altitudinal gradients and have high topographic/physiographic diversity (a mix of valleys, plains, mountains, ridges, etc.) to maximize the potential for climate refuges. This applies on land and in the sea. Ensure that conservation planning encompasses the full spectrum of physical features, defined by elevation, geology and other physical factors (Beier and Brost, 2010; Anderson, et al., 2015).
4. Ensure that the legal and regulatory framework allows PA managers the flexibility to adapt to climate change. For many PAs, governing laws and regulations are written in ways that obligate agencies to manage for persistence, whether in maintaining species or lands or waters in a particular condition. Persistence may be an unrealistic goal for the future and it may not be practical to use past conditions as benchmarks for ecological restoration.
5. Ensure landscape and seascape permeability by retaining and/or enhancing connectivity. Again, prioritize the protection of large, intact ecosystems. Intervening landscapes and waterscapes between formally designated PAs may be critically important to allow species movement and migrations. There are excellent references on this topic, such as *Connectivity Conservation Management: A Global Guide* (Worboys, et al., 2010) or *Assessment and Planning for Ecological Connectivity: A Practical Guide* (Aune, et al., 2011). IUCN is developing a new standard on connectivity conservation areas that will also provide guidance.
6. Wherever possible, integrate PAs into surrounding landscapes so that there is joint planning for and consideration of connectivity, transboundary wildlife populations, etc. The overall aim should be to improve natural resource planning and management to focus on preserving and restoring ecosystem functionality and processes across regional landscapes. There are many global examples where integration has happened, both formally and informally. These include biosphere reserves, buffers zones around protected areas, and conservation agreements with framers and ranchers.

Connectivity conservation projects are now well established around the world. (Left): Gondwana Rainforest pathway in Dorrigo National Park, New South Wales, Australia. The park is part of the Great Eastern Ranges Initiative, which connects people and nature along a 3,600-kilometer corridor (Andrea Schaffer). (Right): A pepper treefrog (*Trachycephalus typhonius*) in Río Plátano Biosphere Reserve, Honduras), part of the Mesoamerican Biological Corridor (Marcio Martinez).

7. Regularly review PA boundaries to see if adjustment is necessary to help achieve commitments in the face of climate change.
8. Managers of marine ecosystems can refer to specific guidance for incorporating climate adaptation into marine PA site and system planning (e.g., Brock, et al., 2012; Green, et al., 2014; Day, et al., 2015).

These guidelines describe a process for selecting adaptation options, not a recipe.

6.2 Evaluating and prioritizing adaptation options

This section describes a general process for evaluating adaptation options that applies across the whole range of strategies. Most situations will start with a “coarse-filter” evaluation to quickly identify a smaller subset of options that merit a more detailed (and time-consuming) examination. The evaluation may need to be iterative, because the range of suitable options may limit the selection of an adaptation strategy, or motivate a re-examination of conservation goals and a shift to a new strategy. The options need to address conservation goals, but the lack of suitable options can also require revision of desired goals and adaptation strategies.

Previous work involving stakeholders and experts to identify potential adaptation options should have resulted in a list of potential actions that will far exceed available resources (Chapter 5). These options will likely vary considerably in terms of cost, feasibility, likelihood of success, and other criteria. Some adaptation actions will be effective soon after they are begun, while it may be years before the benefits of others are apparent. The importance of evaluation criteria depends on the local situation, so the relevant stakeholders should identify and agree on a final list. General categories of criteria include effectiveness towards meeting conservation goals, meeting other goals and values, feasibility, and consistency with ClimateSmart best practices (Hoffman, et al., 2014; Table 6.1). For those PAs where nature conservation is the highest priority, Table 6.1 lists more specific criteria in each category. PAs that provide essential services (e.g. fuels, food, medicinal plants) to Indigenous and local communities will likely need to include additional criteria. There is a large and increasing body of evidence that effective conservation—including climate adaptation—is best achieved when there are positive socioeconomic outcomes for local communities (e.g. Oldekop, et al., 2016). Integration of adaptation and other societal goals is discussed in detail in Chapter 9.

Best Practice 6.2: Select strategies by evaluating adaptation options

For PAs managed for biodiversity, the most important consideration is that the adaptation action be specifically linked to an important conservation goal. All adaptation actions should contribute directly or indirectly to conserving nature, including ecosystem services. The best actions will (1) address an important conservation goal, (2) be feasible and low-cost; (3) have a high probability of success; and (4) still be effective under projected futures in the climate scenarios. These “no-regrets” actions should be a high priority. A common outcome of the evaluation process is to find that some actions, which may include current practices, are ineffective—or even maladaptive—under some or all scenarios for the future climates. This is an important insight, because resources directed to ineffective practices can be redirected to support more effective actions that address emerging climate impacts. Achieving some criteria in Table 6.1 will require considerable effort in conservation planning and they may best be thought about as part of broader conservation planning exercise (see Groves, et al., 2012)

After identifying a set of evaluation criteria suited to local circumstances, one way to initially rank actions or projects is to assign a score (e.g. 1–5) to each criterion, add up the scores, and sort the actions by the overall score. Individual criteria, or categories of criteria, can be weighted differently to reflect the importance of attributes. Ranking all options with a consistent set of criteria can often quickly separate actions that are simply not competitive or feasible from those that require more serious consideration. But always recognize that ranking scores are subjective and they should be used only to inform decisions, not to make a final one. In some cases, actions that address important conservation goals may weigh somewhere in the middle ground for cost and feasibility, in which case trade-offs and risks for failure must be considered.

Once the full set of alternatives has been examined and reduced to a smaller set for final selection, each of the remaining options can be more carefully examined (see full discussion in Groves and Game, 2016). Scenarios are particularly useful at this stage. One informative way scenarios

Table 6.1. Criteria that can be used to evaluate and prioritize adaptation options.

Addresses an important conservation goal
• Mitigates a key vulnerability • Increases population performance • Habitat improvement • Enhances water flow • Increases resilience to disturbances • Effective at short and long periods
Other goals and values
• Time to implement and achieve benefits • Social and economic benefits • Stakeholder acceptance or conflicts • Consequence of no action • Risks or hazards • Ability to monitor and track effectiveness
Feasibility
• Robust to climate scenarios • Institutional and local capacity • Consistency with laws and policy • Likelihood of success • Cost • Opportunities for funding and partnerships • Responsibility for long-term maintenance and upkeep
ClimateSmart considerations
• Robust to future uncertainty • Embraces forward-looking goals • Considers broader landscape • Flexible to future changes and needs • Avoids maladaptation

Damage from catastrophic storms may be so extensive that PA managers have no choice but to retool their goals and objectives: aftermath of Hurricane Stan, Mexico (© IUCN / Marco Calvo).

have been used is to project changes for different periods and evaluate whether options remain suitable under different scenarios at shorter and longer periods in the future (Figure 6.1).

Adaptation strategies reflect realistic options and desired outcomes

Once key vulnerabilities have been identified (Chapter 4) and options evaluated, a picture of possible future management strategies will begin to emerge. If the PA is in a region where recent climate changes are relatively small and ecosystems are largely intact and resilient to current and projected climate and non-climate stressors, then a possible outcome may be to preserve all of the current biodiversity. In the more distant future, very few PAs will remain largely unchanged. For many, the first climate adaptation strategy will be to “buy time” by managing to retain current ecological value. This period of persistence can be effectively used to increase staff knowledge and capacity for adaptation, to develop more forward-looking management objectives, and to monitor and increase understanding of ecosystem responses.

Best Practice 6.3: Align options with desired outcomes

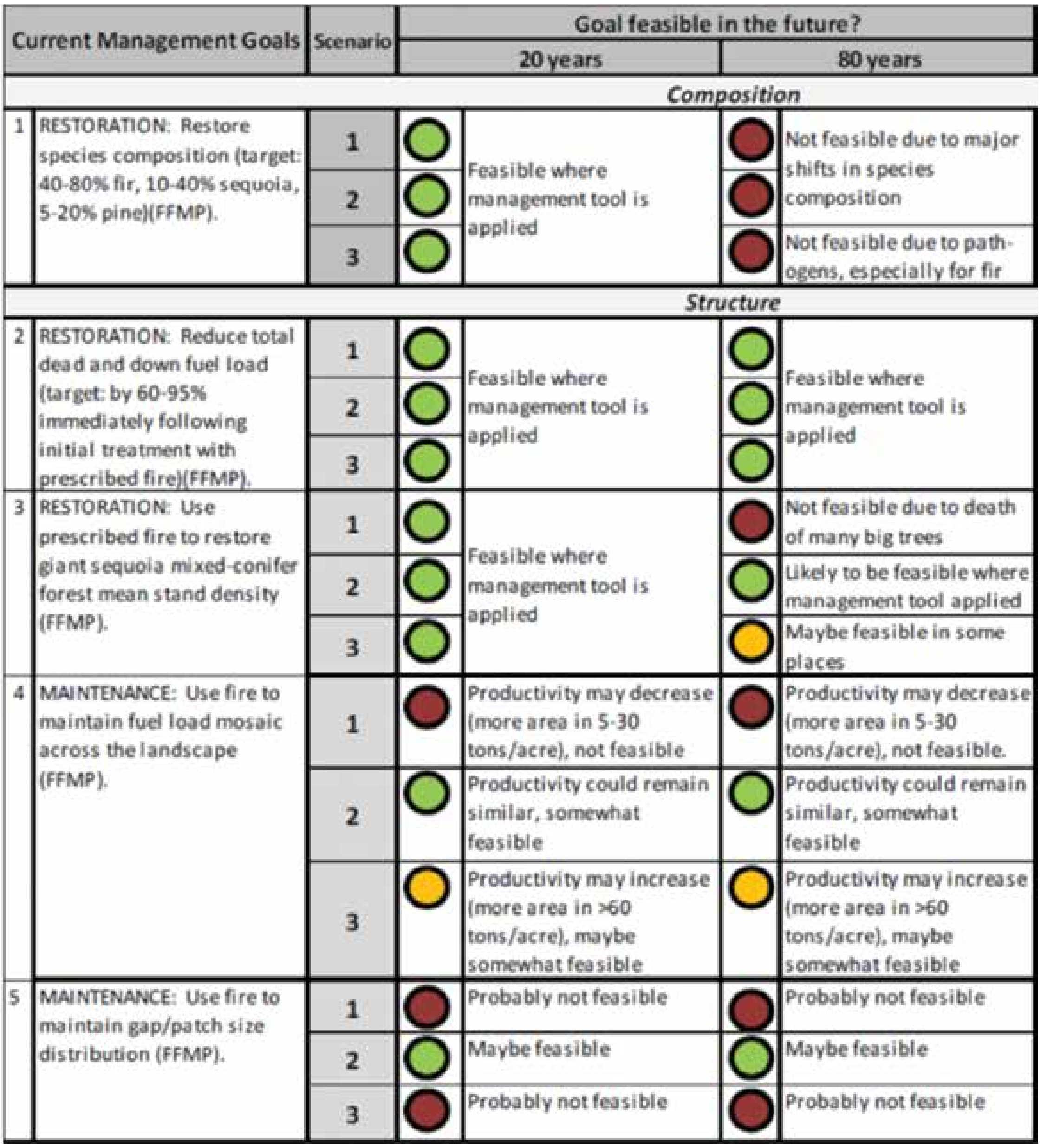
Final selection of an adaptation strategy will be mostly determined by three major factors: the conservation goals for the PA or value, the magnitude of anticipated changes, and the intensity of effort that can realistically be directed to management (Figure 6.2). Given these factors, it will be necessary to develop a strategy composed of options that will most likely lead to a desired outcome. A broad range of adaptation actions can be categorized into strategies that can be generally described as persistence, resistance, accommodating change, and directed change. These are illustrated in Figure 6.2 and described below.

Examples of strategies

We describe potential actions and characteristics of four example strategies (Figure 6.2) that differ in the anticipated magnitude of climate impacts and the vulnerability of the ecological values to those changes, and the intensity of management required to achieve a particular outcome. The four strategies are not exclusive and it can be appropriate to cycle between them. Most PAs with an established management plan will use elements from different strategies at the same time, but for different values. The appropriate strategy will likely differ between species, habitats, or ecosystems, reflecting different vulnerabilities, management priorities, and ability to affect change.

Strategy 1: Supporting ecological integrity to allow greater resilience to changing climate

This strategy can be appropriate in PAs where VAs or other information indicates there is high probability of retaining ecological values and ecosystems by applying currently understood best management practices that promote resilience to climate changes. Climate adaptation is



	Current Management Goals	Scenario	Goal feasible in the future?			
			20 years		80 years	
			Composition			
1	RESTORATION: Restore species composition (target: 40-80% fir, 10-40% sequoia, 5-20% pine)(FFMP).	1	🟢	Feasible where management tool is applied	🔴	Not feasible due to major shifts in species composition
		2	🟢		🔴	
		3	🟢		🔴	Not feasible due to pathogens, especially for fir
			Structure			
2	RESTORATION: Reduce total dead and down fuel load (target: by 60-95% immediately following initial treatment with prescribed fire)(FFMP).	1	🟢	Feasible where management tool is applied	🟢	Feasible where management tool is applied
		2	🟢		🟢	
		3	🟢		🟢	
3	RESTORATION: Use prescribed fire to restore giant sequoia mixed-conifer forest mean stand density (FFMP).	1	🟢	Feasible where management tool is applied	🔴	Not feasible due to death of many big trees
		2	🟢		🟢	Likely to be feasible where management tool applied
		3	🟢		🟡	Maybe feasible in some places
4	MAINTENANCE: Use fire to maintain fuel load mosaic across the landscape (FFMP).	1	🔴	Productivity may decrease (more area in 5-30 tons/acre), not feasible	🔴	Productivity may decrease (more area in 5-30 tons/acre), not feasible.
		2	🟢	Productivity could remain similar, somewhat feasible	🟢	Productivity could remain similar, somewhat feasible
		3	🟡	Productivity may increase (more area in >60 tons/acre), maybe somewhat feasible	🟡	Productivity may increase (more area in >60 tons/acre), maybe somewhat feasible
5	MAINTENANCE: Use fire to maintain gap/patch size distribution (FFMP).	1	🔴	Probably not feasible	🔴	Probably not feasible
		2	🟢	Maybe feasible	🟢	Maybe feasible
		3	🔴	Probably not feasible	🔴	Probably not feasible

Figure 6.1. Evaluating the suitability of adaptation options for different periods and future climate scenarios. Green, yellow, and red represent suitable, maybe suitable, and unsuitable options. Scenario numbers refer to different future climate scenarios, where 1 is much warmer and drier, 2 is warmer with precipitation similar to current, and 3 is much warmer and much wetter (NPS, forthcoming).

distinguished from routine good management by the explicit consideration of climatic impacts and the use of actions that would not otherwise be taken. We know that many PAs are not currently managed to acceptable standards. For many poorly managed PAs, the first step to effective adaptation is to develop plans that explicitly include climate considerations, and to establish an effective management regime.

Strategy 1 applies to situations where (1) basic management practices can be used to increase the integrity of the system and thus its resilience; and (2) managing for persistence (i.e. retaining historical conditions and values) will continue to be appropriate, at least in the short term, and in a few instances over the longer term. With Strategy 1, existing conservation goals are maintained. However, it is useful to also consider the PA itself as a system, and manage it for ecological integrity and resilience. Climate adaptation is more likely to succeed when PAs have goals for the broader ecosystem or landscape, rather than just for species or particular features. Considering the PA as a system will better integrate climate adaptation options that include areas outside PA boundaries as well as changes within.

Characteristics of Strategy 1:

- Retains current conservation goals.
- Assesses current and expected climate impacts, even with limited knowledge.
- Relies on existing management practices, but uses them at different times, places, or intensities, or in new combinations, to support ecological resilience to climate impacts. The link between a practice and a climate impact is explicit (see Best Practice 2.4).
- Supports and promotes the existing ecological capacity

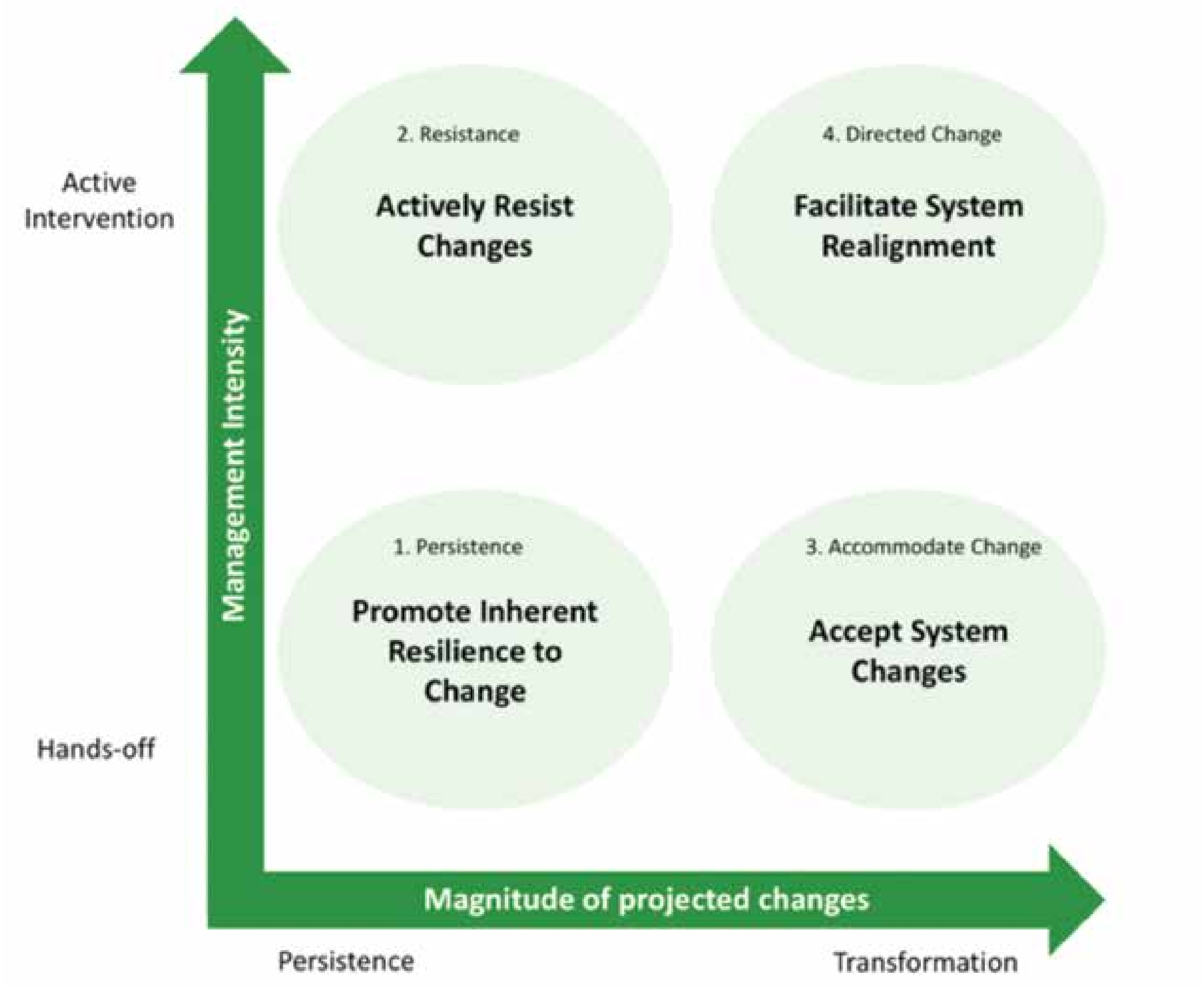


Figure 6.2. Examples of possible adaption strategies based on the magnitude of observed or projected changes, and the intensity of management effort. Numbers refer to descriptions of strategies in the text (modified from Stein, 2016).

of the systems to resist change.
- Tends toward low-intensity and non-invasive management efforts.

Ecological integrity has been chosen as a management goal by many PA agencies around the world. It recognizes that individual valued features (e.g. species) are part of a larger ecosystem and exist because that system is intact. The notion of ecological integrity has been discussed from many perspectives and, with respect to a PA, can be defined as:

> *a condition characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change, and supporting processes* (adapted from Parks Canada, 2000).

Resilience to climate change and the concept of ecosystem integrity are interconnected (Case Studies 6.1 and 6.2). Loss of ecological integrity, as measured by species loss, reduces the efficiency with which ecological communities function, including the production of biomass and the decomposition and recycling of biologically essential nutrients (Cardinale, et al., 2012). Further, there is mounting evidence that some elements of biodiversity (including species diversity and overall richness) increase the stability of ecosystem functions through time. Many existing practices can contribute to persistence if they reduce stressors that are exacerbated by climate. This can include control of invasive species, reducing pollutants, and habitat improvement and restoration.

One way to manage for persistence is to increase protection of habitats that are likely to be less affected by climate changes than the region or species in general. For example, water temperatures in some headwater streams in the north-western USA are warming more slowly than air temperature (Isaak, et al., 2016). The relatively small temperature changes are found in streams with high gradients, resulting in very low climate velocities (i.e. low rates of movement will be needed to remain in an area of suitable climate). These slow-changing

Resilience (of ecosystems) is the capacity of a system to absorb disturbance and reorganize while under-going change so as to still retain essentially the same function, structure, identity, and feedback (Walker et al 2004).

Case Study 6.1

Strategy 1—Supporting ecological integrity and climate resilience

Loggerhead turtle management. A VA evaluated the long-term resilience to climate changes of loggerhead sea turtle (*Caretta caretta*) populations nesting in Reserva Natural da Tartaruga and other beaches on the island of Boa Vista (Republic of Cape Verde, West Africa) (Abella Perez, et al., 2016). The Cape Verde loggerhead turtle population is the third largest in the world, and about 90% of nesting appears to be on Boa Vista. Based on seven characteristics that contribute to adaptive capacity of the turtles, the VA found that this population is likely to be highly resilient to increasing temperatures due to specific features of their habitat use and habitat preferences. An effective climate adaptation strategy for persistence would therefore include (1) special protections for beaches most likely to remain suitable as temperatures rise, and (2) management to reduce non-climate stressors such as human harvest.

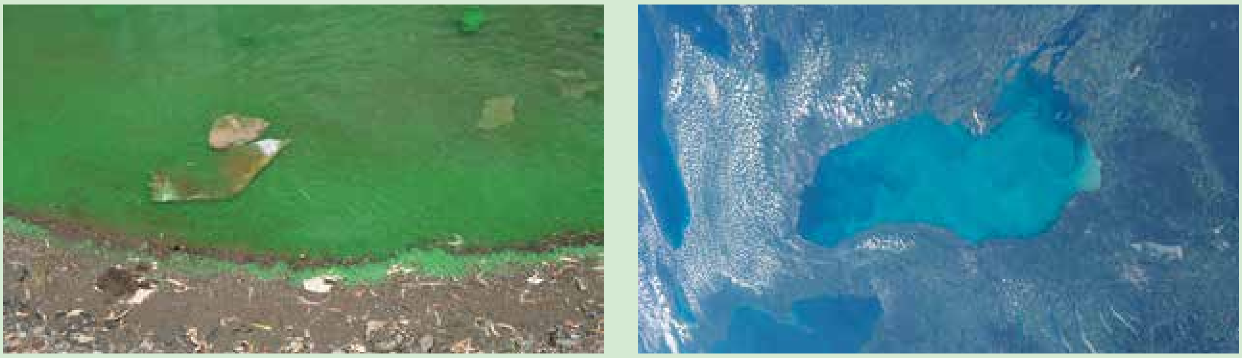
Beavers for riparian restoration. Restoration of ecosystem function can be an effective means of climate adaptation. In the western USA, beaver (*Castor canadensis*) are being reintroduced to ecosystems where climate change is altering patterns of snow melt and runoff, resulting in loss of wetlands and riparian habitats. Beavers build dams that impound water and slow runoff, thereby enhancing riparian vegetation and increasing groundwater levels. As ecosystem engineers, beaver are effectively increasing the resilience of the systems to climate-driven changes in hydrology (Beaver Management Team, 2014).

Loggerhead sea turtle (*Caretta caretta*) (Brian Gratwicke).

Case Study 6.2

Strategy 2—Conserve ecological values by actively resisting change

Active management of known threats that will be exacerbated by climate change. Pollution of water by runoff of agricultural fertilizers, animal waste, and sewage is a common problem, leading to high levels of nitrogen and phosphorus that result in unnatural growth of plants and harmful algal blooms. Such blooms are more common at higher temperatures and produce toxins that are harmful to fish, wildlife, and humans. Further, the death and decomposition of algae leads to hypoxia (very low oxygen concentrations) in water bodies (Pinkney, et al. 2015). In the north-eastern USA, the interaction of climate change and pollutants has led to an increase in the area affected by algal blooms, and to the death of thousands of birds (Pinkney, et al. 2015). Water pollution in PAs is widespread, and actions that resist nutrient pollution of water bodies are likely to increase climate resilience.



Algal blooms, up close and far away. (Left): Algae on shoreline (Lynn Greyling). (Right): Satellite image of big bloom in Lake Ontario, Canada/USA (NASA.)

stream reaches are projected to remain suitable for cold-water fish species much longer than would be predicted from regional rates of temperature increases. Most of the identified slow-changing stream reaches are currently not fully protected, and they are thus high-priority sites for preserving existing ecological integrity and the fish and other biota that require cold water (Isaak, et al., 2015).

Strategy 2: Conserve ecological values by actively resisting change

For many PAs, it will be necessary to use ongoing active management to conserve high-value and/or irreplaceable assets. Strategy 2 assumes that PA managers actively manage to maintain ecological values and *the ecological value would not likely persist without ongoing active intervention, but is likely to persist with it.* This situation is already very common in contemporary PA management, even in the absence of climate change. There is a wide range of conservation-dependent or conservation-reliant species—those that require regular and ongoing conservation actions to remain viable (Scott, et al., 2010).

A resistance strategy (Figure 6.2) may be the best immediate option for many PAs and the only feasible option for iconic or endangered species, or to preserve a community that occurs nowhere else. A resistance strategy may buy time and permit the PA to identify additional adaptation efforts that will be required when current conditions cannot be maintained.

Characteristics of Strategy 2:

- Builds on current good management practices.
- Uses management interventions, some of which may be intense, to actively resist change.
- Relies on existing management practices, but used in new ways. Novel practices may also be adopted.
- Is not, generally, a system-level approach.

For example, more frequent extreme climate events will likely lead to periods of ecological scarcity, which can cause catastrophic population declines and the abandonment of historical ranges (reviewed by Maron, et al., 2015). It may therefore be necessary to provide supplemental food, water, or shelter to support survival of certain species during periods of extreme weather in areas where active management was not needed in the past.

There are limits to the amount of change that can be addressed through Strategy 2. There are ecological or physical thresholds beyond which adaptation responses are unable to prevent climate change impacts (e.g. temperature thresholds for organisms, such as thermal stress in corals or cold-water salmonids). For infrastructure, economic thresholds also exist, whereby the costs of adaptation may exceed those of the averted impacts (e.g. it is more expensive to adapt than to experience the impacts). Finally, there are thresholds beyond which available technologies cannot avert climate impacts

Already-scarce water supplies in dry regions are going to come under immense pressure as the planet continues to warm: aerial view of the channels in Banc d'Arguin National Park, Mauritania (IUCN Photo Library / © Hellio–Van Ingen).

Non-climate stresses on PAs, such as this deforestation outside Taman Negara National Park, Malaysia, may make it harder for managers to pursue strategies of resisting ecological change (IUCN Photo Library / © T. Brooks).

(e.g. limits to captive breeding of particular species for later reintroduction). In practice, the latter two thresholds are highly influenced by society's attitudes toward risk, values, and ethics (Adger, et al., 2009). Strategies 3 and 4, discussed next, address these situations.

Strategy 3: Accommodating significant ecological change
Strategy 3 requires an explicit move away from existing conservation goals when it is no longer possible to rely on ecological resilience (Strategy 1) or active management (Strategy 2) to preserve ecological values. In Strategy 3, managers must fully consider the implications of climate impacts and revise their goals accordingly.

Strategy 3 may be undertaken when observations show that the PA's species and ecosystems are already undergoing significant climate-driven change, or that major changes are imminent. However, for a given PA, not all the species and ecosystems will be affected at the same rate or be altered to the same degree. For example, in a grassland park, the freshwater streams may change dramatically but the grassland component might remain relatively intact. In a marine system, the seagrass beds might disappear but the offshore benthic (sea-bottom) communities remain relatively intact. In Strategy 3 a manager will have to re-write the goals for the PA to accommodate climate impacts, but with more incremental changes in mind than those that will be discussed under Strategy 4. In many situations, we already manage PAs that have changed. Many exist without top predators, or have highly altered individual ecosystems or parts of ecosystems. Australia's Great Barrier Reef Marine Park, for example, lost 50% of its coral cover in the last 20 years, mostly from non-climate stressors (Brodie and Waterhouse, 2012). Climate change is now exacerbating these stressors. In early 2016, an ongoing bleaching event caused by extremely high water temperatures affected 93% of reefs in the park (Figure 6.3), but the reef still has very significant ecological values.

A PA may choose to use an accommodation strategy, or it may be forced to do so. If a PA fails to develop capacity (Chapter 3), anticipate changes, and take other actions to be climate-ready, they will likely be "surprised", and Strategy 3 will be the only available choice. In other cases, even a well-prepared PA may have to adopt Strategy 3-type accommodations because no others are feasible.

Characteristics of Strategy 3:

- Requires new conservation goals in the face of current or expected major ecological changes.
- Responds to changes, but does not attempt to direct them in a significant way, other than to avoid highly undesirable outcomes.
- May result in new management practices that are appropriate for changed systems.

Strategy 4: Facilitating change: Moving to new ecological goals and managing novel ecosystems

Strategy 4 is for those situations where current or inevitable climate change are pervasive and new ecosystem types have become established or soon will be, and the developing ecosystems will be very different from the original ones for which the area was established.

A key question for Strategy 4 is: What are the new conservation values of the area? The answer to that depends on many factors. PAs are very difficult to establish and their value as providers of ecosystem services, species refuges, components of overall ecological connectivity, and human connection to nature goes far beyond whether a particular species or ecological community is present or lost (Stolton and Dudley, 2015). Species will be moving both out of and into PAs over time. Even though the PA has changed, it will almost certainly remain valuable for many reasons. It might conserve rare species, provide ecosystem services for local communities, or be an important part of a network of PAs. A process to engage stakeholders to determine new values, reflected in new goals and management actions, will be needed.

As the magnitude and extent of climate change increases, it is only matter of time before incremental adaptation will be inadequate for some PAs. There is an increasing number of PAs—in the Arctic, along coasts, and elsewhere—that are already experiencing transformational changes in their ecosystems. Feasible options depend on how long the transition takes and what new values will emerge and merit protection. Transformations can occur suddenly with fire or flood, or slowly as established tree species are gradually replaced by others that are more suited to current conditions.

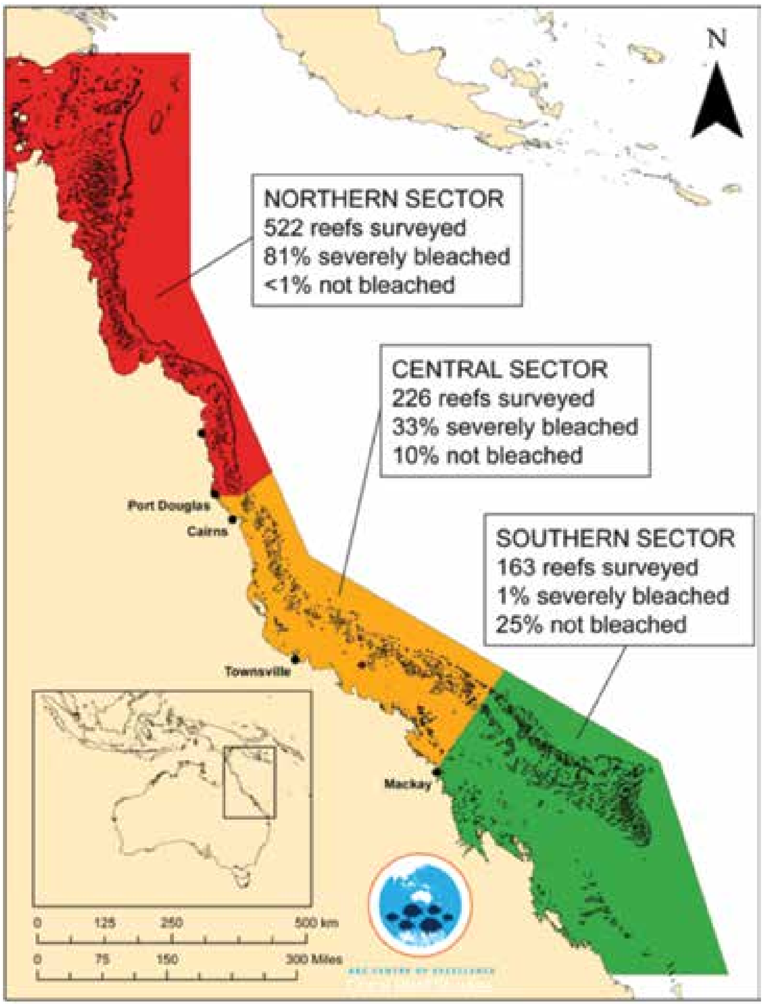


Figure 6.3. Map showing rates of coral bleaching in April 2016, during an ongoing period of extremely high ocean temperatures. Mortality of corals was estimated to be about 50% of bleached corals in the northern sector (ARC Centre of Excellence for Coral Reef Studies / James Kerry).

Transformational adaptation is a difficult, long-term process that requires strong leadership and major up-front investments in planning and outreach (Kates, et al., 2012). Implementation will require sustained commitment. Many actions that support directed change will be controversial. They might involve moving species to locations outside their known range, using prescribed fires to create "corridors" that facilitate upslope migration and establishment of lower-elevation species, or manipulating animal populations to reduce competition and promote establishment of new species.

Characteristics of Strategy 4:

- Requires new conservation goals, based on revised values of the PA.
- Needs a high level of stakeholder engagement and support.
- Intervenes actively to direct ecological changes toward a desired state, and/or to avoid undesirable conditions.
- Adjusts plans and options to a range of possible ecological outcomes.

With transformational change, it will be important to decide whether or not to hasten the transformation to a new ecosystem type through active management, such as species translocations and assisted colonization (Box 6.1).

6.3 Implementing adaptation

After actions and strategies are determined, the adaptation plan needs to be fully implemented if it is to make a difference (Figure 6.4). Established best practices for how to carry out existing conservation also apply to climate adaptation projects (e.g. CMP, 2013). Excellent detailed guides to conservation project implementation include Groves and Game (2016) and Worboys, et al. (2015); appendix C in NAS (2015) is a very good, short summary of implementation steps and issues. However, there also are certain aspects of climate adaptation projects that merit special attention.

Because adaptation activities may address threats or impacts that are projected to occur in the distant future or are just emerging, PA managers engaged in adaptation planning and implementation may find it necessary to explain their approach and reasoning to an even greater extent than they do currently. Leaders and stakeholders will need to be educated about the importance of framing near-term decisions within the longer-term climatic context. This is why it is important to ensure the actions address impacts that are considered particularly relevant to the PA in question (Best Practice 2.4; key vulnerabilities in Section 4.5).

Similarly, the scale of climate impacts means that many adaptation projects will need to be carried out in or expanded to areas well beyond the jurisdiction of the PA. To be successful, considerable effort will be needed to build support for the project, keep stakeholders informed and engaged, and coordinate with partners. The need to build inter-disciplinary and multi-sectoral alliances for adaptation—and to employ effective communication practices—is addressed in more detail in Chapter 3.

Adaptation is a new field of integrated science and management. A key role for early adaptation practices is education: as demonstration projects, to share and learn with stakeholders, and to contribute experiences to the broader conservation community. Compendia of case studies include IUCN Panorama PA Solutions (http://www.solutionsexplorer.

Box 6.1

Assisted colonization

Assisted colonization (also called *assisted migration*) is the intentional translocation of species to establish them in a new location. Climates projected for the 21st century will likely exceed many of the thresholds to which species are adapted, regardless of any management interventions. In such situations, very difficult decisions will be required to decide which species can be saved, and where. “Conservation triage” may emerge as a critical process in the prioritization and selection of which species to assist, along with ethical dilemmas related to such decisions (Schwartz, et al., 2012).

Three different types of assisted colonization can be identified (Ste-Marie, et al., 2011):

1. **Assisted population colonization:** The movement of populations with different genetic makeups within a given species’ current range. This speeds up a process in which the species is likely to have spread anyway.
2. **Assisted range expansion:** The movement of a given species to areas just outside its current range, mimicking how it would naturally spread.
3. **Assisted long-distance migration:** The movement of a given species to areas far outside its current range (beyond where it would naturally spread).

Assisted population migration (type 1 above) and assisted range expansion (type 2) are currently used for climate adaptation in many parts of the world, primarily in forestry and agriculture to bring in genetic varieties to match a changed climate (Ste.-Marie, et al., 2011). Assisted long-distance migration (type 3) should only be considered where a species is likely to go extinct in the wild. This type of assisted migration is riskier than the other two because it involves introducing new genetic stock that may significantly impact the ecosystem into which it is introduced. There are varying perspectives on using assisted migration as an adaption tool, and it should be very carefully assessed for risks and benefits (IUCN, 2013; Richardson, et al., 2009). The wise use of assisted migration will vary according to the goals and objectives for the PA and the intervening landscapes and waterscapes.

(Top to bottom): Various species at the limit of their ranges, such as the American pika (*Ochotona princeps*), western larch (*Larix occidentalis*), and Siberian crane (*Leucogeranus leucogeranus*), are among those that have been broached as possible candidates for assisted colonization—a method hotly debated among conservation biologists.

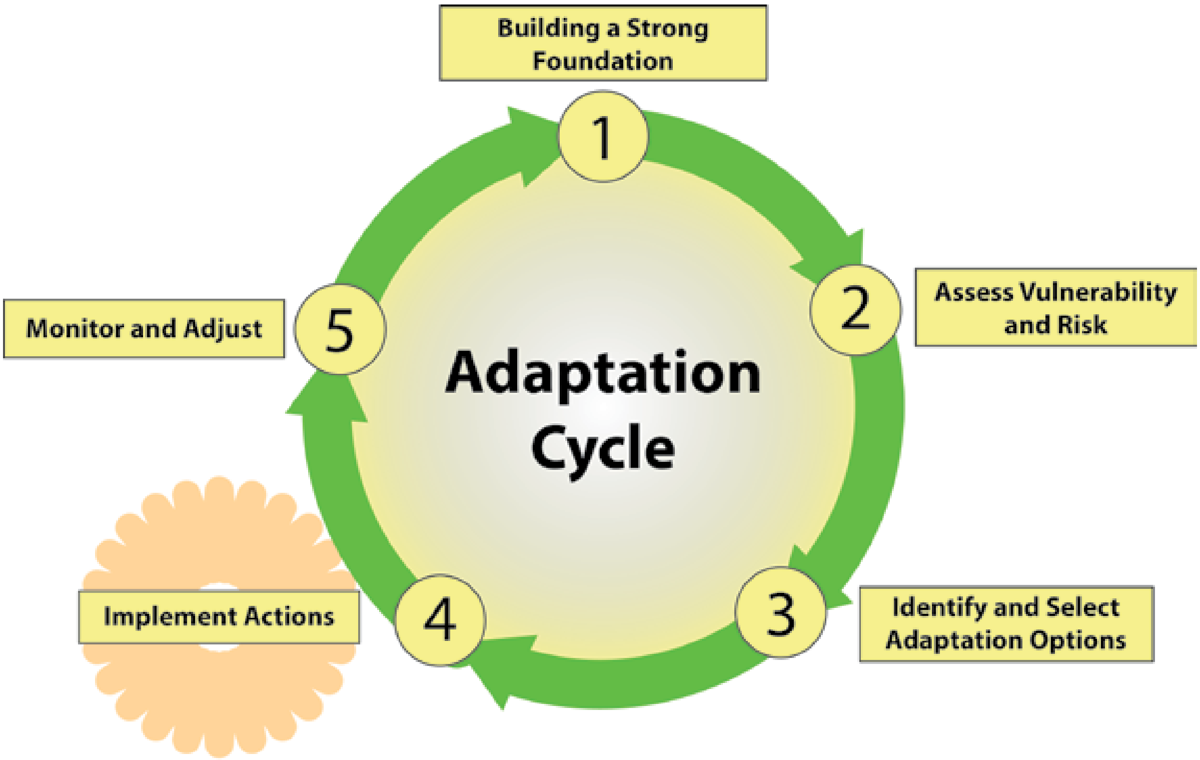


Figure 6.4. Step 4 in the adaptation cycle is to implement the actions that have been identified and prioritized as being the most appropriate. As with all steps in the cycle, this is an iterative and ongoing process (adapted from EEA, 2015).

org/), the Climate Adaptation Knowledge Exchange (http://www.cakex.org/), Schupp, et al. (2015), Murti and Buyck (2014), and online sites described in the Appendix.

6.4 Summary

This chapter describes ways to select adaptation options and strategies. While presented here as a process that proceeds from goals to options and then to a strategy, in most situations the process is not linear. Adjustments and iterations will likely be necessary to allow for ongoing re-evaluation as understanding and learning increase. Adaptation requires flexibility and an adaptive management framework (see Chapters 3 and 7). No single strategy is likely to address the wide variety of values that occur in a PA, and managers will need to engage in a process of continual learning, evaluating, and modifying plans and actions.

Sandgrouse in Negev Desert, Israel. Many species that inhabit desert ecosystems are very vulernable to climate change as their water sources disappear. (Liana Joseph)

The red goshawk (*Erythrotriorchis radiatus*), Australia's rarest bird of prey, is increasingly endangered through habitat change caused by changed fire regimes which are thought to become more problematic as the climate warms across the north of the continent (James E.M. Watson).

Populations of the red knot (*Calidris canutus*) may be falling because of climate-induced changes to its food supplies all along its migratory route from the Arctic to the tropics (Dick Daniels).

Studies show that many Asian bird species, such as this verditer flycatcher (*Eumyias thalassinus*) are likely to suffer under future climate change, and will require enhanced protection of important sites, better management of the wider countryside, and in some of the most extreme cases assisted colonization to help them survive (Raju Kasambe).

Chapter 7

Monitoring, evaluation, and adaptive management

Most PA managers are just beginning to plan for and carry out climate adaptation and there is still much to learn. Some aspects of climate change are certain, but we do not fully understand how ecosystems will respond, nor which management actions are most effective. The best course of action is thus to employ flexible management and "learn by doing". This involves monitoring and then adjusting management based on what we learn (Figure 7.1). Even with the most forward-thinking, climate-informed goals and objectives, changing conditions and ecological interactions can result in outcomes that differ from expectations. In the context of climate adaptation, the need for "learning by doing" is imperative, and monitoring, evaluation, and adaptive management are key elements to a future of effective PA management.

7.1 Monitoring and evaluation go hand in hand

Monitoring is best thought of as both monitoring and evaluation (M&E). The evaluation component of a monitoring plan includes the assessment and reporting of results, which are both as important as the monitoring itself. In an adaptive management context (Box 7.1), which is designed for learning, the information from monitoring is only useful if evaluation occurs and feeds back into management actions. For climate change adaptation, M&E form the basis for identifying successful adaptation processes and management actions. Many funding sources that specifically target climate adaptation require projects to illustrate clearly the linkages between adaptation activities and a reduction in climate impacts and vulnerability. A well-designed M&E programme shows how management actions address climate vulnerability, and allows managers to evaluate how actions contribute to adaptation.

What is the difference between monitoring effects and monitoring effectiveness?
It is important to differentiate between monitoring the "effects" of climate change (e.g. temperature, stream flow, species range shifts), which is often referred to as status or ambient monitoring (Mascia, et al., 2014), and monitoring the "effectiveness" of management response and adaptation actions. Both are important to consider and, while related, these two kinds of monitoring have very different intents.

Monitoring the effects of climate change often involves determining the status and trends of species, habitats, and other factors that reflect the long-term condition and health of PA values and ecosystems. For example, PAs require monitoring to detect trends in attributes such as vegetation cover or runoff that may occur over decades. This is essential information, providing the climatic context for the PA and how it has changed, and is aimed at forecasting how it will continue to change in the future. But doing this alone does not ensure good adaptive outcomes for the PA.

Effectiveness monitoring, on the other hand, usually lasts a few years to perhaps a decade and is designed to evaluate how well a specific project or action has achieved a management goal. Evaluation of individual short-term projects, such as those associated with fire management or invasive plant management programmes, almost always involves effectiveness monitoring.

7.2 Designing a monitoring and evaluation program

Monitoring always involves systematic, repeated measurements that are specifically designed to detect changes and trends. Recording unplanned, inconsistent

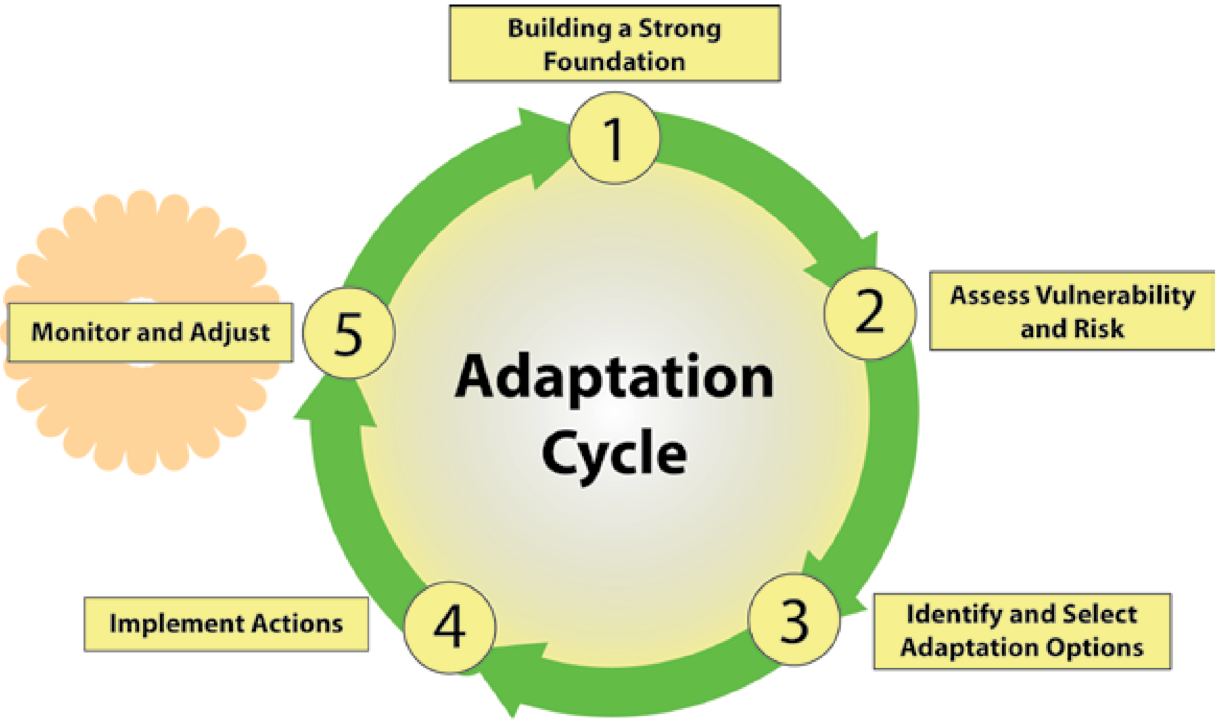


Figure 7.1. Monitor and Adjust: Step five in the adaptation cycle presented in these guidelines represents the importance of monitoring and evaluation that are designed to enhance learning so that adjustments in management practice can be made. Through iteration and "learning by doing" the overall effectiveness of decision making is improved (adapted from EEA, 2015).

Local community-held environmental knowledge relevant to PAs can take many forms: phenology, presence or absence of plant and animal species, weather and rainfall patterns, and much more. Man in grasslands of Simien National Park, Ethiopia (IUCN Photo Library / © Peter Howard).

Box 7.1

Characteristics of adaptive management

Adaptive management embraces an experimental approach where management actions are used to evaluate assumptions and hypotheses about how an ecosystem, PA, community, or other system operates. Key attributes are monitored and examined in a systematic manner that explicitly supports learning how the system responds to management actions. In the context of PAs, adaptive management decisions contribute to achieving goals while increasing capacity of staff and understanding of the PA and its values. While there is no uniform definition of "adaptive management", these are its important characteristics:

- **Regular revisiting of management objectives.** Agreed-upon goals are regularly re-examined in light of emerging data, learning, and insights.
- **A clearly articulated model of the system being managed.** Depending on the system and state of knowledge, the model may be a relatively simple conceptual one, or it may be a highly complex and computationally intensive computer simulation model.
- **A range of management choices.** Several management choices are described, and each is evaluated to estimate the likelihood of achieving objectives, as well as for the opportunity to learn about the system.
- **Monitoring and evaluation of outcomes.** Results are monitored to evaluate the effectiveness of management actions. Sampling is designed so that the monitoring can detect results and improve understanding. This is frequently the most difficult part of adaptive management.
- **An explicit process to incorporate learning into decisions.** Adaptive management achieves results through active learning, which is facilitated by objectives, models, alternatives, and evaluation of outcomes. There must be both a process for management response to new information, and a political will to act on the knowledge.
- **A collaborative process for stakeholder participation and learning.** Meaningful stakeholder involvement requires cooperation among managers, scientists, interest groups, communities, and others, and sharing of the active learning process. The onus is on all participants to be flexible and willing to compromise so adaptive management can be achieved.

Adaptive management is best suited to situations where there is substantial uncertainty about the consequences of management actions and where experimental approaches, monitoring, and evaluation can improve knowledge and lead to more effective decisions (Box 5.1; Williams and Brown, 2012). This describes many climate adaptation actions.

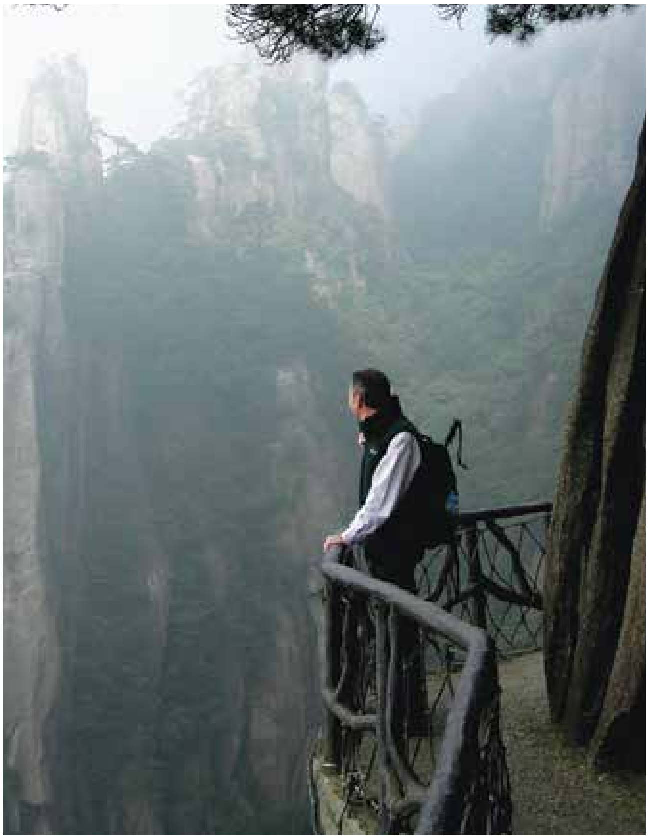
When fully implemented, adaptive management often requires a high degree of expertise, and is costly and labour intensive. It is most likely to be used when there is high uncertainly about what action to take *and* the outcomes of management actions are highly consequential (e.g. species extinction).

We strongly support the fundamental goals of adaptive management, which stress careful planning (goals, objectives, documented actions), accountability (monitoring), learning (evaluation), and responsive management (altering actions based on knowledge). In practice, full "active" adaptive management has been extremely difficult to implement, expensive, and often impractical or impossible to carry out in the field (Westgate, et al., 2013; Fischman and Ruhl, 2016). Nonetheless, conservation organizations worldwide have embraced a less technical definition of adaptive management, one which emphasizes learning and management that is responsive to ongoing change (Williams and Brown, 2012; CMP, 2013).

observations does not constitute monitoring. A carefully designed M&E program has many goals and benefits:

- Determining status and trends of key indicators of ecological condition;
- Evaluating the results of management actions;
- Improving management through learning (adaptive management);
- Establishing a reference or baseline condition for comparison with other (more altered) areas;
- Informing decisions on effective resource allocation (prioritization);
- Promoting accountability and transparency; and
- Involving the community, building a constituency, and promoting PA values.

A well-developed M&E program can be an effective means to involve the community, build a constituency, and promote PA values. It enables PAs to play an important role in helping citizens, decision-makers, and the broader conservation community understand how climate change is impacting ecosystems. PAs often include the least-altered ecological communities and, as such, are important as benchmarks for other areas. Monitoring in PAs provides a reference for comparison with more disturbed areas, and the information obtained is necessary to identify and evaluate the interactive effects of climate change.



Since visitation has major impacts on many PAs, social science has to be part of a comprehensive M&E programme. Walker on suspended trail, Mount Sangingshan National Park, China (IUCN Photo Library / © Peter Shadie).

Best Practice 7.1: Use established principles and support adaptive management

Benefits of effective M&E apply equally to management for climate adaptation and more usual goals for PAs. Established principles for designing and doing monitoring or research for climate adaptation are generally consistent with those that address monitoring for other conservation purposes. Key features of all successful monitoring programmes include early engagement of partners, good data management, clearly documented protocols, use of statistically credible sampling designs, robust and documented methods for acquisition and analysis of data (see Box 7.2 for gathering data from TEK), and regular reporting of results in formats appropriate to primary audiences.

Monitoring and evaluation (M&E) are the basis for identifying successful adaptation processes and management actions. Monitoring at Denali National Park and Preserve, USA (NPS).

There are many excellent publications that can help managers set up a M&E programme (see the Appendix for an annotated bibliography). While not specifically oriented to the problems of climate change, the following documents cover the fundamentals of good M&E:

- The Biodiversity Indicators Partnership (2011) guide provides the key steps to designing and implementing natural resource monitoring for PAs (http://www.bipnational.net/).
- The IUCN *Best Practice Guidelines for Evaluating Effectiveness* (Hockings, et al., 2006; Figure 7.2) provides a detailed, step-by-step guide to designing, implementing, and using results from effectiveness monitoring of projects that will be useful to PA managers.
- Many agencies have catalogues of monitoring protocols that can be readily adapted to any PA (see http://monitoringmatters.org/schemes.htm).
- The IUCN publication *Protected Areas Governance and Management* contains a section on ecological monitoring (Woodley, et al., 2015; http://press-files.anu.edu.au/

Box 7.2

Including traditional ecological knowledge in the monitoring plan

In most PAs, TEK provides a valuable source of knowledge. TEK has been defined by many authors, but the definitions generally follow that proposed by Berkes et al. (2005):

> *a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission….*

TEK can be invaluable for monitoring and adaptive management, for establishing historical baseline conditions, and understanding how systems are changing in the long term. Additional resources for understanding and applying TEK are given in the last section of Chapter 3.

Angas Downs Indigenous Protected Area (Australia) provides opportunities for elders to impart cultural and environmental knowledge to younger generations (AWS10).

TEK may be held by Indigenous peoples, or other people who have resided adjacent to or within PAs for many years. TEK is often qualitative and may be challenging to incorporate into a monitoring protocol that emphasizes Western science. However, there is real value in that this knowledge has been collected over a much longer time period than that obtained exclusively from Western science-based monitoring, and there is important information in the observations and understanding that it encompasses (Nakashima, et al., 2012). One of the greatest contributions to a PA monitoring programme provided by a traditional ecological perspective are descriptions of historical and prehistorical conditions for which there are little or no Western scientific data. TEK can be very useful for understanding ecological baseline conditions, past occurrence of important climatic events, and response of the land (including plants and animals) to past climate extremes, as well as a way to meaningfully engage with those who hold this knowledge.

Local knowledge may also be held by people in park volunteer and citizen scientist groups who have conducted formal and informal surveys in and around parks. For example, numerous bird watching groups, ecotourism organizations, and naturalist societies have been observing biota for many years and their knowledge can inform the development of PA monitoring and the interpretation of results.

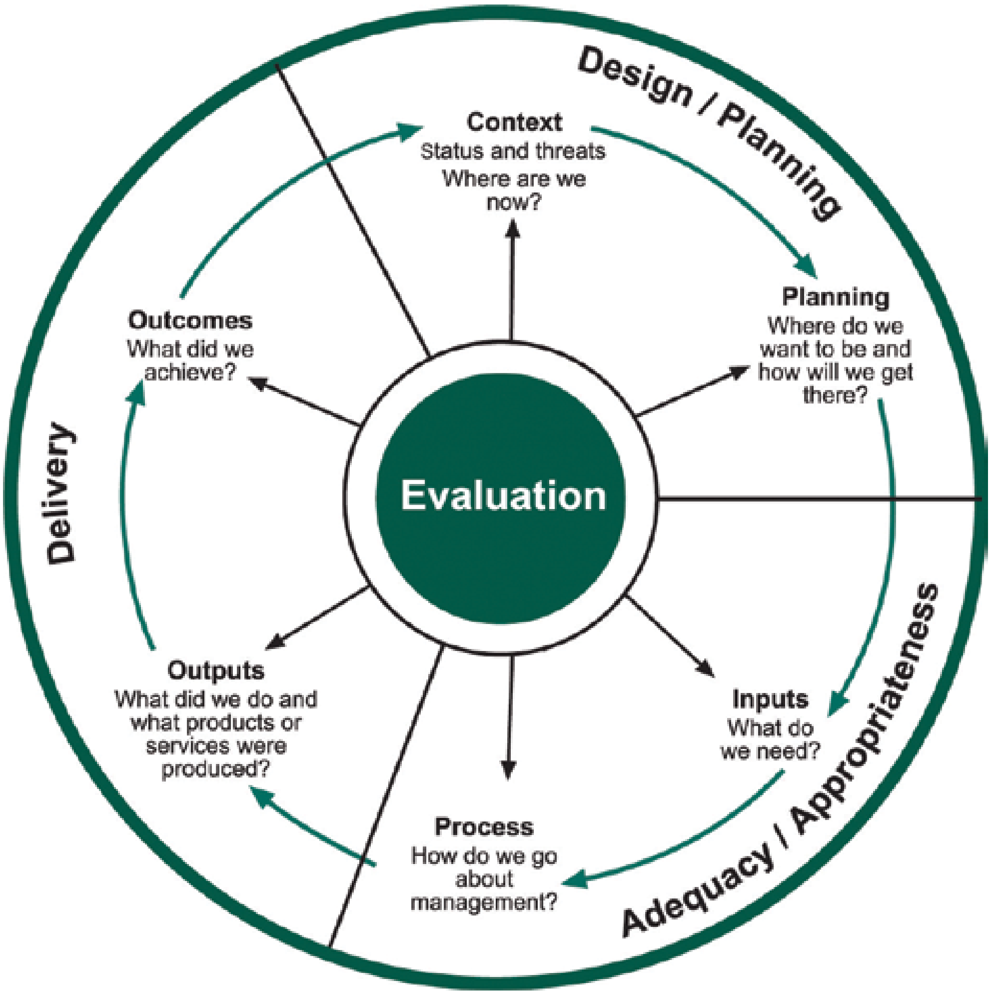


Figure 7.2. IUCN framework for evaluating management effectiveness (Hockings, et al., 2006). An understanding of management effectiveness is important for adaptive management in PAs.

downloads/press/p312491/pdf/CHAPTER21.pdf) with examples and references.

- The June 2016 issue of *Conservation Biology* (http://onlinelibrary.wiley.com/doi/10.1111/cobi.2016.30.issue-3/issuetoc) has a special section dedicated to the use of citizen science. It takes time and investment to use citizen science but it can have long-term benefits for climate monitoring.

More detailed guidance that specifically addresses M&E for climate adaptation also exists, mostly targeted for international development projects at regional to national scales. However, many of the same principles can be modified to address PA adaptation needs at the site level. Bours et al. (2013) concisely reviewed and summarized the key features of 16 prominent studies, and identified the key benefits and challenges of each approach.

Special considerations for monitoring adaptation

Climate change and adaptation pose special challenges for the design and implementation of M&E programmes (Bours, et al., 2013).

- **Requirement for results at short to long time frames.** Many climate adaptation activities may take decades before outcomes are known. This is challenging because there are short-term needs to be accountable and to report progress to funders, managers, and the public. Effective M&E may thus require trade-offs in measuring indicators of progress towards short- versus long-term objectives.
- **Monitoring objectives need to address several disciplines.** Many monitoring programmes have the luxury of focusing on a specific topic or resource—e.g. air, vegetation, fish, etc.—whereas climate adaptation activities often address many topics. Objectives for climate adaptation frequently include management effectiveness, resource stewardship, operations sustainability, mitigation, restoration, and ecosystem services.
- **Unusually high degree of uncertainty.** In addition to normal ecological complexities, climate change has associated uncertainties that can vary widely. Species responses, ecological processes, and interactions with other species are very difficult to predict. Species that are currently distant may colonize PAs, while long-established species and ecological relationships may disappear. The timing of key ecological events is already changing, and all projections are based on models.
- **Shifting baselines—past and future.** Most PAs have already experienced changes related to climate, land use, and other factors. These ongoing changes, which typically affect both PAs and surrounding areas, make it difficult to identify a baseline for comparison. In addition, often the measure of success of an adaptation action is to prevent negative consequences from a future event.

This requires use of a "counterfactual"—a comparison with something that might have happened in the absence of action.

- **Absence of clear metrics for success.** Unlike mitigation to reduce greenhouse gases, there are often no obvious and clear indicators or metrics that can detect and report progress towards successful climate adaptation. Indicators need to be relevant to the PA and the adaptation project.

Regardless of the special considerations, designing a climate adaptation monitoring plan doesn't necessarily have to deviate far from established monitoring frameworks. However, it will benefit from explicitly considering the types of inputs and outputs that are needed (Figure 7.3). Inputs to consider include climate vulnerabilities (Chapter 4) and climate-informed conservation goals (Chapter 2) as well as projections, scenarios, and other information about future conditions along with the associated uncertainties. Useful outputs of a climate adaptation monitoring plan include monitoring objectives, indicators, sampling design, and a reporting plan that includes recommendations for future revisions to adaptation goals, objectives, vulnerabilities, and actions.

Best Practice 7.2: Identify how monitoring and evaluation will contribute to climate change adaptation

M&E that is designed from the outset to contribute to learning and that facilitates exploration of emerging issues, such as climate change, will improve adaptation practices (Villanueva, 2011). Monitoring can benefit climate adaptation by measuring progress towards long- and short-term goals and objectives. For a major project, M&E can effectively measure and report on much more than on-the-ground actions. It can report on the stages of implementation, changes in management actions, management effectiveness, resource conditions or trends, the effects of infrastructure that supports adaptation, or other relevant topics of interest.

Ordinary people often have a strong desire to help care for PAs. "Citizen science"—volunteers helping with research and management projects—has begun to play a significant role in M&E efforts. Volunteers monitoring tidepools at Cabrillo National Monument, California, USA (GEDApix/GEDavis & Associates).

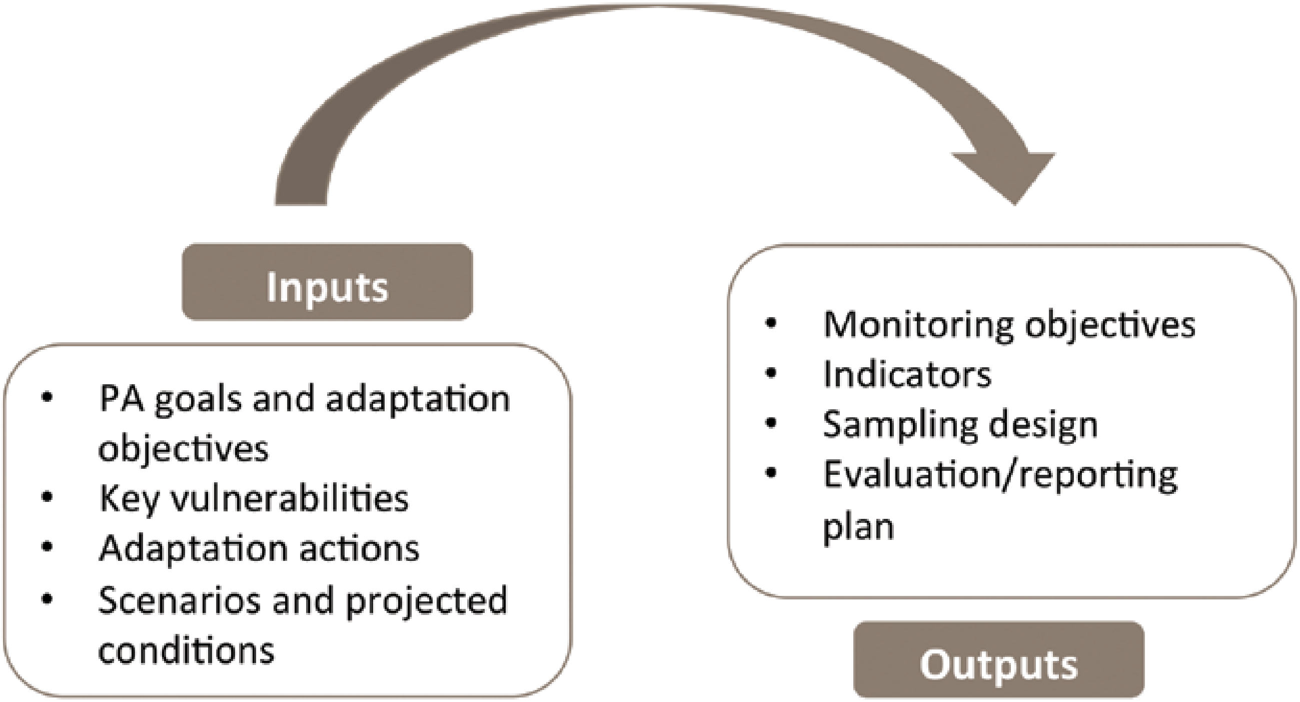


Figure 7.3. Monitoring plans for climate adaptation will benefit from explicit consideration of the types of inputs that are needed and the outputs that will be applied (Patty Glick).

Three key aspects of adaptation can be monitored to show progress (Oliver, et al. 2012):

- Building institutional adaptive capacity (Chapter 3);
- Reducing identified risks and vulnerabilities (Chapter 4); and
- Successful management despite climate change (Chapters 5 and 6).

7.3 Monitoring risks and key vulnerabilities

Most PAs face many threats, some related to climate change and some not. Climate vulnerability assessments (Chapter 4) are an important source of information on threats and key vulnerabilities that may also be good monitoring indicators. Other existing sources of information for identifying indicators include site- and resource-specific management plans, other assessments, broader reviews, and research reports. Adaptation actions that address specific threats to or vulnerabilities of a conservation target are well suited for monitoring.

Best Practice 7.3: Anticipate and design monitoring for change

Unlike most other natural resource monitoring, monitoring for climate adaptation is likely to focus on conservation targets highly vulnerable to loss or transformation, and on changes to organizations and management practices (Wilby and Vaughan, 2011). Monitoring for climate adaptation will thus likely need to accommodate shifting priorities and indicators as project goals, adaptation strategies, and natural systems change and evolve. In some cases, climate adaptation projects will target areas or ecological systems subject to thresholds, where abrupt and dramatic changes (“pulse” events) force managers to adopt an adaptive monitoring design. Other changes may be gradual (“press” events) and these gradual changes will require periodic adjustments to monitoring protocols over time. Even where goals and strategies remain the same, changes in monitoring may be required to address shifts in species ranges, phenology, and community structure or composition. An increased emphasis on managing for change may translate into selecting ecological processes, communities, or services as monitoring targets rather than only particular species.

The increasing likelihood of climate-related threshold events poses an especially important challenge to monitoring. Threshold events likely will be infrequent but extremely important, with long-term ecological consequences. Examples include coral bleaching, massive plant die-offs (e.g. tree mortality from drought), epidemics, insect infestations, intense fires, or major floods. These sorts of events typically occur over a relatively short period, and the magnitude and extent of their impact is difficult or impossible to characterize through routine, ongoing monitoring. Advance planning will likely be needed to modify sampling frequency or location, allocate additional staff and resources, and implement monitoring protocols that can record what happened and where. Effective adaptation will require knowledge of what happened, when, what the effects were, the effectiveness of any response, and the natural course of recovery or transformation. Scenarios developed for other purposes (Chapters 4 and 5) can facilitate

Managers in all countries—including those with the most educated staff—require updated training to learn about climate models and projections, new management methods, interpretation of policy, and a host of other issues. Session of “Parks: The New Climate Classroom” hosted by the Institute at the Golden Gate, Golden Gate National Recreation Area, California, USA (Institute at the Golden Gate).

discussion about rare events that might occur, along with potential monitoring needs and responses.

Best Practice 7.4: Include adaptation-specific indicators into existing monitoring practices

All PAs require routine monitoring, evaluation, and reporting as a foundation for management. As a general principle, climate change adaptation activities should be added to existing M&E programs covering resources and management effectiveness. If a PA is establishing a new monitoring programme, climate change adaptation should be included as a fundamental component.

Additional indicators will usually be needed to specifically evaluate progress towards adaptation goals. To address the monitoring challenges described at the beginning of this section, a broad range of indicators may be needed.

Indicators of climate adaptation are subject to the same criteria as those developed for other purposes. Basic quality criteria for indicators can be summarized as **SMART:**

- **S**pecific: the indicator is precisely, accurately, and concisely described. All of the important characteristics are unambiguously defined.
- **M**easurable: the indicator can be quantified precisely and repeatedly.
- **A**chievable: measurements are practical with available resources.
- **R**elevant: the indicator is an appropriate and interpretable metric of the state, condition, or process of interest.
- **T**ime-bound: there is a time-based reference that includes when the measure needs to be taken and how often it needs to be repeated.

Climate adaptation is a long-term, multi-dimensional process. In many situations, barriers to implementing it involve policy, administration, or other factors not directly related to on-the-ground action. Table 7.1 lists thematic areas suitable for monitoring, and general climate adaptation indicators that may be appropriate. The process of selecting indicators is more complicated than described here, and there are many tools to help select suitable indicators. The Appendix

As the climate changes, natural disasters are expected to increase in frequency and intensity. This will make the role of PAs in mitigating such disasters even more valuable as the years go by. (Left): Forest regeneration projects in Day Forest National Park (Djibouti) are a bulwark against further desertification (Singlab). (Above right): Studies of the massive 2004 Indian Ocean earthquake and tsunami showed that the protection afforded to coral reefs by Hikkaduwa National Park (Sri Lanka) reduced insurge damage by two-thirds (Shehanw). (Lower right): The presence of natural vegetation in Andasibe-Mantadia National Park (Madagascar) translates into reduced flood damage whose value has been estimated to be many times higher than the country's per-capita GNP (Heinonlein).

Thematic area	Indicator
Capacity	• Leadership support for climate adaptation is clearly articulated and communicated to staff. • Training is conducted to enable staff and community to understand the importance and implications of climate change. • Staff members have adequate skills and knowledge to manage for climate adaptation. • There is access to necessary data on climate projections and their specific effects (e.g. hydrological impacts). • Climate awareness is incorporated into policy documents. • Inventories and baseline data are available for conducting assessments and measuring change. • Key management goals are climate-informed.
Threats	• Vulnerability assessments are conducted for key natural resources at appropriate levels and scales (species, communities, ecosystems); for infrastructure, archaeological and other cultural resources, and geodiversity resources; and for operations and visitor impacts.
Planning	• Adaptation options are identified for at-risk resources. • Climate is a routine consideration in all resource management and infrastructure planning. Plans explicitly incorporate likely impacts of climate change, and are checked to make sure they don't inadvertently make problems worse. • The planning process is flexible and responsive to climate-related change and uncertainties. • Climate adaptation actions are incorporated into work plans.
Resource monitoring	• Indicators of key vulnerabilities are measured. • Indicators of physical climate variables are measured and the results routinely reported. • Measures are developed and reported for leading and sensitive indicators of climate impacts (e.g. phenology, runoff). • Monitoring of climate-sensitive ecosystems and processes is implemented.

Table 7.1. Indicators useful for measuring progress toward climate adaptation.

lists tools and references that are particularly relevant. More detailed lists can be found elsewhere (see especially Bours, et al., 2014; and Tables 9 and 10 in Ervin, et al., 2010).

7.4 Summary

Monitoring and "learning by doing" is particularly important with climate change because we have so much to learn about climate adaptation. In general, monitoring activities for climate adaptation should be incorporated into existing M&E programs for resources and management effectiveness. Monitoring programs can include a range of stakeholders and methodologies, including TEK and citizen scientists. Monitoring and evaluation are important to determine whether management actions are effective, to gauge progress towards management objectives, and to maximize learning and sharing results with others.

Chapter 8

Designing resilient conservation landscapes and seascapes

Most of this guide is focused on managing at the level of individual PAs. This chapter discusses considerations that should be taken at larger spatial scales, when planning includes one or more PAs as part of a larger conservation landscape designed to best conserve nature in a changing climate. The far-reaching and unpredictable nature of climate change impacts means that business-as-usual practices for PA design, planning, and management are no longer an option. Preparing for change at the PA site level by fostering flexible management, strengthening critical capacities, and increasing ecological integrity are all critical. However, these practices are insufficient to ensure that a large-scale conservation *network* as a whole can conserve ecosystems, while simultaneously facing more shocks and stresses from climate change as well as greater pressures from human activity. A different set of conservation principles and guidelines at the level of a large landscape, including but extending beyond the PA network, is required to meet these new and complex needs.

In this chapter we use the term "conservation network" to mean a large conservation landscape or seascape that includes core PAs, connectivity areas, and other areas that contribute to conservation and climate change adaptation. A significant portion of a large conservation landscape or seascape may be used for agriculture, fishing, housing, mining, or other non-conservation purposes. Conservation networks are social-ecological systems composed of natural, social, economic, and ecological components and the interactions between them. The importance of these large landscapes and seascapes for biodiversity conservation and climate adaptation is well established (Dudley and Stolton, 2012; Schmitz, et al., 2015; Cumming, et al., 2015).

Few, if any, individual PAs are sufficiently large to sustain its current biodiversity (Hansen, et al., 2011), so ecological connectivity is required even without climate change. Species will need even larger areas with climate change, but existing land and sea uses often constrain expansion of PAs and thus connected networks of PAs will be increasingly important. Conservation networks possess a variety of traits that make them inherently more resilient to climate change than individual sites, and informed management can further enhance the resilience of conservation networks. Game, et al. (2010) provide excellent and more detailed guidance on how to incorporate many of the considerations introduced in this chapter into designing conservation networks at broader scales.

8.1 Three elements of ecological resilience

There are three elements common to most definitions of resilience (Fisichelli, et al., 2016; Angeler and Allen, 2016), (1) an ecological design component—the degree to which the conservation network design allows ecological systems to resist, recover from, and adapt to shocks, stresses, and changing conditions; (2) an ecological management or stewardship component—the degree to which management interventions enable ecological systems to cope with shocks, stresses and changing conditions; and (3) a learning and

Resilience in the face of shocks to and stresses on ecosystems is a key aspect of responding to climate change. Rapanui (Easter Island) is a classic case where the resilience of the system was eventually overwhelmed by human impacts, leading to collapse (uncredited/Wikimedia Commons).

Conservation network design principles	
Ensure ecological representativeness	Ensure all ecological types and species are covered by PAs.
Build in ecological redundancy	Have more than one representative PA for each ecological type and species within the system.
Manage for ecological integrity	Work to ensure ecological integrity at both the site and network level. Systems with integrity are more resilient.
Expand the network	In most parts of the world, existing PAs are insufficient to conserve biodiversity and ecological processes. We need to scale up!
Balance the portfolio	A conservation network that contains a balanced portfolio of sites—focusing on PAs that include species and ecosystems that are both vulnerable and resistant to climate change—is likely to have greater success in ensuring resilience.
Consider future climate and land-uses	Use model projections and associated uncertainties to identify potential future representative locations for new PAs.
Protect the biophysical setting	Design networks to represent and connect the underlying ecological features that support biodiversity across a landscape—so called enduring features including landforms, watersheds, elevation gradients, local climates, geological diversity, etc.
Strengthen freshwater, landscape, and seascape connectivity	Assess and manage for ecological connectivity for the conservation network, working with land owners and managers on areas between PAs, where possible, and prioritize the protection of non-degraded areas.
Network management principles to enhance resilience	
Decrease landscape and seascape threats	Assess threats to biodiversity at a landscape level.
Manage negative synergies	Understand and manage for the interactions between climate change and other ecological threats, including the response of local communities to, e.g., changing water availability.
Manage across boundaries	There are ecological flows across all boundaries, requiring managing across ownership boundaries of all types. We need to work together.
Promote diverse governance	Governance systems of all types are important to network success: government, private, and community and indigenous management.
Learning and adaptation principles to enhance resilience	
Engage the full range of stakeholders and consider all options	Engage experts, traditional knowledge holders, and community thinkers in planning and managing ecological networks.
Increase societal capacity	See Chapter 3.
Encourage adaptive learning	See Chapter 7. Practice "learning by doing."
Promote the relevance of PAs in underpinning biodiversity conservation and human welfare	Ensure the value of biodiversity and ecosystem processes and services is understood and communicated to stakeholders and the public.

Table 8.1. Principles of resilience applied to protected area networks and human–ecological systems.

adaptation component—the ability of PA managers and communities to anticipate, prepare for, prevent, recover from, and learn from shocks, stresses, and changing conditions. These three elements provide a basis for developing a set of guiding principles for applying the concept of resilience to conservation networks that are characterized by their geography (physical setting), natural biodiversity, and human (social) systems (Berkes and Folke, 1998; Allen, et al., 2016; Table 8.1).

Network design principles to enhance resilience

The principles of effective conservation network design are well documented. They include ensuring representation, redundancy, connectivity, and integrity (Dudley and Parish 2006). To a large extent, these principles provide the important steps toward fostering network-level ecological resilience to climate change. By adding the specific aims of ecological resilience to each of these steps, planners and managers can progress even further toward the goal of establishing conservation networks that are more resilient to the impacts of climate change and provide a wider array of benefits to the human communities that depend upon them.

Best Practice 8.1: Design networks to promote ecological resilience to climate impacts

Ensure ecological representativeness. The systems of PAs around the world do not adequately represent the diversity of species, habitats, ecosystems, or even ecoregions (UNEP-WCMC and IUCN, 2016; Watson, et al., 2016). A PA system that fully captures intact examples of species, habitats, and ecosystem types is more likely to be able to withstand shocks and stresses than one heavily dominated by a small sub-set of ecosystems, such as mountains, deserts, and alpine areas (Wilson, et al., 2011; Lawler, et al., 2015).

Maintaining disperal corridors, including riparian zones (left; Salmon River, USA) and altitudinal gradients (right, Grand Teton National Park, USA), are part of restoring ecological integrity (Fredlyfish4 and Jon Sullivan, respectively).

Build in ecological redundancy. Because the intensity and distribution of impacts on biodiversity and ecosystems is uncertain, planners should consider building in a high level of redundancy into PA systems, particularly for those ecosystems and associated services that are most vulnerable to climate change (Green, et al., 2014).

Manage for ecological integrity. Many PAs around the globe contain degraded ecosystems. For example, a recent study of nearly 1,800 PAs across Latin America revealed that almost half had significant land and forest degradation (Leisher, et al., 2013). Ecological integrity, defined as the degree to which a PA maintains important characteristics of a reference natural community (Woodley, 2010), is the key goal of restoration. Managing and restoring ecological integrity increases the ability of an ecosystem to withstand shocks and stresses (Keenleyside, et al., 2012). When establishing priorities for restoring ecological integrity across a conservation network, planners should place particular emphasis on those areas that are in danger of a undergoing a fundamental shift. Determining this may require comparing reference natural communities from the past with possible future communities that would arise under various climate scenarios. Planners should also consider focusing conservation efforts on climate refugia (places that are particularly resilient to the effects of climate change; see Box 5.2), and on areas important for species adaptation, including those used for dispersal along altitudinal, latitudinal, and sometimes longitudinal gradients, as well as riparian and other connectivity corridors (Ervin, et al., 2010; Mackey, et al., 2012).

Expand the network. The single most frequently cited measure for strengthening resilience at the landscape level is the expansion of PA networks (Hannah, et al., 2007). Although there have been great strides in increasing the global extent of PA coverage (UNEP-WCMC & IUCN, 2016), these gains are still not enough to ensure a planet that is resilient to climate change. Parties to the CBD agreed in 2010 to protect at least 17% of terrestrial and 10% of marine areas globally, yet many studies of landscape- and seascape-level resilience suggest that a figure of 30% or 50% or even more may be required to ensure a fully resilient landscape (Wilson, 2016). When evaluating potential areas for expanding their conservation networks, planners might include selection criteria that account for projected changes in climate, land use, and other key factors (Groves, et al., 2012; Magris, et al., 2015).

Ensure ecological connectivity. A conservation network that is composed of core PAs must be ecologically connected. This can be accomplished by identifying the most important areas for connectivity, considering land, sea, fresh-water, and areal linkages. Connectivity conservation areas can be conserved through a variety of methods, including zoning, landowner agreements, and subsidies.

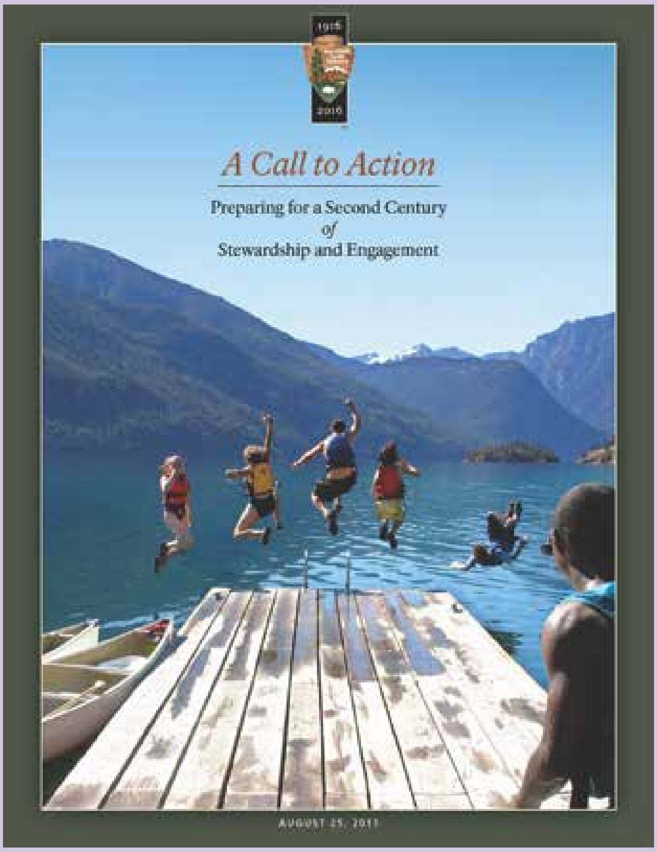
Consider future scenarios. Most assessments of PA representativeness are based on current or historic conditions, but these will shift as the climate changes. Some important coastal areas, for example, will be inundated. Chapter 4 on vulnerability assessments discusses threats to PAs. The challenge for designing networks is to use this information to maximize the benefits of PAs for nature conservation, and at the same time achieve goals for other societal values (Case Study 8.1; also see Case Study 1.1 on the roles of mangroves). While the range of possible futures is large, results from multi-criteria analyses can provide unique information for adaptation planning (Green, et al., 2014; Jantz, et al., 2014).

Protect the range of biophysical settings. When designing a conservation network, planners typically focus on existing biodiversity elements, such as species and their habitats. However, the current distribution of ecosystems and biodiversity is likely to shift radically under most scenarios (IPCC, 2014a; IPCC, 2014b). Therefore, planners should design networks to represent and connect the underlying, enduring foundation of biodiversity across a landscape: the variety of geophysical features that form the “stage” upon

Case Study 8.1

Conservation in the US National Park Service in the 21st century

As the NPS celebrates its centennial in 2016, this is an opportunity to both reflect on the past and look ahead to the future. One hundred years ago, the greenhouse effect and climate change were issues no managers, and very few scientists, were even thinking about. The vision put forward under NPS Director Stephen Mather was one of national parks as areas “maintained in absolutely unimpaired form for the use of future generations as well as those of our own time … faithfully preserve(d) for posterity in essentially their natural state.” We now understand the world to be much more dynamic, and managing these places is much more complicated than what could possibly have been understood when the service was founded in 1916. Yet meeting this responsibility could not be more important than it is today.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2016

A Call to Action

Preparing for a Second Century
of
Stewardship and Engagement

AUGUST 25, 2011

In addition to celebrating its achievements, the NPS has outlined a plan to raise awareness and connect people to parks during its 100-year anniversary in order to strengthen the conservation potential of the service in its second century. *A Call to Action* charts commitments toward a new shared vision, including: a higher level of youth and diversity engagement, a detailed “Green Parks Plan” for reducing the NPS carbon footprint, revisiting the basis for resource management to confront climate change and other emerging issues, assessing the “state of the parks” in a series of reports that summarizes current knowledge, and “scaling up” conservation efforts to promote healthy ecosystems and cultural resources at the landscape level. Thirty-nine specific actions can be found at https://www.nps.gov/calltoaction/, but many more commitments and activities are underway.

The NPS centennial offers a rare opportunity to demonstrate the value and relevance of parks and protected areas far beyond the borders of an individual PA. For example, a recent public survey by the agency’s Chesapeake Bay Prorgam Office found that the NPS instils a trust with the public that can and should be leveraged. By understanding and articulating the ecological, cultural, historical, recreational, and economic values held by the local and surrounding public, the parks can expand their conservation potential to a large landscape level.

By heightening knowledge and understanding among its workforce, and sharing what works and what doesn’t, the NPS plans to consistently improve its response to the challenges ahead, including climate change. In this way, the NPS is positioning itself to work with national and international partners to seize the opportunities that unfold over the next century and beyond.

which evolution plays out. These enduring features—which include bedrock types, aspect, slope, landscape position, watersheds, and elevation—largely determine past, present, and future distribution of species, habitats, and ecosystems, and change on a time scale longer than that of human-caused climate change (Anderson and Ferree, 2010; Beier, et al., 2015, and other papers in the special section). This is exactly what planners did in Papua New Guinea when they conducted a gap assessment that incorporated climate-related shifts in habitat but also focused on underlying features across the landscape (Lipsett-Moore, et al., 2010).

Strengthen landscape connectivity and prioritize the protection of non-degraded landscapes. Despite the wide recognition of the importance of connectivity in maintaining species across landscapes and seascapes, especially considering the long-term implications of climate change, few PA gap assessments explicitly include it (Keller, et al., 2009; Ervin, et al., 2010; Jones, et al., 2015). PA planners should, as an urgent priority, protect those areas that are still intact although found within degraded larger landscapes. This should be followed by increasing the number of connectivity corridors among the intact areas, while at the same time incorporating climate considerations into their siting, design, and management (Mackey, et al., 2008b; Watson, et al., 2013). Some specific steps to designing corridors include incorporating predictive models of species and habitat ranges, using underlying enduring features, including resilient patches, identifying bottlenecks that would likely be exacerbated by climate change, orienting them to facilitate likely species movements; and locating them in environmental transition zones (Hilty, et al., 2006). Some researchers add a note of caution that corridors may also exacerbate climate impacts, including the acceleration of the spread of invasive species, disease, and fire, and encourage planners to explore potential negative aspects of connectivity (SRC, 2014).

Network management principles to enhance resilience

The second consideration of conservation network resilience is the management of the network itself. This includes understanding and addressing threats that extend beyond individual PAs (particularly those that have negative synergies with climate change or that originate from economic sectors such as agriculture or mining), and managing networks in new ways, including by promoting diverse governance and managing across boundaries.

Best Practice 8.2: Manage networks to promote ecological resilience to climate impacts

Decrease landscape and seascape threats through spatial planning. Most assessments of site-level PA management effectiveness include some form of threat evaluation (Leverington, et al., 2010), but many threats facing PAs originate from outside of their borders. This can only be addressed through better spatial planning to integrate biodiversity values into spatial and sectoral development plans at national, regional, and local scales (Ervin, et al., 2010).

Manage negative synergies. Some threats have negative synergies with climate change, including, among others, acidification of soils and waters (Keller, et al., 2009); eutrophication (a process in which water bodies receive excess nutrients that stimulate excessive plant growth; Heino, et al., 2009); land cover alteration (Andries, et al., 2006); fire (Cochrane, 2001); influxes of invasive species (Strifling, 2011); forest fragmentation (Mantyka-Pringle, et al., 2012); draining and mining of peatlands (Joosten, et al., 2012); and overharvesting of biological resources (Lough, 2007; de Young, et al., 2012).

Manage across boundaries. Large transboundary PAs enable climate adaptation at large scales (Thompson, et al., 2009), strengthen overall landscape integrity and resilience (Carroll, et al., 2010), and maintain ecosystem services (Groves, et al. 2010). Creating transboundary PAs is an increasingly important strategy for boosting the number and distribution of large patches of protected habitat, improving connectivity at regional scales, and maintaining meta-populations (Vasilijević, et al., 2015; http://www.tbpa.net/page.php?ndx=20).

Promote diverse governance. Strengthening effective and more climate-resilient conservation networks will require recognition and support for conservation efforts outside

Planners should pay particular attention to threats, such as forest fragmentation, that have negative synergies with climate change. Celaque National Park, Spain (Emeinke).

Transboundary protected areas take on a new importance under climate change. Sněžka, the highest point in the Krkonoše Mountains. It is part of the transboundary protected areas comprising Krkonoše National Park in the Czech Republic and the Karkonosze National Park in Poland (Derbeth).

Conservation easements are part of a suite of diverse PA governance models that can be deployed. Paint River conservation easement, Michigan, USA (Keweenaw Land Trust).

and beyond formal PAs, including privately protected ones, indigenous and community conservation areas, and examples of the "other effective area-based conservation measures" (OECMs) to improve connectivity and expand the area under conservation management . Planners can capitalize on these benefits by ensuring that participants representing various governance models are involved in the design, planning, and management of a conservation network, including PAs in a mosaic of other land uses.

Learning and adaptation principles to enhance resilience
The third side of resilience is the social side—the many ways in which society can anticipate, react to, and learn from various shocks and stresses. This includes the ability to think, organize, and learn in new ways at individual, institutional, and societal levels.

8.2 Summary

Many existing principles for designing effective PA-centred conservation networks also apply to climate-resilient networks, but resilience requires additional and explicit consideration of a range of potential future climates, land uses, and threats. With climate change, conservation networks that include one or more PAs, community lands, sustainable land uses, and other similar activities will be increasingly important to sustain biodiversity. Climate resilience can be significantly enhanced by incorporating guidelines for ecological design, ecological or stewardship management, and learning and adaptation. Social aspects of learning and adaptation are particularly important for networks that include multiple communities, governance systems, and a complex set of stakeholders and management actions.

(Top): A nudibranch in the Red Sea, Egypt. One study found that total nudibranch abundance was highly correlated with the effects of global warming—more intense El Niño events, elevated sea surface height and temperature, and the warm phase of the Pacific Decadal Oscillation (IUCN Photo Library / © Christian Laufenberg). (Bottom): A wandering sea anemone in Taputaranga Marine Reserve, New Zealand. Anemones, on which anemonefish depend, are threatened by warming seas in a similar way to corals. In fact, anemones were affected by the recent coral bleaching on the Great Barrier Reef, which rendered large parts of coral colonies dead or dying in the north and central parts of the reef (IUCN Photo Library / © Cesar Cardenas).

Chapter 9

Mainstreaming protected areas as natural solutions to climate change

Protected areas have important and often underappreciated roles in addressing climate change from local to global scales. The World Commission on Protected Areas advocates PAs as "natural solutions" to help people cope with climate change and urges nations to see them as mainstream solutions to many aspects of rapid change (Dudley, et al., 2010). The IPCC (2014a) warns that changes in temperature, water availability, seasonal patterns, and weather extremes will affect every element of societies' well-being, from energy needs to health, security, agriculture, tourism, and transportation. The often relatively intact ecosystems found within PAs contribute benefits and effective solutions across all of these sectors, including carbon storage, clean water, resilience to storms and other natural hazards, and a host of other ecological services on which human communities depend. Because of the multiple benefits of PAs, it is important that their full value to all aspects of society be considered in dealing with climate change. This chapter emphasizes practices that PA managers, conservation organizations, and others can take to ensure those broader roles are considered as part of all societal actions on climate change mitigation and adaptation.

9.1 The role of protected areas in climate change response

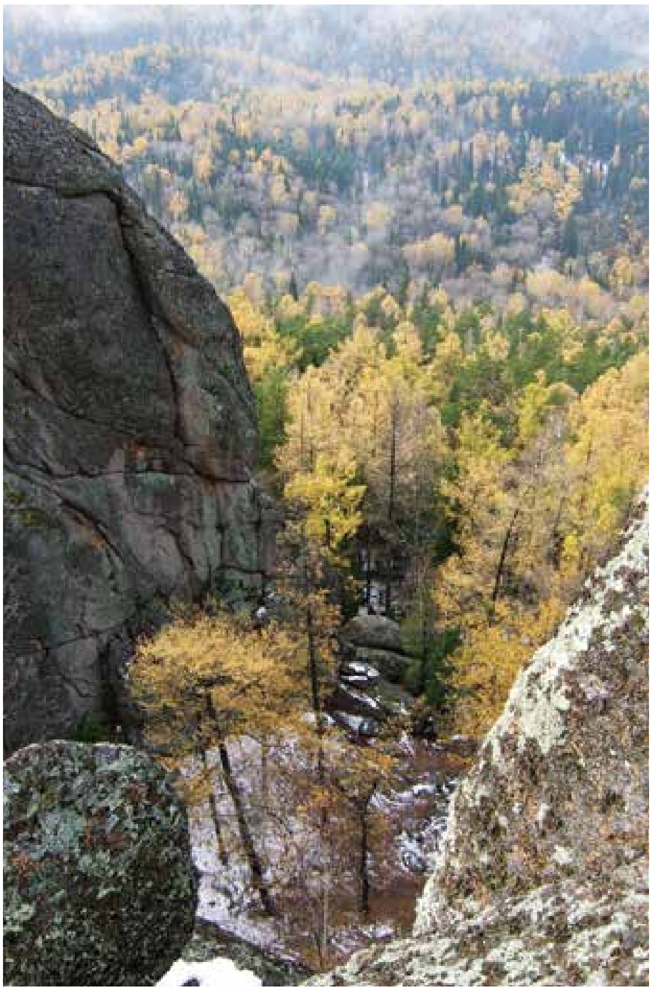
Mainstreaming is the integration of PAs and their benefits into the goals and objectives of all sectors that undertake planning and implementation for climate change. To build an effective case for integrating PAs into broader agendas, it is necessary to clearly understand how PAs can reduce social and ecological vulnerability and increase resilience while providing numerous benefits for both adaptation and mitigation. Dudley et al. (2010) identify three core areas of benefit: carbon sequestration, disaster relief, and supplying human needs (Figure 9.1). Additionally, we emphasize the importance of PAs for climate change research, and the attributes of PAs that enable species and ecosystems to adapt.

Protected area "mainstreaming" is the informed inclusion of PAs into the climate adaptation decisions made by society that drive management policy, rules, plans, investments, and actions on climate change.

Capturing and storing carbon

Protected areas protect some of the highest carbon densities in the world (Gonzalez and Battles, 2013). Conserving biomass in trees, soils, peat, and other ecosystem components reduces the generation of GHGs and can contribute to storing carbon that would otherwise be released into the atmosphere (Mackey, et al., 2015). Deforestation and vegetation degradation are recognized as important sources of GHG emissions (IPCC, 2013). By maintaining and restoring healthy ecosystems, effective PA management can help to secure and add to carbon storage, thereby helping to mitigate climate change. When a PA is degraded by human activities (such as by inappropriate fire regimes or illegal logging), good

Figure 9.1. Climate mitigation and adaptation benefits and ecosystem services that accrue from PAs. Three core areas of benefits are carbon sequestration, disaster relief, and supplying human needs (from Dudley, et al., 2010).



All PAs are reservoirs for carbon, and conserving these stocks in trees and other ecosystem components reduces the generation of greenhouse gases and can contribute to storing carbon that would otherwise be released into the atmosphere. Zapovednik Stolby Krasnojarskij, Russia (Graham Racher).

management can work to stop these destructive activities, thereby changing a carbon source into a carbon sink (FAO 2013). It is therefore important, when considering adaptation goals, that actions are at least carbon neutral or, better, are net positive. This is an essential component of mainstreaming.

Reducing risk from natural disasters

Well-managed and well-designed PAs are more resilient in the face of climate change impacts than other areas. In addition, by enhancing resilience to natural disasters and other major landscape disturbances, PAs are important in reducing social and ecological vulnerability to climate change. These benefits can be enhanced when PAs are considered as part of larger sustainable development strategies. From a systemic perspective, both social and ecological resilience reduces vulnerability and that, in turn, reduces risk (see Chapter 4). Thus, PAs can be a key element in reducing risk from climate-related hazards (Murti and Buyck, 2014; Dudley, et al., 2015).

Improving human health and well-being

For decades, PAs have been the centrepiece of conservation strategies as “hotspots” for biodiversity; for protecting essential ecological, social, and economic services; and for recreation and solace. Many PAs are critical to supplying ample clean water (they provide a third of the drinking water to the world’s 100 largest cities) along with delivering a multitude of other key ecological functions for human health and well-being. Also, by providing sustainable employment and generating billions of dollars in tourism revenues, PAs help to diversify economies in local communities (e.g. Cullinane Thomas and Koontz, 2016). Mainstreaming PAs in this sense means to involve and partner with local and regional communities in ways that demonstrate the benefits of PAs to their daily lives (Case Study 9.1). Protected area projects can simultaneously achieve climate adaptation and other goals of important societal value. For example, securing Indigenous rights to forests can be an effective and economical means to sustain forests and reduce deforestation, preserve biodiversity,

The full range of IUCN PA management categories and governance types should be used as part of mitigation and adaptation projects. Researchers in Kogelberg Biosphere Reserve, South Africa (Abu Shawka).

Case Study 9.1

Protected areas, development, and climate change in the Greater Mekong Subregion

The Greater Mekong Subregion (GMS) is a global biodiversity hotspot. It is home to one of the world's largest networks of PAs, covering close to 20% of the region. The forests and wetlands contained within these PAs support innumerable species and are the foundation of rural livelihoods and local economies. However, PAs in the region are still largely set within landscapes and seascapes of small-scale fishers and farmers. The region has also experienced rapid development over the past 20 years, including significant growth in regional transportation infrastructure and large-scale commercial and industrial agriculture. PAs in the GMS are at risk from a range of pressures, including illegal logging, wildlife trade, commercial crop plantations, and infrastructure development. However, these very areas present an essential foundation for building resilience to climate change.

The International Centre for Environmental Management (ICEM) conducts a range of climate change assessment and EbA projects working with government, the private sector, and local communities to define and implement policies and practices for sustainable development (www.icem.com.au). During 2000–2003, ICEM facilitated a government-led review—bringing together economic development and conservation agencies of Laos, Cambodia, Thailand, and Viet Nam—to assess the status of PAs in the region and define strategies to integrate their conservation within development planning. As a result, the four governments adopted national status reports and action plans for the integration of PAs and biodiversity conservation into national, sector and local development.

Mekong River in Amphoe Khong Chiam, Ubon Ratchathani Province, Thailand (Oatz).

In 2014, ICEM and IUCN, in collaboration with the Asian Development Bank GMS Environment Operations Center, reconvened the region's governments to specifically examine climate change and development implications for PAs and species in the Mekong Region. Over 60 participants from the six countries of the GMS (Laos, Cambodia, Thailand, Viet Nam, Myanmar, and China) participated. The resulting GMS-wide partnership between government agencies, conservation NGOs, and regional organizations provides the operational foundation that will lead to regional and national strategies for better integration of PAs into development planning.

mitigate GHG emissions, and provide for the well-being of Indigenous peoples (Stevens, et al., 2014). These co-benefits can likewise help achieve adaptation goals of PAs.

Enhancing scientific knowledge

Conserving biodiversity and ecosystem function while allowing species to adapt to climate changes will require readily available, high-quality scientific information. PAs offer unique opportunities for research on climate change because these ecosystems represent some of most pristine and least-modified areas. Protected areas have immense and increasing value as baselines from which to understand the complex interactions of Earth's natural systems. Protected areas are also important to the conservation sciences as we become more aware that they are not "islands" but rather interact substantially with surrounding environments. As climate change discussions shift from awareness and evidence to accountability and action, PA managers and other decision makers are presented with many opportunities along with the challenges (Welling, 2011). Sectors for mainstreaming in this regard include the climate science and academic communities as well as cross-cutting sectors such as public health, human migration, security, food, water, and energy. Protected areas must be prepared to interact and thrive in a more connected, transparent marketplace of ideas and actions around climate change at landscape to international levels.

Facilitating climate change adaptation

Well-managed PAs can be among the most effective tools to enable species and ecosystems to adapt to climate change. As the climate changes, PAs can be safe havens for plants and animals that create opportunities for them to adjust to and move in response to changing conditions. By carefully defining and managing connections, targeted restoration networks of PAs within large-scale landscapes can provide the highest level of resilience to climate change (Keenleyside, et al., 2012; see Chapters 6 and 8). Mainstreaming PAs and PA networks can support resilience and ecosystem adaptation by reducing:

- Road construction and infrastructure development that would create new bottlenecks and restrict the movement of wide-ranging species;
- Habitat fragmentation;
- Activities that diminish the size of large, intact patches of habitat, such as forests, thereby reducing the size of

minimal viable populations for species already stressed by climate change;
- Activities such as underwater sonar testing that affect migratory species; and
- Others types of stress that have negative impacts on species vulnerable to climate change.

9.2 The process of mainstreaming

The concept of mainstreaming began with the 1987 Brundtland Commission on sustainable development and the 1992 Earth Summit. Subsequent refinements have been to focus mainstreaming at the scale of national development plans or their equivalent. The broader concept of *environmental mainstreaming* was developed to incorporate environmental issues in general into other agendas, especially those of development. Mainstreaming biodiversity and protected areas into development emerged strongly as conservationists sought to find trade-offs that would result in mutually beneficial gains (Pierce, et al. 2002; Petersen and Huntley, 2005). In the context of discussions to develop a new climate treaty, IUCN and several partner organisations compiled evidence to show how PAs and conservation more generally made significant contributions to both climate mitigation and adaptation (Dudley, et al., 2010).

Mainstreaming almost always involves a complex set of issues and actors. For a good review of approaches to mainstreaming biodiversity in practice, see Huntley and Redford (2014). Each region or country has a different set of political considerations and a unique mix of resource, social, and economic concerns. The approach for successful mainstreaming of PAs is very context-specific and must be tailored to the particular goal and to those that must be involved in the process. Figure 9.2 illustrates key elements in the mainstreaming process and how these interact to determine how mainstreaming might be accomplished.

There is no universal process to fully integrate climate adaptation into the broader arena of national decision-making, but IIED's (2010) review of effective environmental mainstreaming identified steps that are common to most situations. Six key steps are described in Table 9.1.

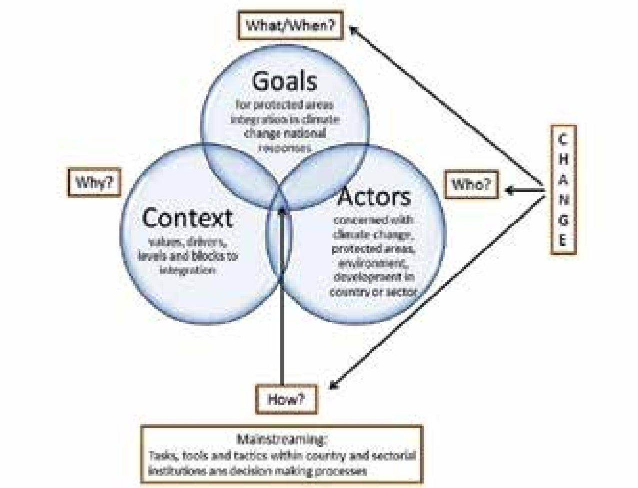


Figure. 9.2. Interacting factors that are important in determining the success of mainstreaming approaches, and that affect how the approach might be carried out (modified from Dalal-Clayton and Bass 2009b).

The steps described in Table 9.1 are presented as a sequential process, but in most cases the activities will be going on at the same time. Furthermore, the steps are part of a cycle with several activities embedded within each step. See Dalal-Clayton and Bass (2009a, 2009b, 2011) for much more detailed descriptions of the process, the actions at each step, and the many tools and practices available to accomplish the actions. The UNDP's Environmental Mainstreaming Strategy (2008) also provides useful references for a more in-depth look, as does the very recent GEF STAP report (Huntley and Redford, 2014).

Best Practice 9.1: Participate in landscape and seascape adaptation planning that extends beyond the boundaries of individual protected areas
Protected areas have a number of characteristics that make

Step	Activity	Result
1. Start up	Evaluate the political economy and governance related to climate adaptation and related issues and initiatives.	Identify key stakeholders; form multi-stakeholder steering group.
2. Identify and assess priorities	Identify a range of priorities, including benefits and costs, and links between adaptation and other national-level issues.	Identify stakeholders to consult. Present proposals and engage stakeholders to refine desirable and credible outcomes with the aim of reaching consensus.
3. Plan and invest	Develop plans to achieve each priority outcome.	Identify entry points into key decision-making processes; map.
4. Implement	Put plan into action.	Changes to policies, plans, and budgets. Promoting key investments for adaptation outcomes.
5. Build capacity	Integrate into institutional systems.	Better integration of institutional programmes, decisions, policies, and abilities.
6. Monitor and evaluate	Identify and implement joint indicators and accountability mechanisms.	Evaluation of program efficacy; continuous improvement of process.

Table 9.1. General steps, associated activities, and desired results of each step needed to effectively mainstream PAs into other climate adaptation activities (modified from IIED 2010).

them valuable to landscape adaptation efforts, including defined boundaries, permanence, established governance, commitment to the long term, and a proven ability to deliver benefits (Dudley, et al., 2010). In many regions, PAs also contain the only remaining large tracts of natural habitat and may support native biodiversity found nowhere else (Venter, et al., 2014). While the need for PAs as refuges for biodiversity and wildlife will increase in a changing climate, accomplishing conservation goals will be more challenging and complex than ever before. New PA strategies will need to be pursued with an unprecedented level of collaboration across jurisdictional boundaries (Chapter 8). Management goals and expectations will have to be re-evaluated under different climate change scenarios to ensure the intended conservation results can be delivered (Chapter 2).

Protected area managers and planners can strengthen the resilience of ecosystems and landscapes in response to climate change, and thus help them adapt. They can:

- Act as knowledgeable experts who build understanding of how species and ecosystems are being impacted by climate change and how they will adjust;
- Establish PAs and restore lands and waters to create resilient, well-connected networks of natural areas that provide habitat and wildlife corridors; and
- Serve as convenors, facilitators, and leaders who inspire resource industries, local and Indigenous communities, neighbours, and other stakeholders to find creative solutions to climate change across wider landscapes.

Protected areas can strengthen the resilience of communities and economies in response to climate change and help them adapt. They can:

- Diversify economic opportunities in remote, rural, and resource-dependent communities through sustainable jobs in tourism and heritage;
- Nurture the ecosystems that support healthy forestry, agriculture, and fisheries industries (Case Study 9.2);
- Protect ecosystem services threatened by climate change, such as clean air and water, stable soils, and recharged aquifers, and reduce risks of natural disasters

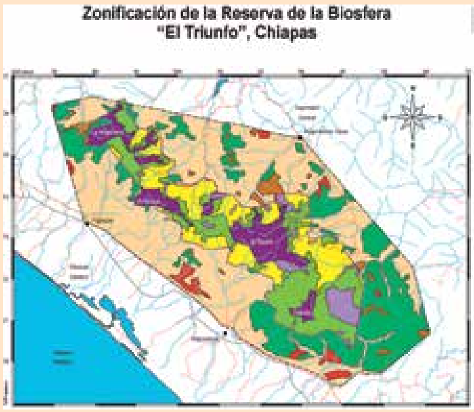
Conserving forests helps mitigate climate change, and brings add-on benefits, such as sustaining aquatic biodiversity. Cockscomb Basin Wildlife Sanctuary, Belize (Pgbk87).

Case Study 9.2

Sustainable coffee and forest conservation

In 2010, Mexico's National Commission of Natural Protected Areas (CONANP) designed a climate change strategy for PAs. The strategy identified priority conservation values, goals, and sites as a guide to management decisions to increase social and ecosystem resilience. As a result, conservation efforts in CONANP's South, Isthmus, and South Pacific regions are focused on the Bug Forest (Bosque de Niebla) located in the Biosphere Reserve El Triunfo ("The Triumph") in the state of Chiapas.

The forest is a source of ecosystem services that are important on the local, national, and global levels. In recent years, the forest's vulnerability has increased as a consequence of climate change impacts. It is an endangered ecosystem that is highly sensitive to changes in land use. Climate change impacts already observed



Case Study 9.2 (continued)

include anomalies in tree phenology and an exponential growth of forest pests, which resulted in economic losses in coffee production, the main economic activity in the region, thereby affecting the local population.

El Triunfo staff have been working on actions to avoid loss of the Bug Forest and protect coffee production. Since 2011, small producers of organic coffee have incorporated adaptation measures into their work. At the same time CONANP, in coordination with UNICACH (the Chiapas University of Sciences and Arts), INIFAP (the National Institute of Forest, Agricultural and Livestock Research), and some NGOS (such as Pronatura Sur and CESMACH, the Sierra Madre Ecological Peasants Organization of Chiapas), have worked on enhancing key ecological and social processes. This effort includes minimizing risks in the La Suiza Basin, fostering social participation to identify climate change strategies, enhancing a water monitoring protocol in the reserve, and improving security to reduce forest fire impacts.

As an example of collaborative actions, INIFAP, TNC, the Forest National Commission, and the Inter-community Group of Territorial Action worked together to improve land, forest, and water conservation in the La Suiza Basin by means of a strategy based on (a) better agricultural practices for raising corn and producing coffee; (b) the preservation of forests; and (c) restoration projects. In addition, CESMACH and other Indigenous organizations of small coffee producers in Chiapas, such as Finca Triunfo Verde and Comon Yaj Nop Tic, have organized international forums on "Coffee and Climate Change" to prepare community representatives for future impacts on coffee production.

Many elements from different climate change scenarios played out. Between 2013 and 2014, 30% of the harvest was lost because of a plague called roya (*Hemileia vastatrix*) that found favourable conditions due to drastic changes in precipitation and temperature. Organizations responded by immediately collecting and distributing different varieties of coffee seeds that are both resistant to plague and compatible with organic certification. The lessons learnt in Biosphere Reserve El Triunfo are:

- Climate change adaptation is only possible with involvement of the local communities and stakeholders.
- Inter-disciplinary and inter-sectorial approaches are indispensable.
- Monitoring is essential for systematizing climate change effects.

The Bug Forest stretches across 56,000 ha in El Triunfo (CONANP).

(Above): The harvest. Coffee plantations cover 19,000 ha in El Triunfo (CONANP). (Below left): Weighing beans (CONANP). (Below right): As the climate warms, the natural values of El Triunfo may be at risk along with the coffee crop (© Miguel Ángel Cruz Rios).

such as floods, droughts and landslips;
- Inspire communities and individuals to support the roles and values of PAs and become engaged in their conservation.

Best Practice 9.2: Encourage the incorporation of protected areas as key solutions in regional and national adaptation and mitigation strategies

In a future in which more people will be competing for fewer resources, and where climate change is likely to cause a greater strain on both people's livelihoods and the availability of resources, the value and relevance of PAs must become more visible to the human communities that live in or depend on them. When regional climate change strategies incorporate PAs in their design, the communities may experience benefits that relate to both adaptation and mitigation. For example, in the Amazon, PAs conserve carbon stocks and provide for the well-being of surrounding communities. Collaborations, such as the Amazon Conservation Vision, bring visibility to the importance of PAs to maintaining a healthy environment that sustains local communities in the context of climate change and other pressures.

Different target groups have to be involved in the process of mainstreaming. In order to get groups who are not focused on the environment to respond positively, it is helpful to use language relevant to them and develop positive arguments that relate primarily to their own goals and aspirations. It is most effective to identify integrated approaches that avoid "development vs. environment" arguments or that foster institutional tensions and associated costs and losses.

Whether they are beneficiaries or those bearing the costs of protection, stakeholders should be involved in planning climate change mitigation and adaptation in PAs. Such involvement includes investigating local needs for ecosystem services and incorporating them wherever possible. There should be full transparency about all current potential and current projects,

Box 9.1

Principles for ecosystem-based approaches to adaptation

Ecosystem-based adaptation is an approach to reduce social vulnerability, as part of an overall adaptation strategy. According to the IUCN, EbA is defined as:

The use of biodiversity and ecosystem services as part of an overall adaptation strategy … (that) aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change (IUCN, 2009).

Mainstreaming can occur at local, regional, national, and international scales. Ecosystems routinely cross governance boundaries, and collaboration and coordination is usually required to undertake EbA projects. A landscape-scale approach is important, but EbA also recognizes that the ecologically and socially relevant scales may not include state capitals or other locations where the decisions are made, and effective mainstreaming of PAs requires working at several scales and with numerous decision-makers.

Best available science is part of EbA's foundation: preparing a vegetation map in Shebenik Jabllanice National Park, Albania (© IUCN Photo Library / Andrea Ghiurghi).

In June 2011 an international group of conservation professionals drafted key principles for ecosystem-based approaches to adaptation (Andrade, et al., 2011). The participants determined that EbA:

1. Promotes multi-sectoral approaches;
2. Operates at multiple geographic scales;
3. Integrates flexible management structures that enable adaptive management;
4. Minimizes trade-offs and maximizes benefits with development and conservation goals to avoid unintended negative social and environmental impacts;
5. Is based on the best available science and local knowledge, and should foster knowledge generation and diffusion;
6. Is about promoting resilient ecosystems and using nature-based solutions to provide benefits to people, especially the most vulnerable;
7. Must be participatory, transparent, accountable, and culturally appropriate, while actively embracing equity and gender issues.

and costs and benefits should be distributed equitably. Finally, knowledge gained from projects carried out within PAs should be used to help communities living nearby.

Best Practice 9.3: Seek opportunities for mainstreaming protected areas into national and international plans and agreements

While landscape-scale mainstreaming is usually focused on local concerns and the opportunities for public engagement, at a national level big-picture and country-wide perspectives are crucial. Consideration of international issues related to global public goods will make the task easier. It is useful to be on the lookout for regional-to-national opportunities in policy, planning, funding, and other cycles that can function as a schedule to motivate the integration of PAs as climate solutions at broader scales. Some catalysts for change to be aware of when seeking opportunities to mainstream are:

- National legislation, regulations, and policy changes;
- Values of progressive organizations;
- Donor conditions and initiatives;
- Government funding cycles;
- Major environmental disasters—especially those that increase in frequency and intensity over several years;
- Requirements for consultation with Indigenous and local communities; and
- International commitments at conventions and congresses (Case Study 9.3).

(Top): Forests hold snow for spring-time water yield and prevent avalanches: Crater Lake National Park, Oregon, USA (WolfmanSF). (Bottom): Estuaries are important breeding grounds for fish and protect coastal areas from floods: Estuary of the River Nith, Scotland, United Kingdom (Doc Searls).

Case Study 9.3

REDPARQUES Declaration at UNFCCC COP21: Scaling up national commitments to an international intervention

PRESS CONFERENCE

Official Announcement of the Declaration on Protected Areas and Climate Change

Amazon Vision

Protected Areas Natural Solutions to Climate Change

Presentation of REDPARQUES Declaration signed by 18 Latin American countries that calls for the inclusion of protected areas in global climate change strategies.

Speakers:

Julia Miranda, Director, National Natural Parks of Colombia
Braulio F. de Souza Dias, Executive Secretary, Convention on Biological Diversity
Yolanda Kakabadse, President, WWF International

Time: December 8 (Tuesday), 15:30 – 16:00
Venue: Press Centre, Room 3 located at hall 5, Blue Zone.
Paris Le Bourget, Paris

Organized by REDPARQUES and WWF Living Amazon Initiative
For more information click here
Contact email: cop21.WWFLAI@wwf.org.co

Recognizing the role of PAs as contributing natural solutions to climate change, 18 countries who are members of the REDPARQUES network of PA agencies from Latin American and Caribbean states (Bolivia, Brazil, Chile, Costa Rica, Colombia, Cuba, Ecuador, France/French Guiana, Guatemala, Guyana, Honduras, México, Nicaragua, Peru, Panama, Suriname, Uruguay, and Venezuela) presented a Declaration on Protected Areas and Climate Change during the UNFCCC COP21 in Paris, December 2015.

The declaration highlights the fundamental role of PAs in providing the "green infrastructure" needed for implementing climate change mitigation and adaptation—and calls on increased international support to intensify and improve the establishment, management, and design of PAs according to climate change criteria. The declaration also recognizes the Amazon as one of the key biomes for the provision of essential ecosystem services that safeguard the social, cultural, and economic interests of society as a whole, and in particular those of Indigenous peoples and local communities.

This is a critical step forward in mainstreaming PAs into the international discussions and negotiations about global climate change, including potential financing for adaptation strategies.

9.3 International agreements are key opportunities for mainstreaming

National commitments under international agreements now provide some of the best opportunities for mainstreaming PAs, particularly for developing countries. National and regional PA leaders and staff may have the best opportunity to act at this level but managers of high-profile PAs may also carry this message. Several of the most important agreements were initiated as part of Agenda 21, an outcome of the 1992 United Nations Earth Summit. The summit's message acknowledged that both poverty and excessive consumption by affluent populations damage the environment. This was the first time that "governments recognized the need to redirect international and national plans and policies to ensure that all economic decisions fully [take] into account any environmental impact" (UN, 1997).

Agenda 21 is a wide-ranging blueprint for action to achieve sustainable development worldwide. It has resulted in the adoption of three global UN conventions: the UNFCCC, CBD, and the UN Convention to Combat Desertification, all of which present opportunities for considering PAs as mainstream solutions to climate change and other development challenges.

The objective of the UNFCCC is "to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". The focus of the annual conferences of the parties to the convention has been to put in place a binding climate treaty that would achieve these objectives through the collective action of all countries. The Paris Agreement agreed at COP21 calls on countries to put forward their best efforts through "nationally determined contributions (NDCs)" and to strengthen these efforts in the years ahead.

Within this framework are significant opportunities for PAs to contribute to these NDCs. Initiatives such as REDD+ provide opportunities for the strengthening of PA systems through additional measures to protect and/or restore carbon-rich ecosystems with co-benefits for biodiversity conservation. The UNFCCC also calls for the development of National Adaptation Programmes of Action (NAPAs), setting out the measures by which least-developed countries identify specific activities that respond to their urgent and immediate needs with regard to climate adaptation (Case Study 9.4, Box 9.2). Setting out the role of PAs in NAPAs is both an opportunity and means for mainstreaming PAs across a very wide set of sectors, including food and water security, disaster risk reduction, health, and well-being.

The CBD was the result of a growing commitment to sustainable development, recognition of the value of biological diversity to present and future generations, and acknowledgement of the threats that species and ecosystems face. It represents a dramatic step forward in the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources (CBD, 2014). The CBD has several formal lines of work, notably the Programme of Work on Protected Areas, that includes a strong orientation to mainstreaming protected areas into wider landscapes and seascapes. The CBD has also embraced discussions on climate change and biodiversity, recognizing they are interconnected, and that biodiversity makes an important contribution to both climate-change mitigation and adaptation. Consequently, conserving and sustainably managing biodiversity is critical to addressing climate change.

The Strategic Plan for Biodiversity 2011–2020 and its 20 Aichi Targets, agreed at the CBD COP10 in 2010, represent a flexible framework for all the biodiversity-related conventions. Faced with ongoing biodiversity loss, the strategic plan emphasizes determined action to value and protect biodiversity that will benefit people in many

Protected areas generate employment and help sustain livelihoods,and should be viewed as an investment by society, rather than a cost to it. Staff of Djuma Vuyatela Lodge, Kruger National Park, South Africa (David Berkowitz).

As the IPCC notes, tourist attractions such as Victoria Falls (Zambia/Zimbabwe) could become much less attractive as a result of reduced river discharge and alteration of the rainforest (Stephen Woodley).

Case Study 9.4

Mainstreaming protected areas into national adaptation planning in the Amazon

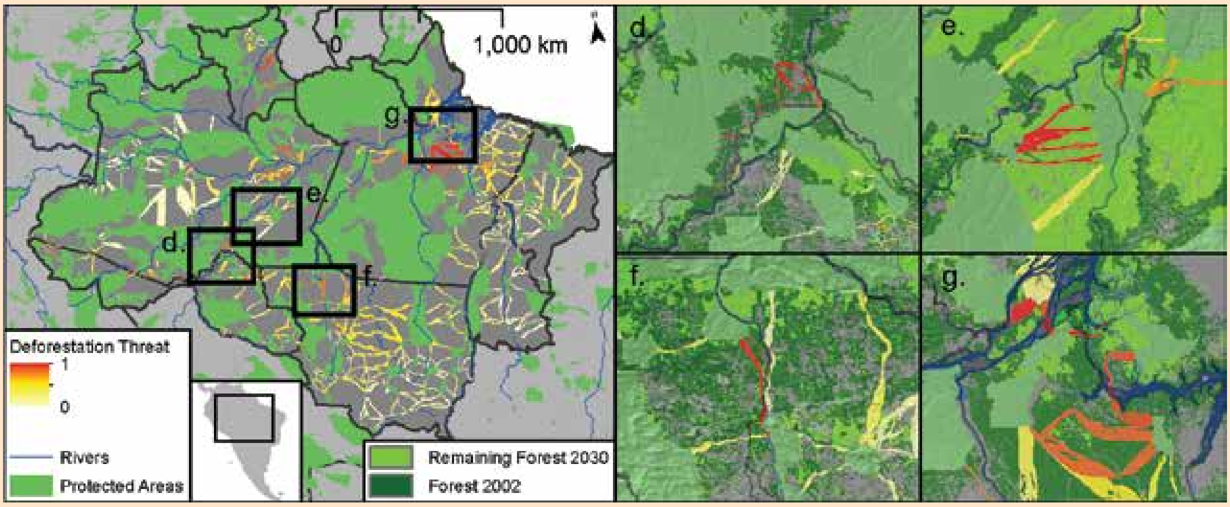
In the tropics, deforestation is a primary cause of habitat loss, fragmentation, and isolation of PAs. Tropical deforestation also contributes significantly to worldwide emissions of GHGs. Support for tropical forest protection has not kept up with increasing pressures in most countries, and further loss of forest habitats and connectivity between PAs and surrounding landscapes is inevitable without additional sources of funding for conservation.

The REDD+ programme can help reduce the gap between needs and available funding. REDD+ funds land-use-based climate change mitigation activities that simultaneously reduce GHG emissions and support nature conservation and sustainable management. REDD+ is a component of deliberations by parties to the UNFCCC, promoting coordination of goals and financial resources to protect forest carbon, maintain biodiversity, and minimize loss of ecosystem services. REDD+ has great promise to support adaptation and biodiversity, but it has proven difficult to achieve multiple objectives. Many REDD+ projects have vague biodiversity goals and inconsistencies between stated goals and proposed actions (Panfil and Harvey, 2016).

Within the Legal Amazon region, the world's largest tropical rain forest, researchers Jantz et al. (2014) identified high-value biodiversity corridors that connect existing PAs. Maps show corridors that traverse carbon-rich areas between existing PAs, representing potential new conservation areas that fulfil REDD+ goals to preserve habitats with high vegetation carbon densities.

This map, created with images acquired by satellite, shows the complexity of Jantz et al.'s carbon-sequestering biodiversity corridors (NASA).

Protection of vegetation carbon stocks is not the most important goal for conservation, but the identified corridors are appealing because they are species-rich, provide a means for dispersal under climate change, and can be conserved at a relatively low economic cost. Meeting multiple goals is important for mainstreaming PAs into national climate action plans, and the ability to simultaneously contribute to climate adaptation, protect rare species, and address mitigation goals can only help to protect nature and the services it provides humans.



(Left panel): Corridors mapped between PAs in the Amazon. The gradient of yellow (low) to red (high) indicates threat of deforestation. (Insets): Corridors between PAs depicted with a yellow-to-red scale where red indicates high vegetation carbon density, high endemism richness, low opportunity cost, and high threat of deforestation. In the background, dark green shows forested area in 2002 while yellow-green shows forest areas projected to persist in the year 2030. Protected areas are shown in light green in all maps (from Jantz et al. 2014).

ways, including through helping to slow climate change by enabling ecosystems to store and absorb more carbon, and helping people adapt to climate change by adding resilience to ecosystems and making them less vulnerable. Better protection of biodiversity is therefore a prudent and cost-effective investment in risk reduction for the global community.

Initiatives such as REDD+, the CBD Aichi Targets, and NAPAs are responses to climate change that came directly from international commitments (Case Study 9.4, Box 9.2). They have received widespread attention and provide both an opportunity and means for mainstreaming PAs across a very wide set of sectors.

Key programmes for developing nations

The international agreements described above provide a context for increasing the contribution of PAs to climate change. At the national level, PA management needs to be integrated into wider efforts to address climate change, such as NAPAs, which have a clear link to the national budget and key decision-making processes.

NAPAs "provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent

Women around the world are essential actors in the fight against climate change, and must be part of adaptation decisions: a landscape visualisation exercise, Hawata, Sudan (© IUCN / Intu Boedhihartono).

Box 9.2

The Aichi Biodiversity Targets

Virtually all countries in the world have ratified the CBD, which came into force in 1993. The convention has three goals:

1. Conservation of biological diversity;
2. Sustainable use of its components; and
3. Fair and equitable sharing of benefits arising from genetic resources.

In 2010, the parties to the CBD adopted the Strategic Plan for Biodiversity 2011–2020 with the mission of halting biodiversity loss and enhancing the benefits it provides to people. Specific reference is made to the value of biodiversity for addressing climate change. Under the strategic plan are the 20 Aichi Targets, named for the region in Japan where they were negotiated.

The Aichi Targets form a comprehensive set of approaches to conserve biodiversity. Target 11 is specifically on protected areas:

> *By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape.*

Target 11 provides an opportunity to mainstream PAs into larger national discussions, particularly with its focus on integration of PAs and other effective area-based conservation measures into the wider landscape and seascape. Target 11 has implication for other Aichi Targets, including Target 12 on species conservation, Target 15 on ecological restoration, and Target 5 on halting habitat loss. The complete discussion of the Aichi Targets and a wide range of related information can be found on-line at https://www.cbd.int/sp/targets.

The Aichi Targets provide strong links to mainstreaming climate change adaptation. They call for improved connectivity (Target 11), and ecological restoration for climate change mitigation and adaptation (Target 15). Most specifically Target 2 calls for "By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems".

Protected areas are the source of significant amounts of drinking water for large cities around the world. (Clockwise from top left): Nikko National Park supplies Tokyo, Japan (Daderot); Bistrishko Branishte Biosphere Reserve serves Sofia, Bulgaria (Delysia v); Maloti Drakensberg Transfrontier Park supplies Johannesburg, South Africa (Francesco Bandarin/UNESCO); Farallones de Cali National Park serves Cali, Colombia (Experiencia Colombia).

and immediate needs to adapt to climate change—those for which further delay would increase vulnerability and/or costs at a later stage" (UNFCCC 2013). The LDCs are those classified by the UN as "least developed" in terms of their low gross national income, weak human assets, and high degree of economic vulnerability. NAPAs take into account existing coping strategies at the grassroots level, and build upon these to identify priority activities, rather than focusing on scenario-based modelling to assess future vulnerability and long-term policy at the national level. The NAPA process gives priority to community-level input, recognizing that people at the grassroots are the main stakeholders. The rationale for NAPAs rests on the limited ability of LDCs to adapt to the adverse effects of climate change. NAPAs are designed to use existing information to address problems, with no new research required. They must be action-oriented, flexible, and based on national circumstances. Further information on NAPAs is available at http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4585.php.

Similarly, Nationally Appropriate Mitigation Actions (NAMAs) refer to "any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative. These may be policies directed at transformational change within an economic sector, or actions across sectors for a broader national focus" (UNFCCC, 2014). NAMAs are sets of policies and actions that are directed to reduce GHG emissions by developing-country parties to the UNFCCC in the context of sustainable development. NAMAs are reinforced by technology, financing, and capacity building and are aimed at achieving emission reductions by 2020. Individual NAMAs are varied, ranging from project-based mitigation actions to sectorial programmes or policies. More information on NAMAs is at http://unfccc.int/focus/mitigation/items/7172.php.

9.4 Summary

Mainstreaming PAs into other sectors and plans, at local to international levels, is critical to the long-term support for climate adaptation and conservation of biodiversity. The key services PAs provide for risk reduction, provisioning, and mitigation are widely recognized, and they offer key opportunities for partnerships towards a more sustainable future.

Appendix

Additional resources for climate adaptation • Glossary

These guidelines are just an introduction to the emerging discipline of climate adaptation. Much more information is available, and this appendix describes resources that will help readers quickly locate more detailed or additional methods, sources of data, and other resources. The list of resources is not comprehensive, but represents a selection of particularly useful websites, publications, and other information.

Many of the resources described below address more than one topic or issue. Nonetheless, they are organized into these categories:

- Highly relevant IUCN resources
- General online portals for adaptation
- Guides to climate adaptation
- Guides to protected area management with strong chapters on adaptation
- Synthesis reports and climate adaptation toolkits
- Regional networks and tools
- Traditional knowledge
- Learning networks and knowledge exchange
- Climate change communication
- Online training
- Vulnerability assessment
- Climate and other modelling tools
- Monitoring and evaluation resources
- Mainstreaming resources

Highly relevant IUCN resources

Ecosystem-based adaptation:

- Ecosystem-based adaptation: A natural response to climate change. https://cmsdata.iucn.org/downloads/iucn_eba_brochure.pdf
- Draft principles and guidelines for integrating ecosystem-based approaches to adaptation in project and policy design: A discussion document. https://portals.iucn.org/library/efiles/documents/2011-063.pdf
- Building resilience to climate change: Ecosystem-based adaptation and lessons from the field. https://portals.iucn.org/library/sites/library/files/documents/CEM-009.pdf

Hazard reduction — Safe havens: Protected areas for disaster risk reduction and climate change adaptation. http://www.iucn.org/content/safe-havens-protected-areas-disaster-risk-reduction-and-climate-change-adaptation

Natural Solutions — Natural solutions: Protected areas helping people cope with climate change. http://www.iucn.org/content/natural-solutions-protected-areas-helping-people-cope-climate-change

PANORAMA — A compendium of case studies to support learning from solutions for climate adaptation and other PA management issues. http://panorama.solutions/

Species vulnerability to climate change — IUCN SSC guidelines for assessing species' vulnerability to climate change. Forthcoming. http://www.iucn.org/theme/species/publications/guidelines

General online portals for adaptation

Climate Change Adaptation — UNDP site includes training resources and toolkits on managing for resilience. http://www.adaptation-undp.org/

Climate Change Knowledge Portal (CCKP) — The World Bank's central hub of information, data, and reports about climate change around the world; aimed at development practitioners and policy makers to query, map, compare, chart and summarize key climate and climate-related information. http://sdwebx.worldbank.org/climateportal/

Climatelinks — Global knowledge portal for climate change and development practitioners; includes information on adaptation and sustainable landscapes. Supported by the US Agency for International Development (USAID). https://www.climatelinks.org/

Marine Climate Change Impacts Partnership — Portal with many updated (maintained) links to a broad range of topics relevant to climate adaptation in marine environments. http://www.mccip.org.uk/

Reef Resilience — Online toolkit that provides the latest information, guidance, and resources to help managers address the impacts of climate change and local threats to coral reefs. http://www.reefresilience.org/

WeADAPT — A collaborative networking platform on climate adaptation issues, with a clickable global map that allows further information and tools by region for practitioners, researchers, and policy makers. The site offers translation in over 100 languages. https://www.weadapt.org/

Guides to climate adaptation

Climate Adaptation Methodology for Protected Areas (CAMPA): Coastal and Marine. 2016. Comprehensive guide with specific activities for each step of the adaptation process. In English, Spanish, and French. http://wwf.panda.org/what_we_do/how_we_work/protected_areas/naturalsolutions/campa/

Climate change adaptation for natural World Heritage sites: A practical guide. J. Perry and C. Falzon. 2014. UNESCO, Paris, France. whc.unesco.org/document/129276

Climate savvy: Adapting conservation and resource management to a changing world. L.J. Hansen and J.R. Hoffman. 2011. Island Press, Covelo, CA.

Climate-smart conservation: Putting adaptation principles into practice. B.A. Stein, P. Glick, N. Edelson, and S. Staudt (eds.). 2014. National Wildlife Federation, Washington, D.C. http://www.nwf.org/ClimateSmartGuide

Management handbook—A guideline to adapt protected area management to climate change. C. Wilke and S. Rannow. 2013. HABIT-CHANGE Report 5.3.2. Online: http://www.habit-change.eu/

Resource guide to NGO climate adaptation resources and tools for state fish & wildlife agencies. D. Palmeri. 2014. Association of Fish & Wildlife Agencies (AFWA), Washington, D.C. An excellent compendium of resources, rather than a more traditional guide. http://www.fishwildlife.org/files/ResourceGuide_NGO-Climate-Adaptation-Resources.pdf

Guides to protected area management with strong chapters on adaptation

Conservation planning: Informed decisions for a healthier planet. C.R. Groves and E.T. Game. 2016. Roberts and Company, Greenwood Village, Colorado.

Protected area governance and management. G.L. Worboys, M. Lockwood, A. Kothari, S. Feary, and I. Pulsford (eds.). 2015. ANU Press, Canberra, Australia. http://press.anu.edu.au/publications/protected-area-governance-and-management

Synthesis reports and climate adaptation toolkits

IPCC 5th assessment reports — The Intergovernmental Panel on Climate Change reports are comprehensive reviews of current knowledge about climate change and its impacts at global and regional scales. The 5th assessment synthesis report (AR5) was released in 2014. http://ar5-syr.ipcc.ch/

IPCC Working Group II report on impacts, adaptation, and vulnerability is split into ***Part A*** (global and sectoral impacts) and ***Part B*** (regional aspects). The ***Summary for policy makers*** is a useful synthesis of both parts. These can be easily accessed at: http://ipcc-wg2.gov/AR5/

UNFCCC compendium of methods and tools — United Nations Framework Convention on Climate Change database of tools and methods with many useful links to established programs. http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5457.php

Regional networks and tools

Adaptation to Climate Change: Coasts — A WWF series of tools and resources to support adaptation for coastal ecosystems, aimed at coastal managers, conservation practitioners, scientists, and educators. http://wwf.panda.org/what_we_do/endangered_species/marine_turtles/lac_marine_turtle_programme/projects/climate_turtles/act_toolkit/

Andes Climate Change Vulnerability Index — Identifies plant and animal species that are particularly vulnerable to the effects of climate change in Colombia, Ecuador, Peru, and Bolivia. http://www.natureserve.org/conservation-tools/andes-version-natureserve-climate-change-vulnerability-index

APAN — The Asia Pacific Adaptation Network brings together publications, news, projects, and events to mobilize knowledge and build capacity for climate resilience. http://www.asiapacificadapt.net/

CAKE — The Climate Adaptation Knowledge Exchange includes learning tools, a virtual library, and many examples of adaptation from the Arctic to the tropics; North America focus. http://www.cakex.org/tools

Climate-ADAPT — The European Climate Adaptation Platform offers numerous adaptation support tools and case studies, including a guide for PA managers. http://climate-adapt.eea.europa.eu/; http://climate-adapt.eea.europa.eu/viewaceitem?aceitem_id=7704

CCORAL — Caribbean Climate Online Risk and Adaptation Tool is an open-access system to support decision making through a climate change lens. http://ccoral.caribbeanclimate.bz/about/

Pacific Climate Futures — A web-based climate impacts decision-support tool for Timor Leste (East Timor) and fourteen other countries in the South Pacific region. http://www.pacificclimatefutures.net/en/

PARCC — Protected Area Resilience to Climate Change is a UNEP project in West Africa; includes climate change and species projections, vulnerability assessment, and resources for managers. http://parcc.protectedplanet.net/en/general-project-information/project-background

Traditional knowledge

CTKW Guidelines for Considering Traditional Knowledges (TKs) in Climate Change Initiatives — Created in 2014 by a Pacific Northwest group of Indigenous peoples and experts, the guide is intended as a resource for tribes, agencies, and organizations interested in understanding TKs in the context of climate change. https://climatetkw.wordpress.com/

Traditional ecological knowledge and natural resource management — Book edited by C.R. Menzies that examines the relationship between Indigenous ecological practices and regional and national programs of natural resource management. For purchase from the University of Nebraska Press. http://www.nebraskapress.unl.edu/product/Traditional-Ecological-Knowledge-and-Natural-Resou,671902.aspx

UNFCCC Best Practices and Available Tools for the Use of Indigenous and Traditional Knowledge for Adaptation — Includes the application of gender-sensitive approaches and tools for understanding and assessing impacts, vulnerability, and adaptation to climate change. A technical report. http://unfccc.int/resource/docs/2013/tp/11.pdf

Weathering uncertainty: Traditional knowledge for climate change assessment and adaptation. This 2012 publication is a joint undertaking of UNESCO and UNU. D. Nakashima, K.G. McLean, H. Thulstrup, A. Ramos Castillo, and J. Rubis. Available online at http://unesdoc.unesco.org/images/0021/002166/216613E.pdf

Learning networks and knowledge exchange

Climate Action Network International — http://www.climatenetwork.org/

Climate, Community and Biodiversity Alliance — http://www.climate-standards.org/

Five principles for the practice of knowledge exchange in environmental management — A 2014 publication from the *Journal of Environmental Management* that is available online or as a downloadable PDF file. M.S. Reed, L.C. Stringer, I. Fazey, A.C. Evely, and J.H.J. Kruijsen. http://www.sciencedirect.com/science/article/pii/S030147971400365X

WikiAdapt — Advancing Capacity for Climate Change Adaptation (ACCCA): http://wikiadapt.org/index.php?title=Main_Page

Climate change communication

***Climate Access* —** A network for those engaging the public in the transformation to low-carbon, resilient communities includes tips and tools such as developing, framing, and presenting messages. www.ClimateAccess.org

Climate Change Communication Toolkit — The US National Park Service online resource for parks and PAS to engage the public on climate change. https://www.nps.gov/subjects/climatechange/toolkit.htm

Creating a Climate for Change — The first book (published 2007) to take a comprehensive look at communication and social change specifically targeted to climate change, offering practical suggestions for educators and interpreters. Editors: S. Moser and L. Dilling. For purchase at: http://www.cambridge.org/us/academic/subjects/earth-and-environmental-science/climatology-and-climate-change/creating-climate-change-communicating-climate-change-and-facilitating-social-change

NASA Climate Change Resources — NASA, the US National Aeronautics and Space Administration, has a variety of graphics and multi-media resources as well as communication tools on global climate change. http://climate.nasa.gov/

The uncertainty handbook — A resource for anyone who wants to understand or communicate climate change uncertainties. A. Corner, S. Lewandowsky, M. Phillips, and O. Roberts. Available to download in multiple languages. http://climateoutreach.org/resources/uncertainty-handbook/

Yale Program on Climate Communication — Conducts research on public climate change knowledge, attitudes, policy preferences, and behaviour, and the psychological, cultural, and political factors that influence them. Includes publications on types of audiences and how to reach them. http://climatecommunication.yale.edu/

Online training

Global UN CC:Learn — The United Nations Climate Change Learning Partnership offers a platform for online learning, building on the expertise of UN partners. Climate lessons are offered in multiple languages and the site is actively adding new modules. http://unccelearn.org

Interpreting Climate Change Virtual Course. US National Park Service on-line course with a study guide and learning companion, and modules on resource issues, audiences, and appropriate communication techniques and strategies. Each module includes a study guide and learning companion. https://www.nps.gov/subjects/climatechange/toolkit-training.htm

POWPA Resources — The CBD Programme of Work on Protected Areas has a module on climate change, and other two-hour online modules relevant to climate change. These courses are offered in English, Spanish, French, and Russian. https://www.conservationtraining.org/mod/page/view.php?id=2864

Vulnerability assessment

IUCN SSC Guidelines for Assessing Species' Vulnerability to Climate Change. W. Foden and B.A. Young (forthcoming 2016). IUCN Species Specialist Commission, Gland, Switzerland. This is the most comprehensive review and synthesis of methods and tools for conducting species-level vulnerability assessments.

Compendium of lessons learned from ARCC climate change vulnerability assessments. L. Wood. 2014. Tetra Tech ARD for USAID. https://www.weadapt.org/sites/weadapt.org/files/legacy-new/knowledge-base/files/1566/54ea0c7b3d3c4integrated-arcc-compendium-cleared.pdf

Climate change vulnerability assessment for natural resources management: Toolbox of methods with case studies. K.A. Johnson. 2014. US Fish and Wildlife Service, Arlington, VA. Compendium of vulnerability assessments from around the world, with an emphasis on North America. http://www.fws.gov/home/climatechange/pdf/Guide-to-Vulnerability-Assessment Methods-Version-2-0.pdf

NatureServe Climate Change Vulnerability Index. Spreadsheet-based vulnerability index for plant and animal species. Probably the most commonly used tool (often with modifications to better suit local needs) to rapidly assess climate vulnerability. http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index

Scanning the conservation horizon: A guide to climate change vulnerability assessment. P. Glick, B. Stein, and N. Edelson. 2011. National Wildlife Federation, Washington, DC. https://www.nwf.org/~/media/PDFs/Global-Warming/Climate-Smart-Conservation/NWFScanningtheConservationHorizonFINAL92311.ashx

Vulnerability Assessment Tools for Coastal Ecosystems: A Guidebook. Marine Environment and Resources Foundation. 2013. Very complete guide to designing and conducting assessments. http://www.coraltriangleinitiative.org/sites/default/files/resources/42_Vulnerability Assessment Tools for Coastal Ecosystems_A Guidebook.pdf

Climate and other modelling tools

Climate Change Resource Center (CCRC) — US Forest Service compendium of tools to help land managers incorporate climate change and carbon stewardship into their decision making. http://www.fs.fed.us/ccrc/tools/

Climate Analysis Indicator Tool — World Resources Institute suite of online data and visualization tools that support the many dimensions of climate policy-making. http://cait.wri.org/

Climate Change Explorer — University of Cape Town Tool from Wiki-Adapt. http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool

ClimateWizard — The Nature Conservancy and partners' climate data toolset. Enables anyone to access historical and projected (CMIP3) climate data and visualize the impacts anywhere on Earth: http://www.climatewizard.org

Connectivity Analysis Toolkit — Research results and resources for conservation scientists. http://www.connectivitytools.org

Corridor Design's GIS tools — For evaluating connectivity, corridor, or habitat modelling. http://www.corridordesign.org/designing_corridors/resources/gis_tools

***Digital Coast* —** US National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. Data, visualizations, topical information, and other tools. Visualizations currently only for USA and its territories. https://coast.noaa.gov/digitalcoast/

Flood Maps — Global models of areas flooded with different changes in sea level. http://flood.firetree.net/

Global Climate Change Viewer — High-resolution climate analyses and visualizations for the US; country-level analyses for the world. Options to obtain results from ensembles or individual models, and for specific emissions scenarios from the most recent set (CMIP5) of projections. http://regclim.coas.oregonstate.edu/visualization/gccv/cmip5-global-climate-change-viewer/index.html

Monitoring and evaluation resources

Evaluating effectiveness: A framework for assessing management effectiveness of protected areas. M. Hockings, S. Stolton, F. Leverington, N. Dudley, and J. Courrau. 2006. 2nd edition. IUCN, Gland, Switzerland. https://portals.iucn.org/library/efiles/documents/PAG-014.pdf

Guidance for national biodiversity indicator development and use. Version 1.4., Biodiversity Indicators Partnership. 2011. UNEP-WCMC, Cambridge, UK.

Open standards for the practice of conservation, Version 3.0. Conservation Measures Partnership. Clear, practical, and mature guide to designing and carrying out monitoring within an adaptive management process. Includes excellent definitions, worksheets, and other practical tools. Specifically addresses climate adaptation. http://cmp-openstandards.org/download-os/

Mainstreaming resources

Climate, Community & Biodiversity Alliance (CCBA) — Standards to evaluate land management projects from early stages through implementation. Many project descriptions (e.g. REDD+) and other projects that demonstrate climate adaptation mainstreaming. http://www.climate-standards.org/ccb-standards/

IIED — Exceptionally comprehensive website dedicated to environmental mainstreaming. Reports, guidance, literature, issue papers, and other resources. http://www.environmental-mainstreaming.org

UNFCC Nationally Appropriate Mitigation Actions (NAMAs) — Programme information, submitted plans, sources of funding, and other relevant information. http://unfccc.int/focus/mitigation/items/7172.php

UNFCCC National Adaptation Plans of Action (NAPAs) — Programme information, background, submitted NAPAs, databases, and related information. http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/7567.php

Glossary

Adaptation
The process of adjustment to the actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects (IPCC, 2014).

Adaptive capacity
The ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences associated with climate change (IPCC, 2014).

Adaptive management
A flexible management approach that values learning, does not penalize mistakes made in good faith, and incorporates a formal plan for responding to new information.

Assisted colonization
The intentional movement and release of an organism outside its indigenous range to avoid extinction of populations of the focal species (IUCN, 2013).

Biodiversity
The variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species, and of ecosystems (United Nations, 1992).

Climate driver
(1) When referring to an effect of climate on a conservation target (e.g. change in species distribution), any climate variable or effect that results in a response. For this use, common climate drivers include temperature, precipitation, sea level rise, and snow cover. (2) When referring to changes in climate, any natural or human-induced climate factor that directly or indirectly causes a change in climate. Greenhouse gases and land use are very important drivers of climate.

Climate model
A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and accounting for some of its known properties. The climate system can be represented by models of varying complexity (IPCC, 2013).

Climate projection
The simulated response of the climate system to a given scenario of future emissions levels or concentration of greenhouse gases (GHGs) and aerosols. *Climate projections,* which generally are derived from climate models, are more speculative than *climate predictions* by virtue of being based on assumptions concerning future developments that may or may not be realized (IPCC, 2013).

Drought
A period of abnormally dry weather long enough to cause a serious hydrological imbalance. A period with an abnormal precipitation deficit is defined as a *meteorological drought.* A *megadrought* is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more (IPCC, 2014).

Ecological integrity
A condition characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change, and supporting processes (Canadian National Parks Act 2000).

Ecosystem
A functional unit consisting of living organisms, their non-living environment, and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined (IPCC, 2014).

Ecosystem-based management (EBM)
A process that integrates biological, social, and economic factors into a comprehensive strategy aimed at protecting and enhancing sustainability, diversity, and productivity of natural resources. EBM emphasizes the protection of ecosystem structure, functioning, and key processes; is place-based in focusing on a specific ecosystem and the range of activities affecting it; explicitly accounts for the interconnectedness among systems, such as between air, land, and sea; and integrates ecological, social, economic, and institutional perspectives, recognizing their strong interdependences (COMPASS Scientific Consensus Statement).

Ecosystem function
Ecological processes that control the changing flows of energy, nutrients, and materials through an environment.

Ecosystem services
The goods and services provided by healthy ecosystems, including medicinal plants, clean water and air, and protection from extreme natural events.

Emergent risk
A risk that arises from the interaction of phenomena in a complex system, for example, the risk caused when geographic shifts in human population in response to climate change lead to increased vulnerability and exposure of populations in the receiving region (Oppenheimer et al., 2014).

Exposure
A measure of the character, magnitude, and rate of climatic changes a target species or system may experience. This includes exposure to changes in direct climatic variables (e.g. temperature, precipitation, solar radiation) as well as changes in related factors (e.g. sea-level rise, water temperatures, drought intensity, ocean acidification) (Gross et al., 2014).

Extreme weather event
An event that is rare at a particular place and time of year, with rarity usually defined as being at least as rare as the top or bottom 10% of observations. When a pattern of extreme weather persists for some time, such as over a whole season or year, it may be classed as an *extreme climate event.* (IPCC, 2013).

Global climate model / general circulation model: See *climate model*

Hazard
The potential occurrence of a natural or human-induced event, trend, or impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, provision of services, ecosystems, and environmental resources (IPCC, 2014).

Key vulnerability
Those vulnerabilities that merit particular attention because they pose the greatest risk to achieving agreed-upon conservation goals and objectives (Gross et al., 2014).

Mainstreaming
The integration of PAs and their benefits into the goals and objectives of all sectors that undertake planning and implementation for climate change.

Mitigation
A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2013). In the context of PAs, it is taking direct action to reduce GHG emissions from operations and/or to enhance the capacity of park ecosystems to remove these gases from the atmosphere and store them in biomass and soils.

Phenology
The timing of periodic (typically seasonal) plant and animal life-cycle events. The study of phenology examines how periodic events—such as migration, first leaf, flowering, and hibernation—are influenced by variations in weather, climate, and other environmental factors.

Protected area
A clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2013).

Reducing Emissions from Deforestation and Forest Degradation (REDD); REDD+
An effort by the United Nations to create financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. It is therefore a mechanism for mitigation that results from avoiding deforestation. REDD+ goes beyond reforestation and forest degradation and includes the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks (IPCC, 2014).

Refugia
Areas that during climatic upheaval, biological stress, or major population downsizings still provide the essential elements of the species' niche for small subpopulations (Calvin, 2002). For example, shaded areas of coral reefs could provide refugia during bleaching events.

Representative concentration pathway (RCP)
A scenario of future climate conditions, extending to 2100, that combines estimates of emissions changes, land use, and land cover (IPCC, 2013).

Resilience (of ecosystems)
The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al 2004).

Resistance
An adaptation strategy that actively seeks to prevent or oppose impacts of climate change.

Risk
The probability that a situation will produce harm under specified conditions. It is a combination of two factors: the probability that an adverse event will occur; and the consequences of the adverse event. Risk encompasses impacts on human and natural systems, and arises from exposure and hazard. Hazard is determined by whether a particular situation or event has the potential to cause harmful effects.

Scenario
A coherent, internally consistent and plausible description of a possible future state of the climate. Similarly, an *emissions scenario* is a possible storyline regarding future emissions of greenhouse gases. Scenarios are used to investigate the potential impacts of climate change: emissions scenarios serve as input to climate models; climate scenarios serve as input to impact assessments.

Scenario analysis
A process of analyzing possible future events by considering alternative possible outcomes or scenarios.

Sensitivity
The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli, including mean (average) climate characteristics, climate variability, and the frequency and magnitude of extremes.

Sequestration
The uptake and storage of carbon-containing substances, in particular carbon dioxide (CO_2), in terrestrial or marine ecosystems. Biological sequestration includes direct removal of CO_2 from the atmosphere through land-use change, afforestation, reforestation, revegetation, carbon storage in landfills, and practices that enhance soil carbon in agriculture (IPCC, 2014).

Stressor
An event and/or trend, often but not necessarily climate-related, that has an important effect on the ecosystems of a PA. Stressors can increase vulnerability to climate-related risk (Oppenheimer, et al., 2014).

Translocation
The human-mediated movement of living organisms from one area with release in another (IUCN, 2013).

Vulnerability (to climate change); vulnerability assessment
The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. A vulnerability assessment is an evaluation of the extent to which a system is susceptible to harm from direct and indirect effects of climate change, including variability and extremes (IPCC, 2014).

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Much of the research about the influence of climate change on flowering plants and the pollinators that interact with them has focused on likely phenological and distributional shifts. But flowering plants and pollinators will also feel the direct physiological effects of higher temperatures. Plant responses include altered flower, nectar, and pollen production, which could in turn reduce floral resource availability and lower the reproductive output of pollinating insects. Likewise, pollinator species may experience disruptions in foraging activity, changes in body size, and altered life spans. These changes could feed back to affect patterns of pollen flow and pollination success of flowering plants. (Clockwise from top left): Savannah vegetation in Nyika National Park, Malawi (IUCN Photo Library / © Nigel Dudley); orchids in Tortuguero National Park, Costa Rica (IUCN Photo Library / © Joëlle Dufour); flowers growing on rocks in Mercantour National Park, France (IUCN Photo Library / © Catherine Gras); red hot poker flower, Simien National Park, Ethiopia (IUCN Photo Library / © Peter Howard); Africanized honey bees pollinating a yellow beavertail cactus flower in the high desert of California, USA (Jessie Eastland).

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