CONSULTATION DRAFT
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Responding to Climate Change

Guidance for protected area managers and planners

Edited by John Gross, James Watson, Stephen Woodley, Leigh Welling and David Harmon

Climate change slogan for a protected planet

Best Practice Protected Area Guidelines Series No. XX

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Read Me First

This WCPA guidance document is aimed at helping protected areas managers think about and develop useful adaptation strategies for protected areas in the face of climate change. This version of the document is intentionally a consultation draft. It was developed for consultation at the 10th World Parks Congress in Sydney Australia, November 2014. Climate change has been called a wicked problem, because it is inherently difficult to solve and the processes managers need to undertake in understanding it are complex and may be contradictory. The document is presented as a consultation draft in a sincere effort to gather input, critique and share global solutions. The authors and contributors are under no illusion that we have all the answers to deal with climate change. We have tried to bring together the best thinking available. We recognize that we are at the start of a long and difficult journey with climate change, which will challenge our assumptions and beliefs. We need and welcome your constructive input to this document. There is certainly a need for guidance on climate change adaptation in protected areas, but no doubt we will be revising our views as the future unfolds.

Comments, suggestions, lessons learned and additional case studies will be incorporated into the final published version. That version will be made available digitally and in hard copy in at least the 3 official languages of the IUCN, Spanish, French and English.

Editorial matters

We plan to substantially revise the guide in early 2015 and complete the final draft for publication by June 2015. Therefore, in this consultation draft we have not attempted to regularize spellings, put the consolidated list of references into a consistent format, and attend to all the other copyediting and publication design details that would be done for a final version. The layout we offer here is intended to make the consultation draft more readable and to give you a general sense of what the final version will look like, once all revisions are complete.

Your input on this draft can be sent to:

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IUCN (International Union for Conservation of Nature)
IUCN helps the world find pragmatic solutions to our most pressing environment and development challenges. IUCN works on biodiversity, climate change, energy, human livelihoods and greening the world economy by supporting scientific research, managing field projects all over the world, and bringing governments, NGOs, the UN and companies together to develop policy, laws and best practice. IUCN is the world's oldest and largest global environmental organization, with more than 1,200 government and NGO members and almost 11,000 volunteer experts in some 160 countries. IUCN's work is supported by over 1,000 staff in 45 offices and hundreds of partners in public, NGO and private sectors around the world.
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The Species Survival Commission (SSC) is the largest of IUCN's six volunteer commissions with a global membership of 8,000 experts. SSC advises IUCN and its members on the wide range of technical and scientific aspects of species conservation and is dedicated to securing a future for biodiversity. SSC has significant input into the international agreements dealing with biodiversity conservation.
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IUCN WCPA is the world's premier network of protected area expertise. It is administered by IUCN's Programme on Protected Areas and has over 1,400 members, spanning 140 countries. IUCN WCPA works by helping governments and others plan protected areas and integrate them into all sectors; by providing strategic advice to policy makers; by strengthening capacity and investment in protected areas; and by convening the diverse constituency of protected area stakeholders to address challenging issues. For more than 50 years, IUCN and WCPA have been at the forefront of global action on protected areas.
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NPS – United States National Park Service
The mission of the National Park Service is to preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. In 2016, the NPS will celebrate 100 years as steward of the Nation's most cherished natural and cultural resources. As the keeper of 397 park units, 23 national scenic and national historic trails, and 58 wild and scenic rivers, NPS is charged with preserving these lands and historic features that were designated by the Nation for their cultural and historic significance, scenic and environmental worth, and educational and recreational opportunities. Additionally, the NPS further helps the Nation protect resources for public enjoyment that are not part of the national park system through its grant and technical assistance programs. **http://www.nps.gov**

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UNDP partners with people at all levels of society to help build nations that can withstand crisis, and drive and sustain the kind of growth that improves the quality of life for everyone. On the ground in more than 170 countries and territories, we offer global perspective and local insight to help empower lives and build resilient nations.
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The Wildlife Conservation Society saves wildlife and wild places worldwide through science, conservation action, education, and inspiring people to value nature. We work in more than 60 countries helping governments and communities conserve some of Earth's last wild landscapes and seascapes and the species that inhabit them--from gorillas in Congo to tigers in India, bison in Yellowstone to sharks in Belize.

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George Wright Society

The George Wright Society promotes protected area stewardship by bringing practitioners together to share their expertise. The Society strives to be the premier organization connecting people, places, knowledge, and ideas to foster excellence in natural and cultural resource management, research, protection, and interpretation in parks and equivalent reserves.

http://www.georgewright.org

BIOPAMA

The Biodiversity and Protected Area Management (BIOPAMA) programme aims to address threats to biodiversity in African, Caribbean and Pacific (ACP) countries, while reducing poverty in communities in and around protected areas. It is financially supported by resources from the intra-ACP envelope of the European Commission's (EC) 10th European Development Fund (EDF). BIOPAMA combines improving data availability with capacity development to strengthen protected area management. It has two main components: one concerning protected areas, jointly implemented by the International Union for Conservation of Nature (IUCN) and the EC's Joint Research Centre (JRC), and another dealing with access and benefit sharing (ABS), implemented by the Multi-Donor ABS Capacity Development Initiative managed by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

www.biopama.org

IUCN–WCPA's Best Practice Protected Area Guidelines Series

IUCN-WCPA's Best Practice Protected Area Guidelines are the world's authoritative resource for protected area managers. Involving collaboration among specialist practitioners dedicated to supporting better implementation in the field, they distil learning and advice drawn from across IUCN. Applied in the field, they are building institutional and individual capacity to manage protected area systems effectively, equitably and sustainably, and to cope with the myriad of challenges faced in practice. They also assist national governments, protected area agencies, non-governmental organizations, communities and private sector partners to meet their commitments and goals, and especially the Convention on Biological Diversity's Programme of Work on Protected Areas.

A full set of guidelines is available at: www.iucn.org/pa_guidelines
Complementary resources are available at: www.cbd.int/protected/tools/
Contribute to developing capacity for a Protected Planet at: www.protectedplanet.net/

IUCN Protected Area Definition, Management Categories and Governance Types

IUCN defines a protected area as: A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. The definition is expanded by six management categories (one with a sub-division), summarized below.

- **Ia Strict nature reserve:** Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are controlled and limited to ensure protection of the conservation values
- **Ib Wilderness area:** Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition
- **II National park:** Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities
- **III Natural monument or feature:** Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove
- **IV Habitat/species management area:** Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category
- **V Protected landscape or seascape:** Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values
- **VI Protected areas with sustainable use of natural resources:** Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non-industrial natural resource use compatible with nature conservation is seen as one of the main aims

The category should be based around the primary management objective(s), which should apply to at least three-quarters of the protected area – the 75 per cent rule.

The management categories are applied with a typology of governance types – a description of who holds authority and responsibility for the protected area. IUCN defines four governance types.

- **Governance by government:** Federal or national ministry/agency in charge; sub-national ministry/agency in charge; government-delegated management (e.g. to NGO)
- **Shared governance:** Collaborative management (various degrees of influence); joint management (pluralist management board; transboundary management (various levels across international borders)
- **Private governance:** By individual owner; by non-profit organisations (NGOs, universities, cooperatives); by for-profit organsations (individuals or corporate)
- **Governance by indigenous peoples and local communities:** Indigenous peoples' conserved areas and territories; community conserved areas – declared and run by local communities

For more information on the IUCN definition, categories and governance type see the 2008 Guidelines for applying protected area management categories which can be downloaded at: www.iucn.org/pa_categories

Foreword

(forthcoming)

Executive summary

(forthcoming)

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Abbreviations and acronyms

CBD Convention on Biological Diversity
CONANP Comisión Nacional De Áreas Naturales Protegidas, México
COP Conference of the Parties
GCM Global Climate Model (or General Circulation Model)
GEF Global Environment Facility
GIS Geographical Information System
ICCA Indigenous Peoples' or Community Conserved Territory or Area
IPCC Intergovernmental Panel on Climate Change
IUCN International Union for Conservation of Nature
M&E Monitoring and Evaluation
NASA National Aeronautics and Space Administration (USA)
NGO Non-governmental Organisation
PoWPA Programme of Work on Protected Areas (of the CBD)
RCP Representative Concentration Pathway
TNC The Nature Conservancy
UNDP United Nations Development Programme
UNDRIP United Nations Declaration on the Rights of Indigenous Peoples
UNEP/WCMC United Nations Environment Programme, World Conservation Monitoring Centre
USNPS United States National Park Service
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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Chapter 1
Setting the stage—Climate change and protected areas

Chapter 1 Setting the stage— Climate change and protected areas

In the last few years there have been a number of good reviews, policy and advocacy publications on climate change and protected areas (e.g. *Natural Solutions: Protected areas helping people cope with climate change*[1] and *Convenient Solutions to an Inconvenient Truth: Ecosystem-based Approaches to Climate Change*[2]), as well as various studies and tools for identifying the likely impacts of climate change on protected area systems.

But there remains a major gap in guidance for site managers as much of this information is aimed at policy makers, protected area system planners and scientists. This publication aims to meet that need.

Climate change basics

Our world is in the early stages of rapid human-induced climate change. According to the Intergovernmental Panel on Climate Change (IPCC), the warming of the climate system is unequivocal (IPCC 2013). The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, the sea level has risen, and the concentrations of greenhouse gases have increased. These changes have, and will have, implications for all aspects of our lives and the lives of all living things on earth. Protected areas are used by all nations as a key strategy to conserve nature, including biodiversity and ecological function and they are also now expected to contribute to livelihoods for local communities, to bolster national economies through tourism revenues, replenish fisheries and to play a key role in mitigation and adaptation to climate change, among many other functions (Watson et al. 2014). Protected areas are an important part of a nation's climate change adaptation strategy, as they reduce threatening processes to species and ecosystems and as such maximize their potential to adapt to a changing climate (Mackey et al. 2008). By ensuring intact ecosystems remain intact, protected areas often store vast quantities of carbon, thereby reducing emissions of carbon dioxide from land use change, and as such are also a critical part of a nation's mitigation strategy (Soares-Filho et al. 2010).

Protected areas can store vast quantities of carbon. [HAMILTON]

1 http://wwf.panda.org/who_we_are/wwf_offices/peru/?183021/Natural-Solutions-protected-areas-helping-people-cope-with-climate-change
2 http://siteresources.worldbank.org/ENVIRONMENT/Resources/ESW_EcosystemBasedApp.pdf

Protected areas managers now have a much more complex task than they did two decades ago, as they not only need to meet the demands of a growing diversity of stakeholders but have to incorporate climate change into their management. Because the world's climate is changing, human and natural systems will need to find ways to adapt and protected areas can have a role that nations will increasingly rely on. This IUCN guideline highlights the latest thinking on what protected area planners and managers can do in the face of climate change. There are no perfect answers and the thinking around climate change is still very much in its infancy. But what is clear is that to be part of the solution to nature conservation, protected areas must be managed in a way that takes into account climate changes. There is much more to do to manage our protected areas networks appropriately and expand them sensibly, connect natural spaces, restore ecosystems and habitats, bring back native species, and inspire and engage citizens to take action. Protected areas also hold great promise as part of a "natural solution" to climate change. Their ecosystems store vast amounts of carbon, and by reducing threatening process, they can often provide the best solutions to ecological resilience to maintain species.

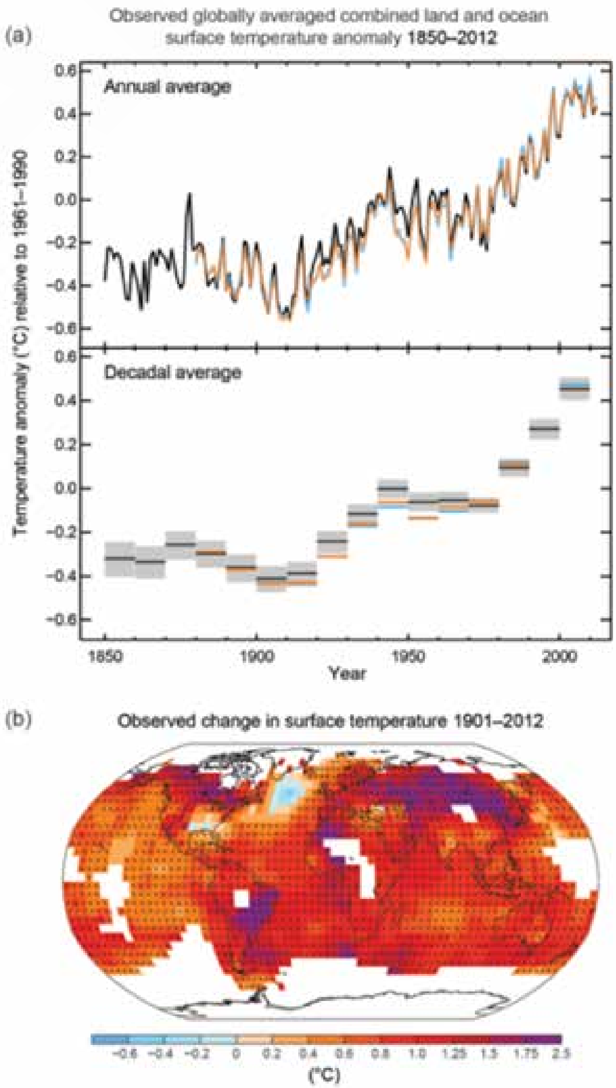


Figure 1. The evidence for rapid human-caused climate change is now considered very certain. Figure 1A below shows the observed globally averaged combined land and stream surface temperature anomalies form 1850 to 2012. The term 'temperature anomaly' simply means a departure from a reference value, in this case the long-term average global temperature. Figure 1B shown the global distribution of those observed temperature anomalies. Note that some areas are of earth, such as the far north, are warming more rapidly than others.

Responding to climate change is usually divided into two separate approaches: mitigation and adaptation. For protected area managers, mitigation involves taking actions to directly reduce greenhouse gas (GHG) emissions from operations and/or to enhance the capacity of park ecosystems to remove these gases from the atmosphere (when ecosystems function in this way, they are carbon sinks). Adaptation is 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 impacts. In practice, climate change mitigation and adaptation are often not entirely separate and both are important for protected area managers. In this guide we focus on identifying the best practices protected area managers can follow when considering adaptation. In chapter 10 (mainstreaming) we provide guidance for how protected area managers can consider mitigation strategies within their protected area but a thorough consideration of mitigation actions is beyond the scope of this document.

Human-induced global warming is primarily caused by an increase in the atmospheric concentration of gases that trap solar radiation, including water vapor, carbon dioxide, methane and nitrous oxide. These gases trap solar radiation in the so-called "greenhouse effect" (Figure 2). The primary driver is carbon dioxide, whose concentration in the atmosphere has risen from 280 parts per million to over 400 parts per million in the last 150 years due to human activities. The IPCC, a consortium of thousands of scientists that regularly reports on the status of climate change, concluded that the increase in global warming due to these gases is very likely to be unprecedented within the past 10,000 years or more (IPCC 2013). Furthermore, there is greater than 90 percent probability that human-produced greenhouse gases have caused much of the observed increase in Earth's temperatures over the past 50 years. The panel's Summary for Policymakers 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 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:

- Energy in the atmosphere must be discharged, and in a warmer atmosphere this will likely occur via more severe events such as hurricanes, cyclones, thunder storms, higher-than-average winds etc.
- Warmer air holds more moisture, and this is the basis for many forecasts of increasing precipitation in locations where it's already moist, as well as less relative humidity (i.e. a less favorable water balance) where it's already dry.
- Overall, extreme events, such as the number of very hot days, will increase. The IPCC (2011) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) is a good summary.
- Globally there will be a rise in sea level caused by a combination of a warmer ocean having a larger volume and the melting of glaciers and polar ice caps. There is evidence that the sea level began rising during the 19th century. Estimates for the 20th century show that, on average, global sea level rose at a rate of about 1.7 mm per year (IPCC, 2011).
- Oceans will become more acidic because they directly absorb carbon dioxide from the atmosphere and it gets converted to carbonic acid.

Why do protected areas need to adapt to climate change?

There has already been an increase of 0.8° C in average global temperature since 1951 due to human-forced climate change (IPCC 2013). This seemingly small change is already having

Increasing greenhouse gas concetrations, most due to human activity, cause global warming. [SMOKESTACKS, CARS, AIR POLLUTION]

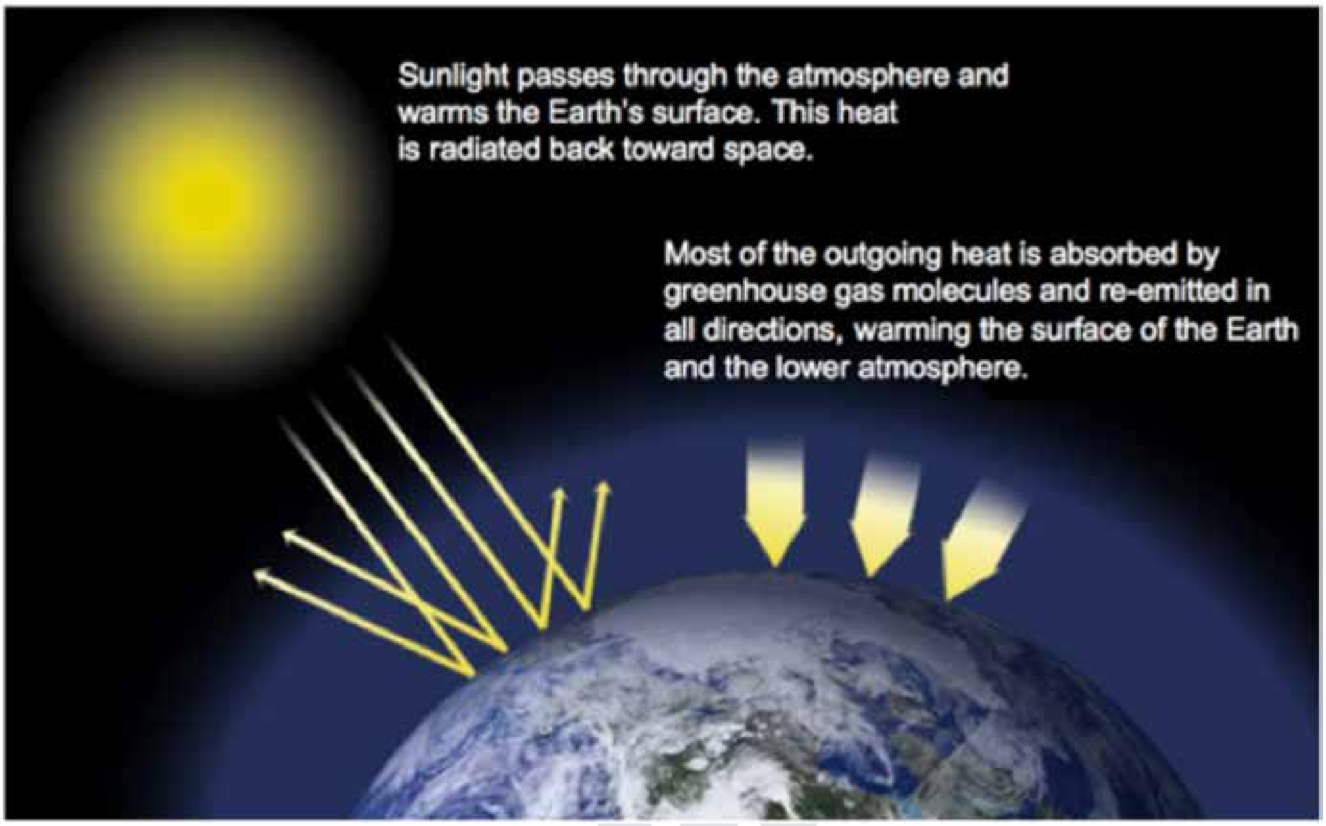
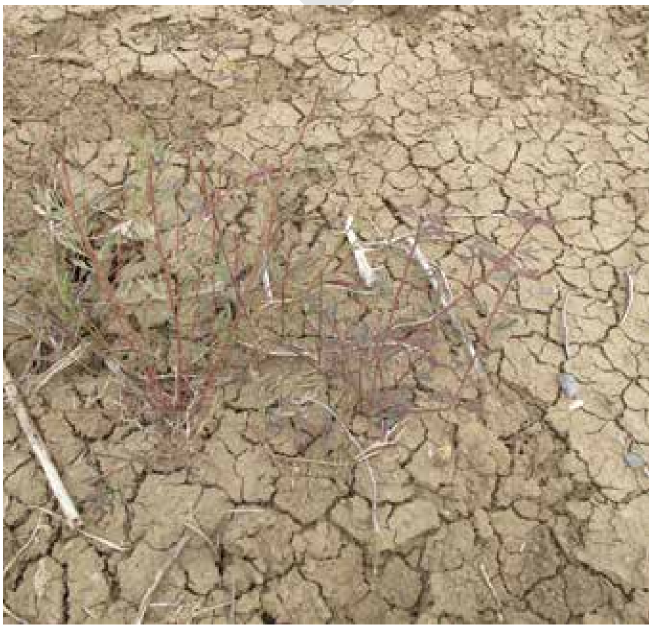


Figure 2. How the greenhouse effect occurs (from NASA - http://climate.nasa.gov/causes - need permission).

a significant effect on ecosystems globally and in protected areas. Even if greenhouse gases were stabilized today, global temperatures would continue to increase because of the lag effect from the gases already in the atmosphere (Solomon et al. 2009), meaning major changes are in store for the world's protected areas. While mitigation efforts are absolutely critical to limit the amount of global warming, adaptation measures will be required under any scenario (Gillett et al. 2011). Many types of adaptation responses are already underway in the world with strategies ranging from redesigning infrastructure to handle increases in storm runoff, protecting coastal zones to withstand the impacts of severe weather events, shifting agricultural practices to more drought- and pest-resistant crops, and increasing the efficiency of water use. As the core objective of many protected areas around the world is to conserve species and ecosystems, this guide is primarily focused on helping managers use best practice adaptation techniques so they can undertake actions that help species and ecosystems within the protected area they manage, best respond to climate change. A good adaptation plan can reduce the adverse impacts of climate change on protected areas but even the best adaptation strategies will not prevent all ecological impacts in some cases.



Warming this century is likely to occur 10 times faster than previously.
[DROUGHT, DESSICATED FIELDS]

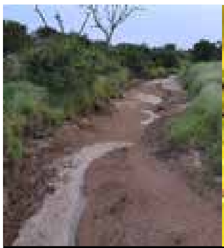
What are the current and likely future impacts of climate change on protected areas?

Changes from global warming already vary significantly from place to place and this variation is likely to continue in the future. However, we can identify some of the generic changes that will affect most protected areas (Table 1, Table 2).

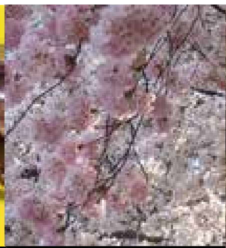
Climate change impacts have been documented across a range of systems (IPCC 2014 WG2 report, Staudinger et al. 2012). This is confounded by the fact that many ecosystems already are contending with multiple other environmental stresses, such as fragmentation, habitat loss, pollution, spread of invasive species, and overharvest (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 stresses. The impacts are cumulative (Kissling et al. 2010, Maclean and Wilson 2011, Williams and Jackson 2007).

Weather and climate	Examples of ecological responses to climate change already witnessed in some protected areas
1. Changes in temperature, primarily increases, but there will also be unequal seasonal changes and warm and cold snaps 2. Changes in the timing, duration and intensity of precipitation 3. Changes in the frequency, intensity and timing of storms	1. Changes in the range of species and ecosystem types. 2. Changes in the composition of ecosystems as some species are lost and new ones enter, including formation of novel ecosystems. 3. Reduction or increase of stream flow in freshwater ecosystems, including drying out of lakes. 4. Loss of symbiotic relationships between species (that is, those that benefit both, such as pollination). 5. Loss of food resources because changes in phenology (the seasonal timing of annual events), such as when a particular plant flowers, mean that they no longer match up with the needs of other species that depend on the event occurring as it did previously. 6. Change on the rates of ecological processes such as decomposition or wildfire (Moritz et al. 2012). 7. Structural damage to ecosystems (e.g. forest blowdown). 8. Loss of seasonal cover, reduction and/or loss of glaciers, loss of snowpack. 9. Oceanic temperature changes, primarily warming. 10. Increase in oceanic acidity. 11. Sea level rise flooding coastal areas. 12. Erosion of beaches during storms. 13. Higher levels of climate-related tree mortality (Park Williams et al. 2013; Anderegg et al. 2013; Allen et al. 2010). 14. Changes in coastal processes with increased erosion and change in deposition pattern. 15. In northern and high-altitude ecosystems, a loss of or reduction in the permafrost layer.

Table 1. Climate change impacts on ecosystems


Changes in stream flow


Disrupted pollination


Changes in seasonality


Forest blowdowns


Flooded coasts


Beach erosion

Conservation target	Climate factor	Key ecological attribute	Hypothesis of change	Likelihood of impact
Mangrove ecosystem	Sea-level rise	Erosion–deposition regime	Increase in sea level will accelerate erosion–deposition regime moving mangrove ecosystem into adjacent upslope areas	Virtually certain
Patch coral reef ecosystem	Ocean temperature	Live coral cover	Increase in ocean temperatures (2-4 degrees C) will reduce live coral cover	Very likely
Riparian ecosystem	Snowmelt	Hydrologic flow regime	Significantly reduced winter snowpack (~20-40%) will alter the spring and summer hydrologic flow regime	Uncertain
Tropical dry forest ecosystem	Temp plus precipitation (no. of dry months)	Fire regime	Higher temperatures (x-y degrees C) and lower/similar precipitation will increase intensity, frequency and extent of fires	Likely

Table 2: Some examples of "hypotheses of change" in key ecological attributes due to climate change (from West and Julius 2014).

Stein et al. (2014a) nicely summarized a number of climate-driven changes that are important to the conservation of species and ecosystems:

> Some plant and animal ranges are shifting or expanding, typically poleward and to higher elevations (Kelly and Goulden 2008). For example, species throughout North America have moved to higher elevations at a median rate of 0.011 kilometers per decade, and to higher latitudes at a median rate of 16.9 kilometers per decade, 2 to 3 times faster than previously reported (Chen et al. 2011). Current rates of climate change will likely exceed the ability of many species to adjust to new conditions, leading to potentially higher extinction rates (Loarie et al. 2009). Shifts in entire biomes also already are becoming apparent in some areas. For example, in rapidly warming areas of Alaska, evergreen forests are expanding

northward into current tundra areas, and grasslands and temperate forests are becoming established to the south (Beck et al. 2011).

Many studies confirm an earlier timing of phenological events among plants and animals that is consistent with a trend of increasing mean spring air temperatures. Many plants are leafing out and blooming earlier, and birds, butterflies, amphibians, and other wildlife are breeding or migrating earlier than they did during the mid-20th century (Parmesan and Yohe 2003, Schwartz et al. 2006, Cleland et al. 2007, Rosenzweig et al. 2007, Bertin 2008, Miller-Rushing et al. 2008, U.S. EPA 2010, Ault et al. 2011). In other cases, changing hydrological conditions are affecting life-cycle events, such as shifts in the onset of summer "monsoon" rains, delaying blooming in arid regions of the southwestern USA (Crimmins et al. 2011), and earlier peak stream flow in snowmelt-driven rivers, disrupting behavior and timing of fish migration (Mantua et al. 2010).

Of particular concern is the fact that species respond to climate change in different ways and at different rates (Walther 2010, Blois et al. 2013). This diversity in responses increases the likelihood that important spatial and temporal connections that evolved over millennia – such as between pollinators and the flowers they fertilize, or breeding birds and the insects on which they feed – will fail. Considerable differences are likely in the responses of short-lived species with high dispersal abilities (such as many birds) and long-lived ones with limited abilities (such as trees) (Montoya and Raffaelli 2010, Urban et al. 2011). As these changes occur, species that are better adapted to new conditions or have broader ranges of tolerance for relevant variables such as temperatures or climate-related disturbances are likely to gain a competitive advantage over those with narrower tolerances (Traill et al. 2010). Therefore, species particularly vulnerable are those species and populations that cannot easily shift their geographical distributions, or that have narrow environmental tolerances (Staudinger et al. 2012).

Importance of protected areas in responding to climate change

- Mitigation: existing and potential forest protected areas are the world's largest carbon sinks, storing 312 gigatonnes of terrestrial carbon that would otherwise be released to the atmosphere. Furthemore, in forest protected areas where afforestation, reforestation and restoration are occurring, the size of the global carbon sink is being increased.
- Adaptation: protected areas maintain ecosystem integrity and reduce vulnerability to climate change.
- Other benefits: Protected areas will continue to provide a wide range of free environmental benefits to human society (known as ecosystem services) under a changing climate. As more human-modified ecosystems lose much of their ability to provide ecosystems services, protected areas are going to be increasingly important in this regard (see Dudley et al. 2010 for a discussion of the additional roles of protected areas).

While the responses of plants and animals to recent climate change indicate some degree of natural capacity for species to adapt (i.e., intrinsic "adaptive capacity), in many cases that capacity may be insufficient given the relatively high rate of climate change and the confounding effects from numerous other human-induced stresses that may hinder or prevent innate adaptive responses (Thomas et al. 2004, Stork 2010, Traill et al. 2010, Hof et al. 2011). Furthermore, as climate conditions exceed the historical range of variability under which our current ecosystems function, it is likely that key ecological thresholds, or tipping points, will be surpassed (Jentsch and Beierkuhnlein 2008). Such concerns exist for forest systems across much of western North America, where in recent years the synergistic effects of higher temperatures, drought conditions, severe bark beetle outbreaks, forest diseases, and wildfires suggest that some areas are increasingly vulnerable to rapid ecological change (Kurz et al. 2008, McKenzie et al. 2009, Westerling et al. 2011). Threshold responses are also evident in coral reef ecosystems, where the combination of climate change (including rising temperatures and ocean acidification) and other anthropogenic stressors (e.g., pollution and overfishing) has contributed to widespread coral bleaching, diseases, and associated mortality in numerous regions, including the Florida Keys and Caribbean (Doney et al. 2012).

Severe bark beetle outbreaks and coral bleaching are two effects of climate change that are already occurring.

The only good news is that protected areas are likely to be better able to withstand climate impacts because they are more intact, and less stressed, than other ecosystems. Protected areas will remain important to preserving biodiversity, even as the species inhabiting these areas shift with the climate (Johnston et al. 2013).

Climate change mitigation

The primary focus of this guide is on climate change adaptation in protected areas, rather than mitigation, but an important component of adaptation is to not make the problem any worse. Many protected area managers feel that individual protected areas, at best, can focus only on climate change adaptation and not mitigation. The initial reaction is that mitigating climate change is too large a problem for individual protected areas. In fact we all need to incorporate mitigation as part of the solution to the climate change problem. By reducing greenhouse gas emissions or protecting natural stores of carbon, mitigation contributes to adaptation by reducing the magnitude of climate changes and thus the amount of adaptation that will be required (Figure 3).

Mitigation — Carbon management

Carbon emissions from deforestation account for an estimated 20% of the global total (IPCC, 2007), second only to emissions from fossil fuel combustion. Ecosystems with exceptionally high carbon densities include temperate rainforests, peat bogs, and tropical rainforests. Protected areas are the some of the world's richest carbon pools and are important areas for conserving carbon. For example, between 2000 and 2005, unprotected humid tropical forests lost about twice as much carbon to deforestation as the same area of protected forest (Scharlemann et al. 2010).

The current protected area system stores 312 gigatonnes of terrestrial carbon which, if lost, would be equivalent to 23 times the total global emissions for 2004 (Cambell et al, 2009). So the first management action is to ensure that ecosystem-based carbon is conserved. Like many climate change actions, this should be basic protected area management anyway.

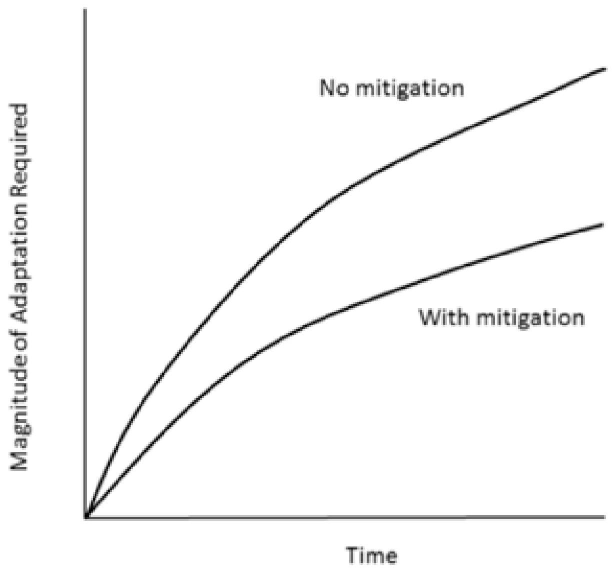


Figure 3. The magnitude of adaptation required with and without climate change mitigation. With mitigation (lower line) the magnitude of climate changes are reduced relative to current practices (upper line). Mitigation is an important component of a climate change response program.

Key best practices for climate change mitigation

- Ensure the integrity of protected area boundaries against development incursions. While this might seem obvious, there are many regions of the world where deforestation and degradation is occurring within nominally protected areas (Geldmann et al. 2012). Overall, human populations are growing more rapidly near terrestrial protected areas (Wittemyer et al. 2008) and they are responding to climate change in a myriad of ways that may affect the integrity of the protected area (Watson, 2014).
- Manage protected areas for ecological integrity so that carbon continues to be taken up and stored.
- Ensure that destructive activities such as logging and mining do not occur within the protected area.
- Ensure all infrastructure built in protected areas (roads, camping areas) is located away from carbon-rich ecosystems such as peatlands, wetlands, and sea grass beds, in locations that minimize impacts to resources.
- Ensure fire management systems are adequate to prevent and control unnatural wildfires during the dry season, especially for ecosystems that are not fire adapted.
- In fire-adapted ecosystems, ensure a management plan is in place with specific targets for fire frequency, extent, and intensity, and with controls to prevent harm to vulnerable ecosystems.

Planning protected areas to conserve carbon

In 2014, there were reports of massive peat forests being documented in a remote part of the Republic of Congo (Congo-Brazzaville) in central Africa. Scientists from the from the University of Leeds, the Wildlife Conservation Society-Congo and Congo-Brazzaville's Marien Ngouabi University estimated that the peatland covers between 100,000 and 200,000 square kilometres (40,000 to 80,000 sq. miles), with the peat depth as much as 7m (23ft) beneath the surface. Some of the area in the Congo-Brazzaville is already a community reserve, managed jointly by the Wildlife Conservation Society, the government and the local people. This is one example where new information on carbon reserves can be used in protected area planning, with an aim to mitigate climate change. Peatlands continue to accumulate carbon as long as they are kept as healthy, intact ecosystems.

Researchers take a core sample in newly discovered peat bog located in a remote area of the Republic of Bongo (Brazzaville). © Simon Lewis

The structure of this best practice guide

We have broken the guide into 10 chapters, following a logical progression from climate impacts through integration of protected areas into and international adaptation plans. We begin by first describing why considering the impacts of climate change are important (chapter 2), then describe best practice methods for assessing vulnerability to climate change (chapter 3) and using this information to identify and select adaptation actions (chapter 4). The next two chapters address best practices around capacity building (chapter 5) and around monitoring the effectiveness of the adaptation actions (Chapter 6). Chapter 7 discusses best practice principles when considering networks of protected areas and chapter 8 summarises the ways to integrate ("mainstream") protected areas into broader adaptation activities. The final chapter also described selected mitigation strategies and topics of special relevance to conservation of protected areas.

Chapter 2
Planning for change: Protected area goals in a warming world

Bruce A. Stein, National Wildlife Federation (USA)

Rapid climate change already is having pervasive effects on our species and ecosystems, as described in Chapter 1, and these impacts are expected to increase significantly over time. Protected areas have long served as the cornerstone for national and global biodiversity conservation efforts, but their place-based nature and fixed boundaries make them particularly sensitive to the broad-scale climate-driven changes underway. As a result, it is now essential to consider climate change and its associated ecological impacts when planning for management of an existing protected area, or for an entire protected area system. Doing so necessarily will require consideration, or reconsideration, of protected area goals.

Clear goals are essential for effective protected area management. Goals define a vision for what one hopes to accomplish, and reflect societal values. In essence, goals are an expression of what matters most to us in the establishment and management of these areas. Clearly articulated goals do four things: (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 outcomes, and (4) serve as a benchmark for measuring the effectiveness of conservation actions.[1] But as a representation of human values, goals are not immutable; they can and do change. As protected area managers carry out their planning in the face of a warming world, it is imperative that a reconsideration of existing goals be part of the climate adaptation process.

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.

Rapid environmental change: The new norm

Protected areas have long been designed and managed in a context loss, one in which natural habitats have been destroyed or degraded, and with many species in decline at both local and global scales. Despite this, or more likely because of it, 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 protected areas 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 paleontological record have illuminated how pervasive climatic and ecological change has 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 timescales, 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

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 protected areas make them vulnerable to climate change.

Protected areas are a representation of human values — and those values can and do change over time. The children of today will bring their own values and expectations to the management of protected areas of tomorrow. Here, chldren enjoy a playground in Fuji-Hakone-Izu National Park, Japan.

In North America, many protected areas sought to replicate conditions thought to occur before the coming of Europeans. Maligne Lake, Jasper National Park, Canada.

managing natural resources within a "range of historical 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 U.S. national parks are already warmer than 95% of historical conditions going back to 1901 (Monahan and Fisichelli 2014). Indeed, in the words of Milly et al. (2008), "stationarity is dead."

The degree of change to which any particular protected area will be subjected will depend 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 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 on assessing vulnerability). Ultimately, the degree of climate change to which protected areas 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, protected area managers must accept that rapid environmen-

Various parts of the globe are experiencing different rates of warming, which is especially pronounced at higher latitudes such as in the Arctic [high-Arctic park]. 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: Franz Josef Fjprd Glacier, Northeast Greenland National Park (Denmark). Bottom: Manú National Park, Brazil.

tal change is the new norm. In fact, it is already underway, and while some locations may be exposed to less of it than others, managers should expect accelerating climatic changes, and corresponding ecological shifts and human responses, especially over the mid- and longer-term. And because change will be ongoing and continual, climate adaptation should not be viewed as simply adjusting to a new static regime; indeed, it should be viewed as an ongoing process rather than a fixed endpoint.

The evolving nature of protected areas

The modern protected area movement has been in existence for well over a hundred years, and over that period it has been far from static. Just as people's perceptions, values, and interactions with nature have evolved, so too have our conservation goals. As noted previously, conservation goals are an expression of human values, and as a result can and do change over time. The goals and purposes for protected areas—stated and unstated—have in fact changed considerably over the past century, shifting from an early emphasis on things 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.

Ervin et al. (2010), for instance, characterized the evolution of societal views towards protected areas as falling into three general phases: the classic model, the modern model, and an emerging model. In the classic model, protected areas generally were viewed as ecological "jewels in the crown," but tended not to be well integrated in broader land use plans, and often were located in areas of low economic value (hence the large number of "ice and rock" parks). They typically were viewed as lands and waters set aside from productive use, and delivering broader societal benefits generally was viewed as irrelevant so long as they met underlying conservation objectives. The "modern" model of protected areas, which began to emerge in the 1970s, emphasized such themes as management effectiveness, protected area network design, governance, and sustainable finance. The importance and needs of local communities began to be incorporated into protected area design and management, and new forms of protected areas arose, including those explicitly focused on sustaining local livelihoods and indigenous cultures. Ervin et al. (2010) argue that an "emerging" model of protected areas currently is in process that takes the connection to integrating with and supporting broader societal goals to a new level. This emerging model focuses on maintaining ecosystem functions and services that provide critical life-support systems, and specifically addresses issues of climate adaptation, mitigation, and resilience.

Another useful backdrop for understanding current roles and goals of protected areas is the recently updated *IUCN Guidelines on Applying Protected Area Management Categories* (Dudley 2013). Those guidelines define a protected area 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.

Protected areas may be set aside 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"[2] must always be a primary goal: "For IUCN, only those areas where the main objective is conserving nature can be considered protected areas; 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 protected areas 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, wild crop relatives, and fisheries. These authors also highlight the important role protected areas 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 One, protected areas 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 degradation"). The role of protected areas 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. (See Case Study 1.)

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

- Manage for change, not just persistence

2 For this definition, conservation refers to the on-site maintenance of ecosystems and natural and seminatural habitats, and of viable populations of species in their natural surroundings (as opposed to the off-site conservation work of zoos, aquariums, and botanical gardens), while nature refers to biodiversity at the genetic, species and ecosystem levels, and can also refers to geodiversity and broader natural values (Dudley 2013).

In the "modern" model of protected areas, the importance and needs of local communities are incorporated into protected area design and management.

Case Study 1 COBAM: Climate Change and Forests in the Congo Basin—Synergies between Adaptation and Mitigation

COBAM aims to provide policymakers, practitioners and local communities with the information, analysis and tools they need to implement policies and projects for adaptation to climate change and reduction of carbon emissions in the forests of the Congo Basin, with equitable impacts and co-benefits – including poverty reduction, enhancement of ecosystem services, and protection of local livelihoods and rights. COBAM is implemented by the Center for International Forestry Research (CIFOR) under the African Development Bank grant to the Economic Community of Central African States for financing the Congo Basin Ecosystems Conservation Support Program.

Among many mitigation strategies, the Congo Basin countries have prioritised REDD+, because of the presence of forests and efforts already made toward their sustainable management. REDD+ is a mitigation mechanism offering financial incentives to countries for reducing emissions from deforestation and forest degradation, increasing carbon stock and forest conservation, and managing forests sustainably.

Even though adaptation is gaining importance in the international climate change arena, national policies and projects in developing countries are still in their very early stages, partly because of the complexity of adaptation. In addition, forests and forest peoples are not adequately considered in adaptation debates and policies.

Moreover, even if it is acknowledged that the forest sector offers opportunities for synergies between adaptation and mitigation, there is not much experience and knowledge to confirm it.

To fill this gap, CIFOR initiated the project ‘Climate Change and Forests in the Congo Basin: Synergies between adaptation and mitigation’ (COBAM) in 2010. The research project is funded by the African Development Bank, in support of the Economic Community of Central African States (ECCAS), through the framework of the Congo Basin Ecosystems Conservation Support Programme (PACEBCo). The project aims to conduct research on synergies and trade-offs between mitigation and adaptation in the forestry sector, in order to provide decision makers with the information and knowledge needed to formulate policies and projects that can effectively address climate change.

Overall objective
To provide policymakers, practitioners and local communities with the information, analysis and tools they need to implement policies and projects for adaptation to climate change and reduction of carbon emissions in the forests of the Congo Basin, with equitable impacts and co-benefits – including poverty reduction, enhancement of ecosystem services, and protection of local livelihoods and rights.

Specific objectives

- Empower local, national and regional stakeholders to define and implement their own adaptation and REDD projects, based on an analysis of regional and national policies on forests and climate change.
- Analyse the vulnerability of local communities and define adaptation in selected sites, through a participatory and multiscale approach.
- Analyse opportunities for REDD+, the governance challenges and the potential impacts on local livelihoods, through a participatory and multiscale approach.
- Recommend approaches to identify local projects that enhance synergies between mitigation and adaptation and to identify and mobilise partnerships for the implementation of such projects.
- Develop national and regional strategies targeting the integration of adaptation and REDD+ into forest policies and the promotion of synergies between adaptation and mitigation.
- Communicate, share knowledge and build capacity at local, national and sub-national levels regarding adaptation and REDD+ in the Congo Basin forests.

Expected results

- Science–policy dialogue on the importance of adaptation and forests and the synergies between adaptation and mitigation synergies;
- Strengthened capacity of policymakers for a better understanding of REDD+ and adaptation concepts;
- Information made available on regional and national vulnerability maps;
- Information made available on national level deforestation and degradation drivers;
- Lessons generated from the first pilot projects on adaptation and REDD+ in synergy;
- Integration of lessons from the field in national and regional decision making.


Cultivation of improved vegetable crops enhances the adaptive capacity of populations living along the Congo River. Photo Alba Saray Pérez Terán

Source: http://www1.cifor.org/cobam/home.html
Thanks to: Josiane Kakeu

Safeguarding food supplies, including wild crop relatives such as this strain of wheat growing in Erebuni Reserve, Armenia, is now recognized as an important role for protected areas.

- Reconsider goals, not just strategies
- Adopt forward-looking and climate-informed goals
- Link adaptation actions to climate impacts
- Integrate climate considerations into existing planning

Best Practice 1: Manage for change, not just persistence

Although the rationale for and management of protected areas has evolved over time, as described above, the dominant strategy for biodiversity conservation has been to maintain existing conditions when possible, or restore systems to an ecologically more desirable historical state. Given the broad and pervasive ecological changes underway and expected as a consequence of a shifting climate, protected area managers increasingly will be challenged to actively manage for change, rather than focus just on maintaining the persistence of existing systems.

Conservation biology has been described as a crisis discipline (Soulé 1985) that fundamentally is about understanding, slowing, and ultimately reversing a host of deleterious changes afflicting the natural world. There are, in fact, few truly pristine ecological systems still in existence, and many protected areas consist of mixes of native and non-native species underlain by altered ecological processes—or what have been termed “novel ecosystems” (Hobbs et al. 2006). Accordingly, most protected area goals and objectives seek either to maintain existing levels of 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 increasingly will no longer be tenable. In particular, as climate-driven changes inevitably push many systems towards ecological thresholds, 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.

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. *Resilience* as a term has experienced a surge in popularity to the point where it is often being used as a synonym for climate adaptation itself. Unfortunately, the term has variable meanings that render many of its usages ambiguous. For example, the increasingly popular protected area goal of “enhancing resilience” is vague and largely uninformative unless it is further specified (e.g., resilience of what, to what). Most frequently, use of the term focuses on the capacity for a system to rebound to its prior state following a disturbance. Other uses emphasize the ability of a system to self-organize and retain functionality during and after an ecological transition. *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. It is worth noting, however, that the first generation of climate adaptation efforts undertaken within the biodiversity conservation community largely has emphasized resistance, even in cases where the concept of “enhancing resilience” is invoked.

The dual pathways of persistence and change are, of course, 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, at the level of an individual protected area it may not be possible to sustain viable populations of all native species currently inhabiting the area. At the regional or national level, however, it may be possible to sustain populations of those same species across an entire network of protected areas, 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 also be appropriate to cycle between managing for persistence and managing for change. In some instances, it will make sense to purposefully plan for realignment by managing for persistence (often referred to as “buying time”) until such time as the system begins reaching, or passes, an irreversible ecological threshold or transition. At that time, shifting to an explicit change management strategy may be appropriate to help shape the ecological outcome of the transition. Of course, predicting when such thresholds are approaching is extremely challenging, and often they become apparent only after the fact. Nonetheless, in the face of continual change, protected area practitioners will need to determine when managing for persistence versus change is appropriate, and when to cycle between the two is.

Best Practice 2: Reconsider conservation goals, not just management strategies

As we noted earlier, having clear goals is important in establishing and managing protected areas for many reasons. Indeed, the discipline of systematic conservation planning is predicated on being explicit about what one is attempting to protect (Margules et al. 2007). Similarly, best practices for conservation (e.g., Open Standards for the Practice of Conservation [CMP 2013]) depend on a clear articulation of goals and objectives. Clear goals and objectives are essential both for identifying needed management interventions as well as for monitoring and evaluating the effectiveness of those actions. Well-crafted and explicit conservation goals are the underpinning of good conservation and protected area management in general, regardless of climate change. Unfortunately, many conservation and protected area goals are very general and overly vague, and core values and assumptions often are left unstated.

The added challenges that climate change poses for place-based conservation make it even more important to be explicit about one's conservation goals at an individual site, as well as across an entire protected area system. Given projected climatic shifts, and the associated ecological and human responses, there will be difficult decisions to make, involving trade-offs among various resources, stakeholders, values, and goals. Being as clear as possible about protected area goals, and the assumptions and values that underlie them, is essential to successfully incorporating climate change considerations into protected area establishment and management.

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 are to us. As a result, a key aspect of climate adaptation for protected area management will be conducting an honest and open reconsideration of goals and objectives (Hobbs et al. 2011, Glick 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, as described above, conservation goals are a reflection of human values, and there has been a continuing evolution in how society understands and values nature and protected areas.

Most conservation and resource management today is focused either on the protection of biodiversity, the provision of commodities and ecological services, or the maintenance of human well-being and livelihoods. Reflecting this range, Camacho et al. (2010) summarized the variety of possible conservation goals in the context of climate change by asking "whether we want to be curators seeking to restore and maintain resources for their historical significance; gardeners trying to maximize aesthetic or recreational values; farmers attempting to maximize economic yield; or trustees attempting to actively manage and protect wild species from harm even if that sometimes requires moving them to a more hospitable place?" As these alternatives make clear, it is the underlying human values that will largely determine which goals are regarded as most relevant in any particular place, keeping in mind the IUCN guidance that for protected areas "conservation of nature" should always be the primary concern (Dudley et al. 2013).

There are many existing approaches and best practices for goal-setting, many of which incorporate some version of the so-called "SMART" framework. In this approach, each letter represents a desirable feature of the goal or objective: 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. On the other hand, aspirational goals have their place, and this is not to imply that goals should be unduly constrained, and limited only to those things that are easiest to accomplish under existing social, financial, and political constraints, since constraints change over time. Nonetheless, aspirational goals should be tempered by and balanced against the reality of likely future climatic conditions and their implications for the ecological resources of interest. If, for instance, a particular fish species requires cold water, and there is virtually no likelihood those conditions will exist in the future in a particular protected area, then a goal of maintaining long-term viability of that species at that site no longer makes sense.[3]

Best Practice 3: Adopt forward-looking, climate-informed goals

As noted previously, many existing conservation goals are retrospective, focusing on past conditions as a template and guide for management actions. While past conditions, both climatic and ecological, can be highly informative, in light of rapid climate change there is a need 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 in which 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 5).

Crafting climate-informed goals

Reconsidering long-held goals can be psychologically demanding, and many managers may have difficulty knowing where and how to start on this challenging but important task. The following approach for deconstructing goals into discrete components can help facilitate a review of existing goals, and then crafting more climate-informed versions. Oftentimes modifications may be needed in just one or a few components, rather than a wholesale revision of the goal. To that end, goals can often be divided into the following components to facilitate a climate-informed review and revision process:

- **What** (the conservation target or subject of the goal)
- **Why** (the intended outcomes or desired condition)
- **Where** (the geographic scope)
- **When** (the time frame)

What. Are existing conservation targets still appropriate, or is a change needed in which ecological features or processes should be the focus of attention? Conservation targets can range from individual species to species assemblages, habitat or ecosystem types, ecological processes, or sets of ecosystem goods or services. 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

3 A goal focused on viability over a shorter period of time, however, might be appropriate. See the following section below on "crafting climate-informed goals."

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 protected area 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 continue to make sense, or is there a need to modify time frames? Many current goals explicitly or implicitly assume a time frame of "in perpetuity." Modifications 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, >50 years).

Respect the past but plan for the future

As described above, many protected area and biodiversity conservation goals are retrospective in nature, looking to past ecological conditions for guidance. With climate change, 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 will require that we focus our conservation goals and objectives on future, rather than past, climate and ecological conditions. This does not mean that historical information is irrelevant. Indeed, information from the paleoecological and historical record is essential for understanding how climate has shaped the evolution of life on earth, and how species and ecosystems have responded over time to changes in climatic variables. 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.

The concept of "historical fidelity" has played a particularly strong role in shaping the vision and goals of many protected area 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 protected area values, such as maintaining "naturalness" or, in the case of designated wilderness, an "untrammeled" nature (i.e., untouched by human hand, including active management). Certainly in the context of continual change, goals designed to achieve historical fidelity will increasingly be difficult to achieve.

Broaden planning horizons

Broadening the planning horizon by considering the wider landscape in protected area planning and management is another core element of crafting climate-informed goals. By this we mean not only the broader physical landscape (i.e., space), but also a broader conception of time and relevant institutions and stakeholders. Protected areas exist within a matrix of other land uses and societal values. While planning at a landscape scale has become fairly routine in biodiversity conservation, planning and management for many protected areas still emphasize within-boundary concerns. As climate change causes species to shift across the wider landscape, and exacerbates threats from within and outside protected areas, it will be imperative to think at much broader spatial scales. It is important to acknowledge, however, that in most instances "landscape-scale conservation" does not so much consist of carrying out actions across vast areas, but rather in taking that broader landscape into account when planning for and carrying out local-scale conservation actions.

In a climate-changed world, adherence to historical fidelity goals may conflict with other goals, such as those associated with designated wilderness. Hoover Wilderness boundary, Toiyabe Nationa Forest, USA.

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 only be a concern over the longer term. Protected area 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 only be appropriate or feasible 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 protected area 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 protected areas 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 institutions, communities, and individuals in protected area planning and goal setting.

Emphasize ecological and evolutionary processes

Many existing biodiversity conservation goals focus on protecting existing patterns of diversity, particularly related to compositional elements of biodiversity (e.g., patterns of species occurrences) or structural elements (e.g., patterns of structural vegetation types).[4] As climate impacts increase, many species are expected to shift ranges, and existing ecological communities are predicted to break up, with new and novel 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 protected area goals will need to emphasize the processes that underlay 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 in protected area planning, in light of climate-driven changes these types of process may need to be viewed as the target of goals themselves, rather than simply as supporting factors.

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.

Protected areas need to emphasize important ecological processes, such as seed dispersal, which is facilitated by species such as the flying fox.

Embrace uncertainty

For many protected area 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.

Protected area 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. Protected area 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 uncertainties, managers will need to learn to embrace it.

Best Practice 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 protected area. Each protected area is different, not only based on the ecological, social, and cultural setting, but also on the combinations of threats (climate-related and otherwise) to which they are subject now and in the future. As a result, it is essential that

4 Biodiversity is typically viewed as consisting of three major components: composition, structure, and function (Noss 1990).

the adaptation strategies be capable of addressing the most relevant impacts and vulnerabilities. Indeed, one of the IPCC's (2014) key recommendations on effective adaptation is that "adaptation 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 protected area 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 relabeling 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 relabeling existing conservation efforts as "adaptation" regardless of their link to climate impacts can at a minimum delay needed action, and at worst may actually make things worse.[5]

To be effective, climate adaptation must be carried out in a purposeful, deliberate, and intentional manner (Stein et al. 2014). This is true no matter whether new and novel conservation approaches are indicated, or existing practices and traditional strategies continue to make sense. Adaptation planning that is purposeful and intentional 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 (CMP 2013) concept of "theory of change," which describes how particular efforts will lead to desired conservation outcomes.

The sophistication and rigor 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 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 protected area planning and management, and it is better to get started with simpler and less complex approaches than not to proceed at all.

5 Relabeling of existing efforts is not unique to adaptation, but tends to occur whenever new conservation paradigms emerge (as happened with "sustainable development").

Reducing vulnerability and risk

The very definition of adaptation provides an indication of the importance of linking actions and impacts. The IPCC's fourth assessment (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 (IPCC 2014), 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 (as discussed in Chapter 3) is essential for identifying adaptation strategies and linking actions to climate impacts.

Showing 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 on-going process, rather than a one-time event. For this reason, there will be a premium on being agile and adaptive in protected area management, and thinking of conservation and adaptation actions as hypotheses to be monitored, evaluated, and refined as needed. Being open and transparent about the rationale for, and assumptions underlying, adaptation choices contributes to a culture of continual learning. Just as enhancing the adaptive capacity of ecological systems is important for climate adaptation, so too is the adaptive capacity of the institutions charged with protected area establishment and management. Promoting a culture of learning is a key aspect of institutional adaptive capacity, and not only includes celebrating and replicating successes, but being honest about and learning from failures. "Showing your work" is therefore key to practicing a truly adaptive form of protected area conservation, and managing in the face of an increasingly variable and uncertain climatic future.

Best Practice 5: Integrate climate into existing planning

For most protected area 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 protected area 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. Thus, while there are times when stand-alone adaptation plans are appropriate, in most instances it will be 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

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. (CRAUSABAY)

impacts to competing demands, limited resources (e.g., time, staff, money), and institutional inflexibility (Moser and Ekstrom 2012). Mainstreaming 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."

Integrating climate considerations into existing work also helps to connect longer-term adaptation needs with short-term conservation challenges. Although climate change already is having discernable effects on protected areas, many managers feel that they do not have the "luxury" of worrying about what they perceive as a longer-term threat. Indeed, apart from the psychological challenge of dealing with uncertainty, the longer time-scale of many climate impacts is one of the biggest impediments to adaptation action. One way to bridge this gap is to focus on those near-term conservation strategies and actions that are consistent with longer-term adaptation needs. Such approaches are sometimes referred to as "no-regrets" or "low-regrets" strategies, since they keep adaptation options open and are designed to be robust in performance against a range of possible future conditions.

However, there are times when it makes more sense to carry out adaptation planning as a separate process. 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, then a stand-alone plan will likely be appropriate. 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. As agencies and managers gain familiarity and expertise in putting adaptation principles into practice, however, we expect to see climate considerations become an indispensable and integral component of virtually all protected area planning and management.

Chapter 3
Assessing climate change vulnerability and adaptation options

Ecological vulnerability to climate change refers to the extent to which a protected area's ecology (including species, ecosystems, and ecological processes) is susceptible to harm from the direct and indirect impacts of climate change (Schneider et al. 2007). Understanding how species, ecosystems and ecological processes are already affected by climate change and how they are likely fare under future conditions is essential for developing enduring adaptation strategies. Climate vulnerability assessments (VAs) aim to understand:

- *Which* species, systems, or other conservation targets are most vulnerable;
- *Why* they are vulnerable; and
- *Where* they are vulnerable within a given protected area.

VAs should be done early in adaptation planning because information from them provides a scientific basis for a broad range of adaptation planning activities. Results from VAs are often presented as a categorized list or ranking of the relative vulnerability of the conservation targets (e.g., Foden et al. 2014). These types of rankings can be important because they help identify key vulnerabilities and inform decisions on priorities for action. VA assessments also identify why the conservation target is vulnerable – the link between ecological factors and risk. This information is needed by managers to identify which adaptation actions are appropriate (and which are not), and to design strategies and actions to address vulnerabilities. All VAs apply to a specific area, and in some they are 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).

Vulnerability has three underlying components: exposure, sensitivity and adaptive capacity (IPCC, 2007a, 2012; see Box 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 amount of exposure. Vulnerability is then assessed based on 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 help estimate risk, which is the combination of the likelihood that a future event actually happens and the magnitude of the impact from that event.

Using this general three-component framework, VAs can be conducted on a wide variety of scales and have different scopes. When designing a VA, it is important to ensure the assessment fits the needs of the protected area in terms of

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 (IPCC 2007 TS p. 27)

Exposure is the nature and degree to which a system is exposed to significant climate variations (IPCC 2001). 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. Most 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)(IPCC 2007 WG2 Appendix 1). Sensitivity depends on a variety of factors, including ecophysiology, life history, and microhabitat preferences. These can be assessed by empirical, observational, and modeling studies.

Adaptive capacity refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2007 WG2 Appendix 1). 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, migrating to more suitable regions, phenotypic plasticity, 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 modeling studies.

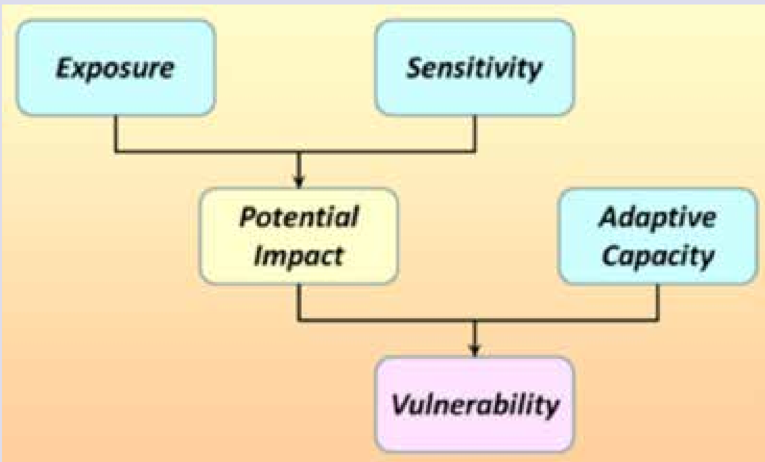


Diagram of the three components of vulnerability, illustrating that the potential impact is determined by exposure and sensitivity, and vulnerability may be moderated by adaptive capacity the geographical area, level of detail of the study, and the resources (e.g., species, ecosystems) that it evaluates. Some VAs are largely qualitative and they may be accomplished simply by holding a multi-day workshop where conservation targets are evaluated by a knowledgeable team, using a set of established criteria (Figure 1). In contrast, 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, audience, available data, and information needs and capacity of those who will use the results.

The specific resource targets of a VA can be species, vegetation communities, a site, an entire protected area, 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.

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

- Evaluation of exposure, sensitivity, and adaptive capacity of the species, ecosystem or ecological process.
- Evaluation of historical changes, driven by both climate and non-climate factors. Where possible, attribute these changes to either climate or non-climate drivers.
- Analyses of observed and projected data on climate, land use, demography, and other key climate and non-climate drivers.
- Evaluation of relative vulnerabilities of species, ecosystems or processes based on an objective scoring system.
- Estimation of uncertainties. There are various ways to estimate uncertainly using expert knowledge or technical methods such as computer models, future emissions scenarios, and statistical variation.
- An analysis of spatial information on vulnerable areas and potential climate refugia.
- Narratives that describe key information sources, relevant ecological and geographical contexts, and justifications for rankings.

Best Practice 1: Design the vulnerability assessment to match the needs of your protected area

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. Key aspects of VAs are selecting the area, period, and number and specific types of conservation targets to be assessed (e.g. a species, ecosystem type or area), as well as the methods and data to be used in the assessment. This section introduces these decisions, which are described elsewhere (Glick et al. 2011).

How large and how long: Space and time scales

VAs can be conducted at local, regional, national and even global scales, and a number of factors will need to be considered to identify the most appropriate one for an assessment. 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

- Expert opinion
- Use conceptual models
- Can use general climate scenarios
- Faster and less inexpensive
- Tightly or loosely structured
- Categorical results

- Computer-based models
- Specific climate projections
- Tend to be data and resource intensive
- Spatially explicit
- May include problematic assumptions

Figure 1. The spectrum of climate vulnerability assessment and characteristics often associated with more qualitative or quantitative approaches.

thinking is especially true when important conservation targets are migratory or widely ranging species, or when ranges shifting in response to climate change may be have important consequences.

For assessments focused on a particular PA, a first consideration should be to identify the area required to support existing biodiversity and key ecological functions. The concept of a Protected Area Centered Ecosystem (PACE; Hansen et al. 2011) was developed to provide a science-based, credible map of the area critical to preservation of terrestrial protected areas. The area addressed by the VA will almost always be larger than is obvious, to be sure the analyses include species or habitats likely to migrate into a PA (including invasive species), changing patterns of land or water use that affect critical habitats or seasonal resources, or changes that can affect the magnitude or frequency of ecosystem-structuring disturbances (fire, floods, etc.). If no guidance is available, a good starting point for larger parks is to consider an area that extends 30 km around the protected area. This 30 km buffer will accommodate natural disturbances and the most impactful land uses around a park.

The period of an assessment must match time scales of management plans and adaptation goals. Most management plans are for periods of less than a decade, but climate change is continuous and requires a much longer view. It's therefore generally useful to evaluate vulnerability for multiple periods. A VA that considers a period 15–20 years in the future as well as mid-century (2050–2060) will support a broad range of decisions. Both time frames can inform on-the-ground management decisions, and identify conservation goals that may not be achievable with future conditions.

Scenarios

While there is value in considering changes over longer periods, perhaps to 2100, the uncertainty in projections increases with the length of time (Hawkins and Sutton 2009, 2011). Over shorter periods, most uncertainty in climate projections is from natural climate cycles and variation. Further into the future, the amount of greenhouse gases in the atmosphere has a much greater effect. Worldwide emissions of greenhouse gases are now close to those of the IPCC projections with the greatest warming (RCP 8.5; http://cdiac.ornl.gov), and use of a high emissions scenario seems most prudent. There are now many choices for selecting climate projections that differ in geographical scale, climate variables, time resolution (e.g., daily, monthly) and methodology. Snover et al. (2013) review these details and provide more detailed guidelines. Regardless of climate model, the Earth's systems respond slowly to past increases in greenhouse gases, and these historical emissions have committed the world to future warming. Re-

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, such as these Mongolian cranes, *Anthropoides virgo.*

ductions in greenhouse gas emissions will have only a small influence on climate changes over the next couple decades, but a successful global mitigation effort could greatly reduce the degree of warming by 2100.

Approaches to assessing vulnerability

Assessments vary widely in regard to scales of space, time, and focus. In this section, we describe only a few common approaches, but assessments relevant to PAs are in no way limited to these categories. With advances in institutional knowledge, data, and tools to support climate adaptation, VAs are continually expanding in scope, complexity, and content.

Species-based approaches

Many methods have been developed to assess species' vulnerability to current climate change, as well as the potential impacts in the coming decades. The IUCN Species Survival Commission's Climate Change Specialist Group has just developed an IUCN Best Practice guidelines on species vulnerability assessment (Foden et al. 2014). We therefore only summarise the three main approaches to assessing species vulnerability:

- Those that start with the current geographic range of a species and then use statistical models to project changes in its size and position using climate change forecasts. These models (referred to as *correlative approaches*) have the advantage of being based on actual geographic information. They can be applied to a wide range of species and at various spatial scales, and a key result is a map of projected suitable habitat. Most models with this approach do not account for behavior or species-specific traits, which can be important (Ockendon et al. 2014).
- Those that use information of species-specific behavior, life history, and other ecological and physiological factors, along with the mechanisms they have developed to cope with changing climatic conditions. The models use this information to project future trends in distribution and population size. These *mechanistic models* are developed from laboratory and field observations of physiological tolerances, behaviour, distribution, and habitat requirements of species.
- Those that use species' innate biological traits as predictors of extinction risk due to climate change, often in combination with estimates of exposure. Methods in these *trait-based approaches* typically involve selecting traits related to sensitivity (e.g., typically describing ecological specialization, inter-specific interactions) and adaptability (i.e. traits related to dispersal and phenotypic and genetic adaptability) and scoring each according to observations or expert judgment. Trait-based VAs are increasingly being used by conservation organizations and management agencies because they permit a relatively rapid climate change VA for multiple species, which can be used to prioritize conservation planning and implementation of adaptation schemes.

Ecological communities to landscapes

Ecological systems are organized at various levels, each of which has unique properties and vulnerabilities to climate change. Assessing vulnerability at multiple levels can inform priorities for adaptation planning. Assessment of the broader levels of organization can help identify very broad-scale changes, such as shifts in major biome types (e.g. deciduous forest to grassland; Gonzalez et al. 2010). VAs typically focus on species, habitats, ecosystems, and functional groups such as plant functional types and biomes (Table 1).

Table 1. Levels of organization of ecological systems that are typically considered in vulnerability assessments.

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; Thuiller et al. 2005
Habitats	Provide key resource for species	Largely via responses of dominant species	Structural complexity Food and other resource provisioning	Location Aerial extent Spatial configuration connectivity	Comer et al. 2012; Manomet Center for Conservation Sciences and the 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 Arial extent Spatial configuration	Schröter et al.; 2005 Teck et al. 2010
Biomes or plant functional types	Broadscale units that define vegetation lifeform 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	Aerial extent Location	Neilson et al. 2005; Rehfeldt et al. 2012.

The genetic level of organization is typically not used in Vas because of sampling difficulties and challenges in interpreting data, and because species integrate many of the important components. Communities are defined as assemblages and as such respond to climate change largely through the responses of individual species and thus are infrequently considered in VAs. Landscapes are recurrent patterns of ecosystems and many VAs focus on ecosystems themselves.

Among the levels of organization, species are of direct interest, both as a key level of biodiversity and because of their value to humans. Species' populations respond to climate change based on their tolerances to environmental conditions; thus species represent the fundamental level of response of higher levels of organization. An increasing number of data sets are available for quantifying species abundance and distributions and how these may interact with climate change. These extensive data sets are valuable for climate assessments. For example, using widely available data, Foden et al. (2013) evaluated the three components of vulnerability (exposure, sensitivity, and adaptive capacity) for nearly 17,000 species, distributed worldwide. Similarly, Lawler et al. (2010) examined climate impacts on amphibians throughout the western hemisphere. While national to global analyses need to be used with caution at the scale of an individual PA (see Franklin et al. 2013), these analyses are sometimes the best available.

Our understanding of the demographics, life history, and habitat predictors of extinction is getting better (Pearson et al. 2014). For all these reasons, the species level is the most widely used in VAs. Species-level assessments typically focus on vertebrates and vascular plants, with lesser-known taxonomic groups being considered mostly through habitat and ecosystem assessments. The various methods of assessing species are described above and in the IUCN best practice guidelines on assessing species vulnerability (Foden et al 2014).

In cases where circumstances prevent a focus on species, habitats or vegetation communities may be used as the basis for a VA. To the extent that species are dependent on habitats, they represent a "coarse" filter (Glick et al. 2011) by which inferences can be drawn s in a more cost-effective manner. Habitat type can often be detected through remote sensing, which makes determining spatial patterns across large areas and changeover time readily feasible (e.g., Comer et al. 2012).

Ecosystems are defined by the collective interactions of organisms with the environment and have emergent properties that are highly relevant both to native species and to humans. A number of assessments look at how stable ecosystems are likely to be when considering future climate change (Iwamura et al. 2012, Watson et al. 2013) and how the processes that sustain these ecosystems will be affected (Mackey et al. 2010).

Recently, ecosystem services — which include provisioning of resources such as water, regulating services such as carbon storage, and cultural services such as aesthetic beauty (Gitay et al. 2001) — have become important part of the assessment framework (Ingram et al. 2013). Consequently, some VAs focus on these services and on the effects of climate change on the resilience of ecosystems to disturbances. A high priority is to identify tipping points where small changes in climate cause ecosystems to undergo major changes (Wall 2007, Laurance et al. 2011). At the spatial scales at which VAs are conducted, simulation modeling is often the only feasible method of assessing potential ecosystem response to climate change. These models often use data from networks of in-situ monitoring stations (e.g., meteorological stations) combined with remotely sensed data on climate and vegetation (Nemani et al. 2009).

Biomes or plant functional types are typically the coarsest organizational level considered in VAs. Plant functional types are defined by physical, phylogenetic and phenological characteristics (Poulter et al. 2011). Examples include temperate needleleaf evergreen and tropical herbaceous forests. Many plant functional types occur within the broad climate zones of the earth. The responses of biomes to climate change can have large consequences for ecosystem services. Change from coniferous forest to grass and shrubland, for example, may lead to reduced retention of snowpack and major changes in the level and timing of runoff. Importantly, biomes are often mapped at spatial scales that are relevant to regional and global climate systems. Vegetation mediates radiative, hydrological, and temperature processes that feed back on climate (Jiang et al. 2013). Consequently, many global climate models include dynamic biome submodels in order to represent interactions between vegetation and climate (Poulter et al. 2011). Continental and global VAs typically consider biome vulnerabilities (Neilson et al. 2005, Rehfeldt et al. 2012, Watson et al. 2013).

The selection of an organizational level or combination of organizational levels to include in a VA depends on the conservation targets, data availability, available resources, and spatial and temporal scales of interest. While we might expect that projects in local areas focus on species and those at continental and larger areas focus on coarse organizational levels, many VAs consider two or more organizational levels – usually species and communities or habitats - because of the additional information they provide (e.g. Aubry et al. 2011; Amberg et al. 2012).

Best Practice 2: Use a structured process to conduct the assessment

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

While every protected area is unique, there are steps and principles that are common to designing and conducting most VAs (Polsky et al. 2003; Harvey and Woodroffe 2008; Glick et al. 2011; Gross et al. 2014). These can be categorized into four general stages as outlined in Table 2 and briefly described below.

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

This stage is essential the initiation of the study and it serves to define the overall goals, engage participants, and articulate details that will determine the scope of work. As with other projects, it is particularly important to be very clear on the purpose, audience, and intended use of 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. If the purpose is to inform detailed, site and species-specific management plans, it may be necessary to use regional climate projections to drive sophisticated population models. It's very important to match assessment characteristics to the desired 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

Information gathering and evaluation will constitute the bulk of work for most assessments. Frequently, information will be applied in the context of an existing framework for evaluating the components of vulnerability (e.g., NatureServe CCVI – Young et al. 2011). For most assessments it is very important to meet with stakeholders fairly early. This meeting is to achieve two goals. First, most recipients of the information will need repeated presentations of the data sources, vulnerability ranks or indices, methods, and consideration of final projects before they understand what is being done. Without full engagement, results are unlikely to be fully used. Second, decisions on a method to assess vulnerability must be made during Stage 1, but problems in applying it may not be apparent until the analyses are underway. Such problems may relate to data availability or quality, spatial context, attributes of the conservation targets, or ambiguities in the methods.

At the end of Stage 2, most assessments will have scores for each conservation target that permit identification of those elements most at risk, and an indication of the cause of the vulnerability. This is the raw information for developing adaptation options.

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

Depending on the number and complexity of conservation targets and evaluation methods, 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) very effectively used 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.).

VAs are, in general, not intended to comprehensively identify and evaluate adaptation options. But in practice, the assessment team is likely to have thoughtfully considered adaptation responses and their potential impacts. It's usually most efficient to include insights and options derived from careful consideration of the ecological and other data used for the assessment.

Potential adaptation measures include active intervention to improve habitat for specific species; here, the western pond turtle in California, USA.

Table 2. General steps to designing and conducting a climate change vulnerability assessment. Feedbacks between processes are not indicated.

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 • 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 (ranks, 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 (casual) 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 and discuss methods, preliminary results, challenges, and issues with stakeholders. • 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 to stakeholders and decision-makers • Revise and submit final products

Stage 4. Reporting and communication

Because VAs are relatively new and rapidly evolving, the methods, results, and implications will likely be unfamiliar to PA managers and other stakeholders. Results from most VAs will include descriptions of the study area, methods, tables, and frequently maps that rank or categorize vulnerability, and narratives that summarise information on the conservation targets and explain the assessment results.

In addition to the usual reports, short summaries, videos and stories can very effectively engage and inform park visitors, staff, and community members. Reports from assessments are often very dense, highly technical documents. Summaries that highlight "key vulnerabilities" (explained below) can be highly effective ways to increase the likelihood that results will be accepted and used by managers and other stakeholders.

Best Practice 3: Focus on key vulnerabilities

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 can be defined as those that pose the greatest obstacles to achieving agreed-upon conservation goals and objectives (Gross et al. 2014).

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 a particular situation, but the following criteria (from Gross et al. 2014) will apply to many situations:

- **Implications for other relevant societal values.** The choice of key vulnerabilities may also take into consideration the extent to which they affect other social and economic values, from mitigating climate risks to human communities to maintaining valued historical or cultural resources.
- **Ecological significance.** Is the vulnerable species or system particularly significant for ecological reasons (e.g., listed as threatened or endangered, keystone species, or ecosystem engineer), or for cultural reasons (e.g., provides a valued ecosystem good or service; contributes to local traditions or customs)?
- **Magnitude of impacts.** What is the scale and intensity of the impact likely to be and would the consequences be especially harmful (e.g., cause cascading extinctions)? Would the relevant impact affect an extended geographical area or large number of species?
- **Likelihood of impacts.** Are the impacts already being observed, or projected to occur with high certainty, or are they based on more uncertain future projections with multiple assumptions?
- **Reversibility of impacts.** Are the potential impacts likely to be persistent or irreversible (e.g., result in species extinction or system collapse), or could actions taken later still be effective? Is there potential for the system to reach an ecological threshold or tipping point of concern?
- **Timing of impacts**. Are the impacts already occurring or expected to occur in the near term, or are they only expected to manifest in a longer time frame? Near-term impacts may be more likely to rank as key vulnerabilities, in part because people tend to discount future values (both costs and benefits). However, even where impacts may be further in the future, opportunity costs might be incurred by failure to act in the near term.
- **Potential for successful adaptation.** Although this should not be the primary criterion for identifying key vulnerabilities, particularly since one may not at this

Focusing on key vulnerabities, such as risk of cascading extinctions, is a Best Practice. A classic example of cascade effects occurred with sea otters. Starting before the 17th century and not phased out until 1911, sea otters were hunted aggressively for their exceptionally warm and valuable pelts, which could fetch up to $2500 US. This caused cascade effects through the kelp forest ecosystems along the Pacific Coast of North America.

point have a sense for what adaptation options might be available, opportunities for successful adaptation can be relevant.

VAs are a critical step towards climate adaptation. They identify what is at risk, why, and where, but this information alone cannot determine priorities for action. A structured process to identify key vulnerabilities provides a means to explicitly link adaptation actions to climate impacts.

Chapter 4
Management strategies:
Moving to action

The evidence is clear that climate change is upon us and protected area managers can expect to be dealing with a profound new challenge. We are now in an era of managing for change as much as managing for persistence or historical conditions (see section on Developing and Modifying Goals under climate change). This section looks at management strategies and actions to address these challenges. Perhaps first and foremost, it is important not to simply conclude that this is such an enormous problem that nothing can be done at a protected areas level or even by a system of protected areas. Indeed there is much that can be done.

Perhaps first and foremost, it is important not to simply conclude that this is such an enormous problem that nothing can be done at a protected areas level or even by a system of protected areas. Indeed there is much that can be done.

Climate change adaptation

Planning for climate change normally includes a re-examination of conservation goals to ensure they are still realistic and achievable, take into account risks and sources of vulnerability, and an appreciation and consideration of the local situation and management capabilities. Information on what is at risk and why it is at risk, is needed to ensure that current conservation goals are realistic, achievable, and consistent with projected climate changes. A list of key vulnerabilities and threats, identified from vulnerability assessments, literature reviews, management plans, and information from park staff, stakeholders, and outside experts, is important information that can focus adaptation efforts where they will make the most difference. Conceptual models are useful for developing and communicating a common understanding of ecosystem dynamics, identifying key linkages, and clarifying relationships between adaptation options and desired conservation goals.

As discussed earlier, climate vulnerability assessments provide information needed to help identify adaptation options, including lists of important conservation targets, projections of key climate variables, and ecological consequences of changing climatic conditions. Important ecological consequences of climate change will likely include changes in patterns of rainfall and water runoff, increased annual and seasonal temperatures, increased numbers of extreme events (e.g. droughts, floods), changes in length of growing season or frost-free period, timing of seasonal migrations, and changes in snow cover.

Climate change will likely affect many aspects of the protected area's natural and cultural resources, as well as those of local human communities that live in or around the park at the same time. Adaptation options will thus need to consider factors outside parks 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 park to other natural areas.

Adaptation actions may be anticipatory (i.e., actions that prepare for known or potential future impacts) or reactive (those that respond to impacts already apparent). Either or both approaches may be appropriate, depending on the circumstances (Palmer et al. 2009). For instance, a decision to relocate a facility or road out of a floodplain following a major flood constitutes a reactive adaptation action, while a decision

Adaptation options will thus need to consider factors outside parks that contribute to their integrity and sustainability, including protecting habitats critical to species of concern (e.g. seasonal needs of wildlife such as the Hawaiian nene, left), uplands that protect water quality or quantity (Dominican Republic, right), buffers from disturbances, and habitats that connect the park to other natural areas. [CRAUSABAY] not to build there in the first place would be anticipatory. Similarly, reactive actions may involve efforts to control an invasive species after it has expanded into new areas as a result of changes in climatic variables. Anticipatory actions 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 designed to keep them from invading sensitive areas.

Best Practice 1: Begin "no-regret" actions common to all PAs

These are actions that protected area managers can undertake to be ready for climate change, regardless of any chosen strategy and regardless of the amount of climate change the PA is going to experience. These might be called good management, or simply being ready. Organizations that effectively address climate change have these "hallmarks of adapting organizations" (Wilby and Vaughn 2010):

1. Ensure **management capacity** is in place for effective management in a changing climate. Dealing with climate change will require people to plan, manage and act. Effective management capacity involves strong leadership that is credible and broadminded. Leadership is necessary to help shape and implement adaptation priorities. If investments or partnerships cannot be found to develop this capacity, success is doubtful.

Anticipatory actions 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 designed to keep them from invading sensitive areas. Worker removing exotic Brazilian pepper plants.

2. Make sure that there is i**nstitutional support for adaptive management**, which is the conscious endorsement of learning while doing (see section xx on adaptive management). Adaptive management requires a flexible approach that values learning, does not penalize mistakes made in good faith, and responds to new information. Many protected area agencies will need a shift in culture to become adaptive managers.
3. **Increase knowledge and information** of impacts and responses by animals and plants to a changing climate (see section on monitoring). Climate change shares some characteristics with previous threats, with the key difference that it is operating over larger areas and longer time periods. As with managing all threats, as knowledge about the problem increases, so too does the likelihood of success.
4. Increase awareness and motivate action by others through i**mproved communications** (see section on communications). Most PA managers must be continuously engaged in learning about emerging climate changes, ecological responses, and adaptation practices that they might implement. A common understanding of the problem and shared learning of solutions among managers is key.
5. **Engage participants and partners** in common solutions. Climate change is an enormous problem that affects all ecological systems and the people that rely on them. Implementation of effective adaptation cannot be undertaken alone.

Best Practice 2: Identify the full range of potential adaptation options

A highly varied list of adaptation options is critical for fostering the creative thinking that may be required to meet new challenges. Climate changes that will occur in some areas include new combinations of species, different patterns of fire or flood, and alterations to established ecological processes such as the timing of spring green-up, water runoff, or outbreaks of pests. Conventional management practices are no longer adequate, and managers and scientists must work together to consider new practices, or significant adjustment to existing ones, that can address impacts not previously experienced. It is longer good enough to apply the same tools "better" or "more". At this stage, creativity can contribute to identifying the broadest range of options, without regard to whether they are currently considered logistically, technically, or politically "practical" or even "possible". In some areas, the magnitude of climate change is already dramatically affecting decisions, and practices considered unrealistic a short time ago are now being implemented.

A good way to begin is to consider general approaches to adaptation. A number of 'best practice' principles are becoming established. Table 4.1 describes general approaches that are applicable to most PAs and can serve as a basis for generating more specific adaptation options that are tailored to local situations. Each location will have its own set of non-climate stressors such as invasive species, land use intensification, pollution, and extreme weather events. The approaches described in Table 4.1 should be used as initial guidance. The following section of this guide addresses more specific strategies.

Table 1. General approaches to identify adaption options. Derived and modified from West et al. (2009), Mawdsley et al. (2009), Groves et al. (2012), West and Julius (2014) and Watson et al. (2011, 2013)

Principle	Description
Reduce non-climate stressors	Pollution, disturbances, disease, and other stressors reduce the ability of species and ecosystem to adapt to climate change.
Prioritise the protection of intact, connected ecosystems	Intact, functioning ecosystems are more resilient to climate change than degraded systems. Prioritising the protection of intact systems is essential for allowing species to adapt to current and future changes.
Identify and protect climate refugia	Climate refugia are local areas that experience less climate change than the broader surrounding area and are areas that in the future that are likely to experience less climate change. 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.
Conserve key ecological features	Focus management on enduring ecological features (the geophysical stage), structures, organisms, and areas that are the foundations of communities and ecosystem properties. Riparian corridors, freshwater supplies (springs, lakes, etc.), and critical habitat for keystone species are typically high priority.
Preserve and enhance connectivity	Connectivity operates on multiple levels. For species and communities, provide the opportunity to respond to climate changes by shifting their distributions. Facilitate the movement of water, nutrients, energy, and organism between resources and habitats. Connectivity is often considered to enhance system resiliency.
Sustain or restore ecosystem process and function to promote resilience	Climate changes will challenge our ability to preserve all current species, and the focus here is to preserve fundamental ecosystem properties like primary productivity (biomass growth), decomposition, wetland filtration of nutrients and sediments, and nutrient cycling. These processes contribute to ecological integrity even if there are changes in species composition and ecosystem structure.
Improve representation, redundancy and replication	Both within and across PAs, attempt to conserve or protect samples of key species, habitats, and ecosystems (representation) at multiple sites (redundancy and replication). This addresses a fundamental conservation principle to spread risk and bet-hedge against catastrophic losses at a specific site. Where possible, manage to assist adaptive evolutionary change by e.g. supporting populations in diverse habitats, facilitating gene flow, or actively managing genetic composition of species (e.g. via forest management).
Assist colonization	It may be appropriate, or necessary, in some situations to actively move organisms and assist in their establishment at locations where they currently or never previously existed. Some argue that this is an essential task due to human-caused habitat fragmentation and artificial barriers to species movements. Assisted colonization is highly controversial as a climate adaptation strategy, but relocations, introductions, and reintroductions have been routine practices in conservation, wildlife management, and agriculture for centuries.

A variety of techniques are available for expanding the list of potential adaptation options. Regardless of technique, it is important that participants in the process have varied backgrounds and expertise. A better outcome will be achieved when ideas originate from a mix of topical experts (climate scientists, ecologists, hydrologists), park resource managers, park decision makers (e.g. superintendents or directors), and citizens or others with local and/or traditional knowledge. A broad range of participants help ensure that discipline-specific insights are expressed and become part of the process.

More traditional techniques for identifying options are to review the scholarly and managerial literature and case studies, and to conduct brainstorming workshops. These techniques are familiar and relatively easy and inexpensive, but the information they generate needs to be carefully filtered to ensure it applies to the area of interest; in some cases the options may be more limited to past practices than desired. West and Julius (2014; their table 8.1) briefly describe a number of other techniques that can be used at this stage to stimulate thinking and help identify a broad range of options.

Scenario planning is a promising technique that is increasingly used to facilitate climate adaption planning. Scenarios explore and describe plausible characteristics of several specific future conditions, enabling managers to better define their goals under changing circumstances. Scenarios are not predictions about the future, but alternative accounts of what might happen. Scenario planning can be a particularly valuable approach for situations with high uncertainty and relatively little control, where some of the unknown changes may be unlikely but highly consequential (Peterson et al. 2003; Weeks et al. 2011; NPS 2013). In the context of adaptation planning, a scenario is a detailed story about the future which is driven by external changes (including climate) and is plausible, provocative, and that challenges current thinking. Scenario planning differs from more traditional planning by acknowledging our inability to predict the future, and by encouraging decisions that can be adjusted as it becomes more apparent which conditions are likely to actually happen. The main role of scenario planning is to provide a way to explore a broader range of potential futures than is typically addressed, as in, for example, processes that seek to identify and achieve a desired future condition.

Selecting adaptation options

As noted above, there is not always a clear line between adaptation and mitigation. Still, the strategies and actions that fall most within the responsibilities of a protected area manager or planner are those that are called adaptation. In section 2, there is a focus on understanding the magnitude of potential climate change and the susceptibility of a particular ecosystem to

This guidance document proposes a process to adapt to climate change, not a recipe

that change. This understanding is a fundamental first step to developing adaptation options. Climate change is global, but adaptation is local. Whatever choices are made by PA managers, they must first and foremost be right for the local situation. This guidance document proposes a process for adapting to climate change, not a fool proof recipe for how to do it.

It should be stressed that adaptation is not a management endpoint or even a specific goal. It is a continuous process that is itself adaptive. Adaptation must become a routine part of planning and management, rather than being viewed as project to complete. Within this new way of doing business, perhaps the greatest challenge is that there are higher levels of uncertainty than previously. Climate change takes protected areas into an uncertain future, where our ability to predict ecological cause and effect is, at this stage, minimal.

This guidance document cannot specify all potential adaptation actions. Rather we have grouped actions into four strategies, depending in the expected magnitude of change and the ecosystems' relative susceptibility. The strategies discussed here are for ecosystem conservation, and not for managing hazards to people or protecting facilities. There are other comprehensive guides to those topics.

Protected area system-level considerations

Species are already responding to current levels of climate change. Some birds, larger mammals, marine fish and plants are adapted to long-distance dispersal can rapidly move as the climate changes. They will move faster than other species they now live with and so will begin to form new ecological community types (Hobbs et al. 2009). Other species, such as amphibians, turtles, large seeded plants, move very slowly, certainly not quickly enough to respond to climate change. Chen & al (2011) estimated that the distributions of species have recently shifted to higher elevations at a median rate of 11.0 meters per decade, and to higher latitudes at a median rate of 16.9 kilometres per decade. These rates are considerably faster than previously reported and greatest in studies showing the highest levels of warming. They also noted that there is wide variation around the average movement range because of the diversity of responses by individual species. In Arctic communities there are several examples of recent large scale movements. Examples include American robins (*Turdus migratorius*) breeding for the first time on High Arctic islands and red fox (*Vulpes vulpes*) moving into Arctic landscapes and displacing native Arctic foxes (*Vulpes lagopus*).

The rate of reported shifts in species distributions is so rapid that such changes must now become a protected area system planning consideration, transcending the boundaries of individual parks (Hole et al. 2011). The movement of species and reforming of ecosystems has been a characteristic of evolutionary history. What is different now is the rate at which they are predicted to happen. We likely have never had such a rapid rate of climate change as is predicted for the next century (citation). So if species are being driven to move, systems planners must decide whether to facilitate that by enhancing ecological connectivity. The question of connectivity is a complex one. Certainly there are protected areas where isolation may be beneficial. Isolation may benefit rare species when connectivity may facilitate transmission of disease, or allow predators or competitors to invade. Dispersal of invasive species – both weeds and animals – may be inadvertently boosted, especially if corridors are in disturbed areas. Connectivity should be routinely considered as part of adaptation planning, with the recognition that there may be both good and bad consequences.

Despite these potential negative effects, ecosystem connectivity is generally desirable to create, maintain, or restore throughout a protected area system. Conservationists have long recognized the importance of taking a large landscape approach. Now with rapid, climate-driven shifts in species distributions already underway, the need for considering the broader landscape context takes on added significance for climate adaptation.

Species are already shifting their ranges in response to climate change. For example, red fox are moving into Arctic landscapes and displacing native Arctic foxes.

Best practices for system-level thinking in climate change adaptation

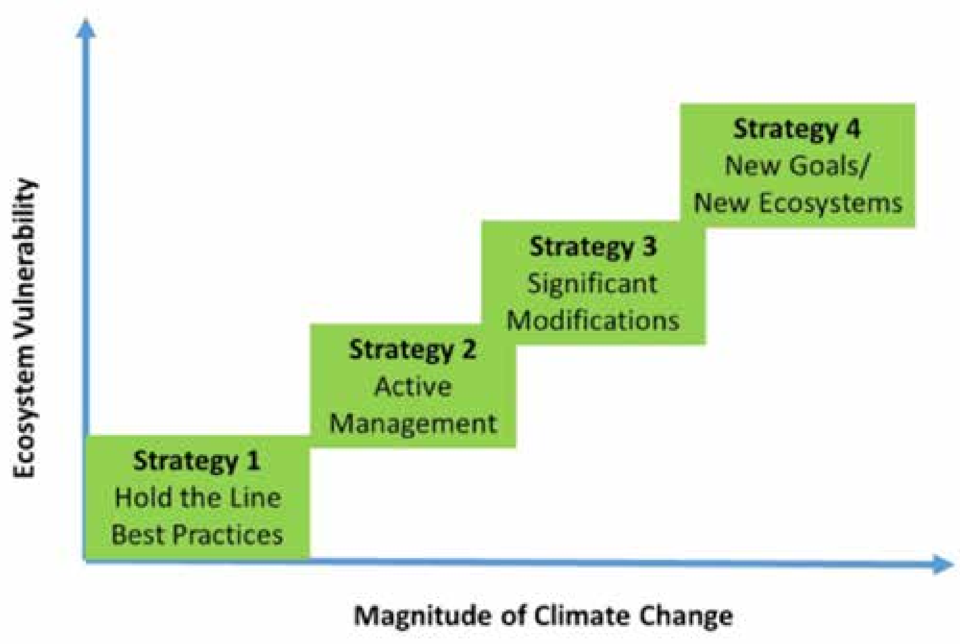
Overall we must plan for a system of protected areas that is most adaptive to climate change:

1. Expand the protected areas network in ways that enhance species and ecosystems adaptation to climate change. This means prioritising intact, functioning landscapes and seascapes for future protection, prioritising environmental gradients and avoiding areas that are seriously degraded and likely experience significant climate change. Almost all nations have already signed on to the Convention on Biological Diversity's global commitment to Aichi Target 11 change (http://www.cbd.int/sp/targets/) in land and sea. Target 11 call for expansion of protected area systems, more effective management, better planning for site areas to conserve biodiversity and ecosystem services and ecological connectivity. This provides an opportunity for planners to add to existing protected areas to make them more resilient to climate change. It also provides an opportunity to develop ecological connectivity by conserving linkages.
2. Plan for a mix of protected area sizes in the system, but prioritise for very large representative units. Large, intact protected areas will generally have larger populations of any given species, with resulting resilience inherent to larger populations. Large protected areas will also generally have more topographic diversity, when compared to smaller protected areas in the same region and greater chance of containing climate refugia (Watson et al. 2011).
3. Where possible, plan protected area units that have high physiographic diversity (valleys, plains, mountains, ridges, etc.) to maximize the potential for climate refuges. This applies in land and sea. Ensuring that conservation planning encompasses the full spectrum of physical settings defined by elevation, geology and other physical factors (Beier and Brost, 2010).
4. Ensure that legal and regulatory framework allows park managers the flexibility to adapt to climate change. For many protected areas, 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 benchmark for the future as 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 linkages, corridors and connectivity and prioritising the protection of large, intact systems. Intervening landscapes and waterscapes between formally protected areas may be critically important to achieving protection commitments and to allow species movement. There are excellent references on this topic such as "Connectivity Conservation Management: A Global Guide" (Worboys et al, 2010.) or the Wildlife Conservation Societies Assessment and Planning for Ecological Connectivity: A Practical Guide. http://www.wcs-ahead.org/kaza/ecological_connectivity_07_20_11_2.pdf (Aune et al, 2011).
6. Wherever possible, integrate protected areas into surrounding landscapes so that there is joint planning and considerations for 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.
7. Regularly review protected area boundaries to see if adjustment is necessary to help achieve protection commitments in the face of climate change.
8. For marine ecosystems, managers should refer to considerations for incorporating climate adaptation into marine protected area site and system planning by Hoffman (2003), Hannah and Hansen (2005), and Dudley et al. (2005).

Protected area-level strategies and actions

At the level of individual protected areas, we suggest four different strategies for protected area management to consider. They are based earlier stages of this guide, predicting the magnitude of climate change and the vulnerability of the ecosystem to those changes (see Figure 1). The four strategies are not always exclusive and there may be cases where it is appropriate to cycle between different ones, depending on changing circumstances. In particular, there are many situations where it's effective to cycle between strategies to maintain current conditions (Strategy 2) and to then facilitate transformation to a new system (Strategy 3 or 4) (see Climate-Smart guide).

PA systems should prioritise for very large representative units, such as (left) Sundarbans National Park (India) here represented by a mangrove forest. Systems should also Where possible plan protected area units that have high physiographic diversity such as at (right) Sierra Nevada de Santa Marta National Park (Colombia).



Strategy 1: Holding the line – managing for existing conditions by ecological integrity and resilience

This strategy is for those protected areas where the vulnerability assessments indicate there is high probability of retaining the same ecosystem type by applying currently understood best management practices. It is critical that protected areas managers begin thinking hard about climate change right now. However, for many protected areas it will be practical to employ sound basic management practices as an initial climate change strategy. We know that many protected areas are not currently being managed to acceptable standards. A 2010 global assessment of 4,151 protected areas concluded that only 24% had fully sound management, 36% had basic management, 27% had major deficiencies and 13% were completely inadequate (Leverington et al 2010). The weakest aspects of management related to the adequacy and reliability of funding, facilities and equipment, staff shortages, and the lack of appropriate benefit-sharing programmes for local communities (Leverington et al 2010). This conclusion applied in both rich and poor countries. In Europe, a supplementary study found a higher percentage (30%) of protected areas under sound management, but still noted major deficiencies or completely inadequate management in 33% of the protected areas for which data were available.

Strategy 1 applies to situations where 1) improvement in basic management practices will increase the integrity of the system and thus its resilience; and 2) managing for persistence will continue to be appropriate, at least in the short term, and in a few instances over the longer term. With Strategy 1, existing ecosystem goals are maintained. However, it is also recommended that the protected area itself be considered as a system, and thus managed for ecological integrity and resilience. This is an important distinction as many protected areas have goals for only particular features or individual species, and not for the broader ecosystem or landscape.

Ecological integrity has been chosen as a management goal by many protected areas agencies around the world. It recognises 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 (Edwards & Regier, 1990; Woodley et al 1993, Pimentel et al, 2000), and, with respect to a protected area, 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 inter-connected (see section on resilience). There is now unequivocal evidence that loss of ecological integrity, as measured by species loss, reduces the efficiency by which ecological communities function, including the production of biomass, and the decomposition and recycling of biologically essential nutrients (Cardinale el al, 2012). Further, there is mounting evidence that biodiversity (measured by species richness) increases the stability of ecosystem functions through time. Ecosystems have characteristic levels and interactions of primary producers, herbivores, and carnivores, often described as food webs. Levels within a food web are termed trophic levels. Loss of species across trophic levels has the potential to influence ecosystem functions very strongly. Food web interactions are key mediators of ecosystem functioning. For example, the loss of top-level predators, such as large carnivores, can cascade through a food web, leading to alterations in vegetation structure, fire frequency, and even disease epidemics in a range of terrestrial ecosystems (Cardinale el al, 2012). It seems that these general principles of ecosystem function also apply to carbon cycles, at least for some ecosystems. For example, the removal of large-bodied seed-dispersing species leads to reduced forest carbon density (Brodie & Gibbs, 2009).

Best Practices for Holding the line: Managing for ecological integrity in protected areas

Ecosystems, especially those within areas that are likely to have relatively stable climates, will be the most resistant to

The loss of top-level predators, such as lions and other large carnivores, can cascade through a food web, leading to alterations in vegetation structure, fire frequency, and even disease epidemics in a range of terrestrial ecosystems. [CRAUSABAY]

climate change if they are managed for ecological integrity (Cardinale et al, 2012).

1. **For a holding the line strategy, protected areas should aim to conserve all native species.** This is because ecosystem's lose integrity when they lose species. Some of the main cause of species loss are habitat loss and fragmentation; many protected areas lose species because they are too small. For example, western North American parks have experienced extinction rates that are inversely related to park size (Newmark 1995). Other examples of stressed ecosystems losing species include Canadian boreal forests subject to high sulphur dioxide emissions (Freedman and Hutchinson 1980); temperate deciduous forest subject to radiation exposure (Woodwell 1970); and estuarine diatom communities subject to heavy metal pollution (Patrick 1967).
2. **Populations of carefully chosen indicator species in protected areas should be managed so as to be viable.** For practical reasons, it will only be possible for protected area managers to assess and monitor the viability of a few indicator species. There is a large literature on the selection of indicator species (see Simberloff, 1998, Lindenmayer and Lichens, 2010). The status of indicator species is usually determined by examining population vital rates (e.g. birth, death, immigration and emigration). In some cases, the monitoring data can be incorporated into a population viability analysis to estimate the probability of survival (or conversely the probability of extinction) for a relevant period of time (Burgman et al. 1993).
3. **Ecosystem trophic levels in protected areas should be intact.** Highly impacted ecosystems tend to have food webs whose trophic levels are simple in comparison to unmodified ecosystems. For example, the loss of top carnivores can result in hyper-abundant ungulate (hoofed grazing animal) populations, which have cascading adverse effects on plant communities (Estes et al. 2011).
4. **Disturbance regimes in protected areas should operate to maintain biological communities with a mix of age classes.** Ecosystems are inherently dynamic, driven by disturbances such as fire, climate change, weather-related events such as storms and drought, and changes in component populations. After a disturbance, ecosystems pass through sometimes-predictable successional stages. Repeated disturbances create a mosaic of biological communities over time. The resulting configuration of community types of different sizes and ages determines the survival of individual species. Since some disturbances (e.g. fire and herbivory) can be influenced by protected area managers, this aspect of ecological integrity is at least partly under their control.
5. **Productivity and decomposition in protected areas should not be allowed to exceed limits for system persistence.** Most ecosystems are driven by primary productivity, the amount of organic matter produced by biological activity per unit area over a given period (Hooper et al. 2012). The onset of ecosystem problems occurs when subtle shifts in productivity take place and major problems happen when energy is lost from the ecosystem in an uncontrolled manner. For example, in stressed systems, such as heavily logged forests, decomposition rates rise significantly. For a given ecosystem, productivity and decomposition operate within a range that allows it to persist. When these vital processes move outside that band, the ecosystem is fundamentally impacted and loses its integrity. Studies in the eastern United States found that local factors played a far greater role than climate in wood decomposition rates, with subsequent impacts on regional carbon cycling. Because decomposition of organic matter strongly influences the storage of carbon, or its release into the atmosphere, it is a major factor in potential changes to the climate (Bradford et al 2014). In many areas, trends in above-ground productivity can be monitored from changes in the normalized difference vegetation index (NDVI), using readily available data from satellite-based sensors (http://glcf.umd.edu/data/ndvi/).

6. **Ensure ecological connectivity for the protected area**. It is important to work at the landscape and regional levels to ensure ecological connectivity between protected areas and integration with populations using the landscape around protected areas. Connectivity increases the effective population size and allows gene flow among protected and natural areas (Di Minin et al 2013, Sawaya et al 2013). Guidance on managing for ecological connectivity can be found from several sources(see esp. Worboys et al, 2012).
7. **Manage known, non-climate, threats**. Reduction of the known "non-climate" threats (e.g. habitat loss, water pollution, or unsustainable harvest) is a commonly cited adaptation approach. Non-climate stressors can reduce the vigour of species and thereby increase their susceptibility to climate effects. Climate changes do not affect species in isolation of the many other challenges we face in conservation (Hansen and Hoffman 2011). If there are known threats to an ecosystem in a protected areas, it is generally best practice to monitor, act early and adapt as required (see section on Monitoring and Adaptive Management). Early action is especially critical for certain threats, such as invasive species.

Strategy 2: Actively managing to maintain specific ecological values

For many protected areas, it will be necessary to use ongoing active management to conserve high-value and/or irreplaceable assets. This strategy assumes that the protected areas retain their existing ecological goals, but then move well beyond the ecological integrity practices outlined in option 1. With this strategy, it is essential that park managers actively manage to maintain ecological values. *In these cases, the ecological value would not likely persist without ongoing active intervention, but is likely persist with it.* This situation, while sounding quite extreme, is actually very common in contemporary protected area management, even in the absence of climate change. There are a wide range of conservation-dependent or conservation-reliant species (Scott et al, 2005) — those that require regular and ongoing conservation actions to remain viable.

In some cases, active management for persistence may be appropriate to forestall the effects of climate change. A resistance strategy (Table 1) may be the best option for many protected areas (Gilbert et al. 2010, Pearce-Higgins et al. 2010). A resistance strategy may "buy time" and permit the protected area to identify and implement adaptation efforts that are required when it's no longer possible to maintain current conditions.

Reduction of the known "non-climate" threats, such as overgrazing (exclosure pictured above), is a commonly cited adaptation approach.

Many protected areas will contain areas whose local climates change less than others. For example, in mountain areas north-facing slopes may remain cooler and wetter and actually change less than the region in general. Such areas are termed "climate refugia," defined as areas where the effects of climate change are likely to be buffered to the extent that particular species can be expected to survive over the long term (Ashcroft 2010, Keppel et al. 2011).

An active management strategy does not mean that the sound management practices of Strategy 1 can be abandoned. On the contrary, the basic good management practices to ensure ecological integrity must be continued as complimentary to active management. Below are some additional active management practices that might be considered:

Best Practices — Active management to maintain species, ecosystem and processes

1. Manage populations of species likely to be lost that are identified as part of the goal of the protected area.

Population enhancement can be done by a wide range of techniques. All populations are driven by only four rates; birth, death, immigration and emigration. So population management is about influencing at least one of those rates. A first avenue to consider is to enhance the habitat for a given species. Increasing the effective habitat size within the protected area for a given species means that it can contain more individuals of that species. Effective habitat size can be increased through land acquisition, or by ecological restoration or enhancement, using techniques such planting, the use of fire, or cutting. There are many other direct techniques available to enhance populations depending on the species and the ecosystem, including planting, species translocation, provision of next boxes etc. (see IUCN Guidelines on Reintroductions and Other Conservation Translocations - http://cmsdata.iucn.org.iucn.vm.iway.ch/custom/image-viewer/launch.cfm?img_id=31062).

There will always be a mix of actions directly related to climate change and those that are not. This is because climate change is a stressor that acts in concert with other ones. For example, park managers have long been protecting nests of marine turtles and even using artificial nests to enhance populations. With climate change, there will be a rise in beach temperatures. Sex determination in a turtle eggs depends on the temperature at which it incubates, with males being produced from cooler nests (citation). Warmer beaches will result in a higher proportion of female turtles. One active management technique is to incubate eggs at the range of temperatures to get a desired sex ratio of hatchlings.

Control of predation and herbivory. Controlling predation can be a very effective way to manage for species of high conservation value, especially when predation by non-native species (e.g. pigs, goats, feral cats, rats) is strongly depressing a population. Predator culling can be highly controversial as well as ineffective, such the killing of wolves to enhance

Park managers have long been protecting nests of marine turtles tles and even using artificial nests to enhance populations. With climate change, there will be a rise in beach temperatures. Sex determination in a turtle eggs depends on the temperature at which it incubates, with males being produced from cooler nests (citation). Warmer beaches will result in a higher proportion of female turtles. One active management technique is to incubate eggs at the range of temperatures to get a desired sex ratio of hatchlings, such as these at Cape Hatteras National Seashore, USA.

caribou populations in Canada and Alaska. But there are many other ways to control predators. For example, turtle nests can be covered by mesh boxes to prevent predation. For plants, it may be important to manage against excess herbivory using fencing, repellents, or even culling of grazing animals. In general, predator control will rarely be appropriate for native predators, but is often warranted for introduced predators.

Control of overabundant species. In ecosystems missing certain natural processes and/or predators, the population size of some species may grow unchecked, potentially until it reaches the carrying capacity of the area, defined as the number of individuals an area can support, given available resources (Stokes 2012). Unnaturally abundant populations may end up exhausting the local resources leading to a population crash, as has happened with elephants in some African protected areas (Whyte 2007) or white-tailed deer in North America. Large populations of herbivores or mid-level predators (such as raccoons (Procyon lotor) or coatis (Nasus spp.)) can dramatically alter ecosystems and threaten ecological values.

Most herbivore populations exhibit large, natural population cycles (Gross et al. 2010) and a decision to use culling of species that seem to be overabundant should never be taken lightly. Any culling action requires a detailed population model, a prediction of the impacts of the action, and considerable follow-up monitoring to evaluate its effectiveness. Culling of native herbivores is a practice that is suitable only in very specific situations.

2. Maintain genetic diversity of key populations

Small populations can be augmented by translocation of individuals from larger and healthier populations in order to increase local population size and increase genetic diversity (Bouzat et al 2009). This is a well-established principle with many examples around the world, such as reintroduction of tigers [SPECIES NAME] to Sariska National Park in India and golden lion tamarins (Leontopithecus rosalia) in the Atlantic forests of Brazil. Before conducting any movement of animals, managers should carefully examine the IUCN Guidelines on Reintroductions and Other Conservation Translocations - http://cmsdata.iucn.org.iucn.vm.iway.ch/custom/image-viewer/launch.cfm?img_id=31062).

Active management of known threats that will be exacerbated by climate change. Threats can be considered and classified in a systematic way. The IUCN-Conservation Measures Partnership (CMP) has constructed a threat hierarchy with three different levels, analogous to families, genera, and species in the Linnaean system. Called the Miradi threat rating system, and designed to be used with proprietary management software, (Miradi 2007), this is designed to be applied to assess the impact of a specific threat on given conservation target, using a combination of extent (area) and severity (intensity). Miradi uses specific four-point rating scales for each criterion (very high, high, medium and low) that, where possible, are linked to specific percentages. The thresholds between criteria are designed to represent both ecologically and practically meaningful breakpoints between the categories. Guidance for management of most specific threats is outside the scope of this document. However, invasive species are so relevant to protected areas and climate change that we include them next.

Management of Invasive Species - Invasive species are one of greatest global threats to ecosystems. This is well documented by the IUCN Invasive Species Specialist Group, who have a range of resources on the topic (http://www.issg.org/). Certainly globalization facilitates the spread of invasive alien species as international commerce develops new trade routes, markets, and products (Meyerson & Mooney, 2007). With climate change, many species are now on the move on their own, migrating to meet their life needs and taking advantage of changing conditions. In the Arctic for example, red foxes, grizzly bears (Ursus arctos) and American robins are appearing where they have never been recorded before.

These are species moving in response to climate change, a rather different phenomenon than when species arrive in shipping containers or escape (or are released) from the pet trade. Protected area managers will need to make difficult decisions about managing species that are migrating on their own in response to climate change, as opposed to the merely opportunistic spread of invasive alien species. Monitoring is the first step. There are tools available to assess the likely impact of invasive alien species. These same tools can be used to assess vulnerability of ecosystem to climate change migrants.

3. Proactively identify and actively manage climate refugia, Refugia are less likely to be affected by climate driven-processes of drought, fire or warming. Examples include marine canyons with upwellings, slopes facing away from the equator (north in the Northern Hemisphere, south in the Southern), and areas around persistent springs. Micro-refuge networks may play an important role in maintaining diversity at a regional scale and contribute to the stability, resilience, and adaptive capacity of ecosystems in the face of climate change. A method for identification of climate refugia has been published by MacKay et al, 2012. Protected areas managers should proactively identify and protect these locations within protected areas. (See section x on refugia)

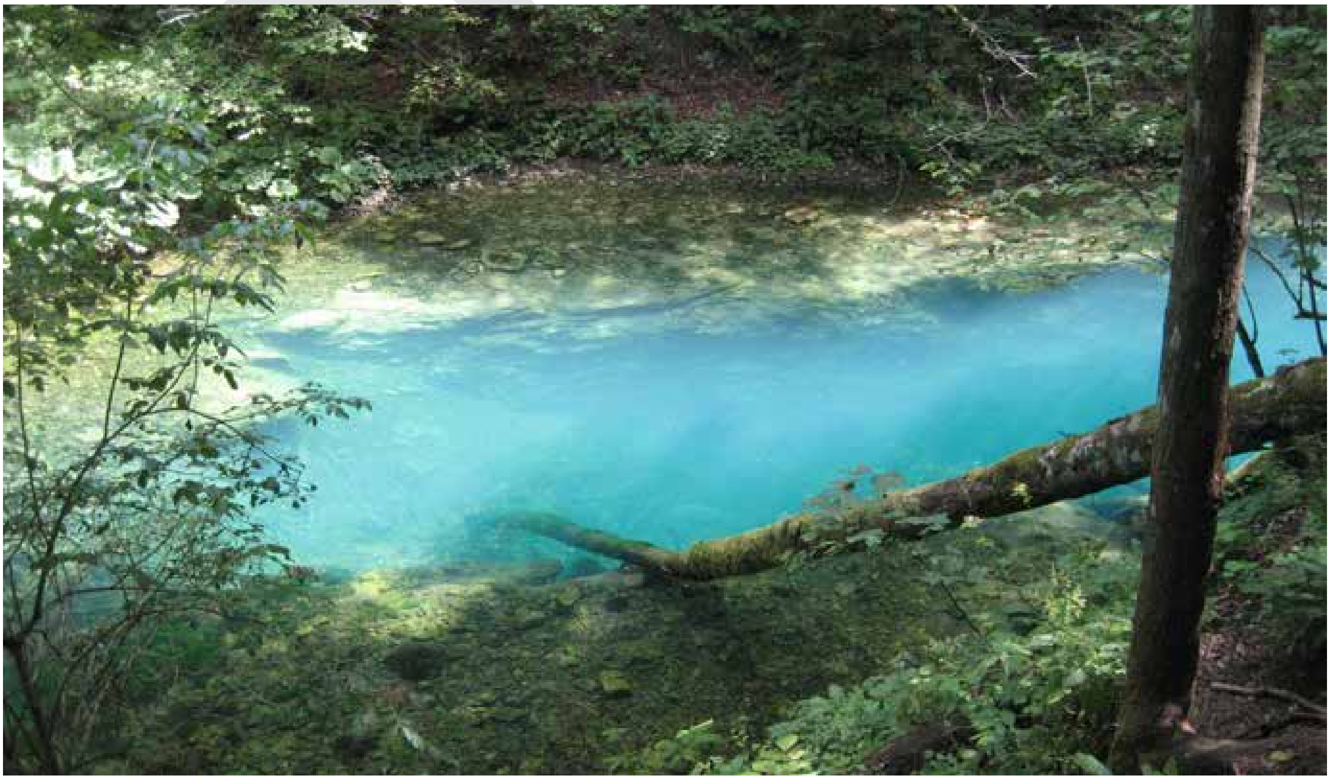
4. Active management and restoration of ecological processes. Disturbances are an essential part of ecosystems. While the intensity and frequency of such regimes change between ecosystem types, disturbances such as flooding, drought, insect eruptions, fires and storms characterize an ecosystem. Climate change tends to alter the intensity and frequency of disturbances. While many are difficult or impossible to manage, protected areas managers can often influence their impact. For example, Parks Canada manages fire in the fire-adapted boreal forest through the use of prescribed burns that are intentionally set according to plan. For freshwater systems, impacts of flooding can be managed by reducing or eliminating timber harvest and grazing in headwaters, and by restoring riverbank vegetation (Jacob et al, 2012). The World Commission on Protected Areas guide to Ecological Restoration for Protected Areas describes considerations required for success (Keenleyside et al. 2012; https://portals.iucn.org/library/efiles/edocs/PAG-018.pdf).

5. Consider how climate change is impacting essential ecological services. Many protected areas provide essential ecological services to neighbouring communities. It is important to identify these services and consider management techniques that retain them to the extent possible. Many of the techniques will be extensions of ones already discussed above (Dudley et al. 2010).

Strategy 3: Managing for significant modifications to former ecological conditions

There are limits to the amount of change that can be accommodated through active management (Strategy 2) without major ecosystem disruptions and loss of biodiversity. Limits to adaptation tend to revolve around thresholds of an ecological, economic or technological nature (Adger et al. 2009). 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 (i.e., it is more expensive to adapt than to experience the impacts). Finally, there are thresholds beyond which available technologies cannot avert climate impacts (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).

Strategy 3 requires a transparent move away from existing conservation goals as it is no longer possible to just have excellent park management (Strategy 1) or active management (Strategy 2) as the means of holding the line. In Strategy 3, managers must consider what the implications of future mean



Refugia are less likely to be affected by climate driven-processes of drought, fire or warming. Examples include areas around persistent springs; above, Kamancik spring, Croatia.

for the protected area and reconfigure their goals accordingly. Strategy 4 (below) also requires a new set of goals. We have purposefully divided Strategies 3 and 4 on the basis of the magnitude of the expected change and how much the protected area's objectives must change as a result.

In Strategy 3, it is assumed that the protected area's species and ecosystems are already undergoing significant climate-driven change. However for a given protected area, not all the species and ecosystems will change 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 sea grass beds might disappear but the offshore benthic (sea-bottom) communities remain relatively intact. So in Strategy 3 a manager might have to re-write the goals for the protected area, but they will require only partial change rather than the wholesale change envisioned in Strategy 4. In many situations, we already manage protected areas that have changed. Many exist without top predators, or have highly altered individual ecosystems or parts of ecosystems. Australia's Great Barrier Reef, for example, has lost 50% of its coral cover in the last 20 years (Brodie and Waterhouse 2012). While this is a great tragedy, the reef still has very significant ecological values and should be retained as a protected area. Coral loss is caused by a number of interacting stresses, and high water temperatures caused by climate change is only one of them (citation).

Under a changed climate, nnot all the species and ecosystems will change at the same rate or be altered to the same degree. For example, in protected areas such as Grassland National Park, Canada, the freshwater streams may change dramatically but the grassland component might remain relatively intact.

Australia's Great Barrier Reef Marine Park has lost 50% of its coral cover in the last 20 years. Here, a coral outcrop on Flynn Reef, near Cairns.

Best Practices when climate change has made significant modifications to a protected area

1. **Undertake a vulnerability assessment of how and why the protected area is changing.** Given that all species and ecosystems types will not change to the same extent or at the same rate, it is important to pinpoint those which have changed, or will change, so much that they become new ecosystem types.
2. **Forecast what the future looks like for species and ecosystems in the protected area**. It is critical to assess what the future species assemblages are going to be so that new conservation goals can be established. It is important to evaluate if the new condition has important values (see Cole and Yung, 2010).
3. **Working with those who have an interest in the protected area, develop new goals** (see section xx on Goals) for those major ecosystem types that have changed. Revise the formal management planning to ensure that the new goals are now a clearly understood part of managing the area.
4. **Revise the monitoring plan for the protected area** (see section xx on monitoring) to include the new ecosystem components.
5. **Assess which of the new ecosystem components require active management**.

Strategy 4: Moving to new ecological goals and managing a new ecosystem type

Strategy 4 is for those situations where climate change is so pervasive that there new ecosystem types have become established or soon will before the entire protected area. Using the best available information from climate change projections and a vulnerability assessment, the manager has concluded that the developing ecosystem will be very different from the original one for which the area was established.
The key questions for Strategy 4 is: What is the new conservation value of the area? The answer to that depends on many factors. Protected areas 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 species or ecological community is present or lost due to changing climate. Even through the protected area has become a different system, it could still be very valuable for many reasons. It might conserve rare species, provide ecosystem services for local communities, or be an important part of a network of protected areas.

Best practices for managing for a new ecosystem type

1. **Use the best available information to forecast species and ecosystems.** Under Strategy 4, there is a clear agreement that climate change has transformed the species assemblages and ecological processes within the protected areas. For example, a given protected area might be predicted to change from a forest ecosystem to grassland. The next step is to best understand what that new ecosystem will be, how long the transition will take and what new values to protect will emerge. The projected values should include both the species and ecosystem type, as well as the ecosystem services expected to be delivered by the new ecosystem that will occur in the protected area. Projecting ecosystem change is not simple. There are many examples of sophisticated modelling exercises using climate envelopes. These are useful and instructive but should not be taken as definitive. If a

protected areas has the capability to do modelling, either by itself or in partnership with a university or NGO, this should be done. If not, the best practice is to conduct an expert workshop of scientists and traditional knowledge holders to make these predictions. The basics for the prediction will have been done during the vulnerability analysis described in chapter 2.

2. **Based on this analysis, determine the new values of the protected areas in the regional, national and global context.** Determine how ecosystem services and sustainable livelihoods are affected. This will require linkages with national and regional systems plans, consultation with stakeholders and partnerships with local peoples.
3. **Modify the protected area's goals and write a new management plan based on them**. The new goals represent a departure from the original purpose of the protected area, and this will be a challenge for many people. There probably will be discussions on whether or not the area should remain as a protected area. The advice of the World Commission on Protected Areas is that protected areas will remain important even if they undergo significant change due to human-caused climate change. Because protected areas are generally less modified by human activities, even in a transformed state they will be important for nature conservation and the provision of ecosystem services. Protected areas should be more resilient to climate change than human-dominated ecosystems. If climate change proceeds to the point of causing major modifications to protected areas, it will be all the more important to retain them as centres of nature conservation, where species can find refuge and ecosystems can adapt and re-form under new conditions.
4. **Decide if it is important to hasten the transformation to a new ecosystem type** through active management, such as species translocations and assisted migration.
5. **Revise the monitoring plan for the new protected area** (see section xx on monitoring) to include the new ecosystem components.

Tools

In addition to the four tools mentioned above, a number of others are potentially useful in planning climate change responses:

- Future International Climate Change Action Network: http://www.fiacc.net/
- Climate Change Resource Center USFS: http://www.fs.fed.us/ccrc/tools/
- UNEP WCMC: http://www.unep-wcmc.org/climate/
- Climate Analysis Indicator Tool (World Resources Institute): http://cait.wri.org/
- Climate Change Explorer Tool from Wiki-Adapt and the University of Cape Town: http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool
- US EPA http://www.epa.gov/climatereadyestuaries/monitoring.html
- SERVIR, http://www.servir.net/en/biodiversity_and_climate_change
- Connectivity Analysis Toolkit http://www.connectivitytools.org
- GIS tools for connectivity, corridor, or habitat modelling, Corridor Design http://www.corridordesign.org/designing_corridors/resources/gis_tools
- Connectivity GIS tool: http://el.erdc.usace.army.mil/emrrp/gis.html
- Flood Maps: http://flood.firetree.net/
- Climate Wizard TNC and partners: http://www.climatewizard.org/

Assisted migration

Assisted migration is the intentional movement and establishment of species to a new location. The rate and magnitude of climate change projected for the 21st century is likely to exceed many of the thresholds to which current species assemblages have become adapted, regardless of any management interventions. In such situations, very difficult decisions will be required to decide which species can be saved. As such, 'conservation triage' may emerge as a critical process in the prioritization and selection of which species to assist. The allocation of scarce resources to help certain species (and not others) has considerable ethical implications.

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

- **Assisted population migration:** 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.
- **Assisted range expansion:** The movement of a given species to areas just outside its current range, mimicking how it would naturally spread.
- **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 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 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 (see Riccardi and Simerloff, 2008; Aubin et al., 2011; Pedlar et al., 2011, 2012; Larson and Palmer, 2013; Schwartz et al. 2012; Thomas et al. 2011). The best practice is to be very careful and only use this tool after a complete assessment of the risk and rewards. This is a rapidly developing topic and managers should obtain careful advice before proceeding. The wise use of assisted migration will vary according to the goals and objectives for the protected area and the intervening landscapes and waterscapes.

- UK Met Office: http://www.metoffice.gov.uk/climatechange/science/projections/
- Climate Predictability Tool, International Research Inst. for Climate and Society:
- Climate Change and Sea Level Rise Tool, University of Arizona: http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm
- Sea Level Rise and Coastal Flood Frequency Viewer, NOAA Coastal Services Center: http://www.csc.noaa.gov/digitalcoast/tools/slrviewer/index.html
- GTK Sea Level Rise Modelling Tools: http://www.gtk.fi/slr/toolmethod.php?id=1
- SLAMM VIEW: http://www.slammview.org/
- EPA coastal: http://www.epa.gov/climatereadyestuaries/vulnerability.html

Learning Networks

- Adaptation Network: http://www.adaptationnetwork.org/
- WikiAdapt - Advancing Capacity for Climate Change Adaptation (ACCCA): http://wikiadapt.org/index.php?title=Main_Page
- Climate Action Network: http://www.climatenetwork.org/
- Climate Change Knowledge Network: http://www.cckn.net/
- Future International Climate Change Action Network: http://www.fiacc.net/
- University of Edinburgh: http://www.hss.ed.ac.uk/climatechange/about.htm
- Climate, Community and Biodiversity Alliance: http://www.climate-standards.org/
- IUCN/SSC 2013

Principle	Description
Reduce non-climate stressors	Pollution, disturbances, disease, and other stressors can reduce the ability of species and ecosystem to respond or adapt to climate changes.
Protect climate refugia	Climate refugia are local areas that experience less climate change than the broader surrounding area. They may be shady, humid areas, or spring-fed freshwater systems. These areas preserve existing biodiversity and may be a destination for future climate-sensitive migrants
Conserve key ecological features	Focus management on enduring ecological features (the geophysical stage), structures, organisms, and areas that are the foundations of communities and ecosystem properties. Riparian corridors, freshwater supplies (springs, lakes, etc.), and critical habitat for keystone species are typically high priority.
Preserve and enhance connectivity	Connectivity operates on multiple levels. For species and communities, provide the opportunity to respond to climate changes by shifting their distributions. Facilitate the movement of water, nutrients, energy, and organism between resources and habitats. Connectivity is often considered to enhance system resiliency.
Sustain or restore ecosystem process and function to promote resilience	Climate changes will challenge our ability to preserve all current species, and the focus here is to preserve fundamental ecosystem properties like primary productivity (biomass growth), decomposition, wetland filtration of nutrients and sediments, and nutrient cycling. These processes contribute to ecological integrity even if there are changes in species composition and ecosystem structure.
Improve representation, redundancy and replication	Both within and across PAs, attempt to conserve or protect samples of key species, habitats, and ecosystems (representation) at multiple sites (redundancy and replication). This addresses a fundamental conservation principle to spread risk and bet-hedge against catastrophic losses at a specific site. Where possible, manage to assist adaptive evolutionary change by e.g. supporting populations in diverse habitats, facilitating gene flow, or actively managing genetic composition of species (e.g. via forest management).
Assist colonization	It may be appropriate, or necessary, in some situations to actively move organisms and assist in their establishment at locations where they currently or never previously existed. Some argue that this is an essential task due to human-caused habitat fragmentation and artificial barriers to species movements. Assisted colonization is highly controversial as a climate adaptation strategy, but relocations, introductions, and reintroductions have been routine practices in conservation, wildlife management, and agriculture for centuries.

Table 4.2. Framework of general principles for identifying more specific adaption options. Derived and modified from Kareiva et al. (CCSP 2008), Mawdsley et al. (2009), and Groves et al. (2012); West and Julius (2014).

Chapter 5

Combined with Chap 4 — chapters to be re-numbered in final version

Chapter 6
Capacity building for adaptation to climate change

The IPCC defines *adaptive capacity* as “The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences” (AR5 WG2 glossary). Building this capacity is necessarily a complex process because it involves learning on the job, even more than in other aspects of management: we are still at the early stages of understanding both the likely impacts of climate change in a particular protected area and what can be done about it. So capacity building involves an *internal* process of protected area managers learning how best to respond and an *external* process of them passing such information on to other stakeholders involved with the protected area, and in some cases to people not associated with the protected area but facing similar management challenges in their own lands and waters. It also means building understanding about at least three different stages of adaptation: (1) what changes are likely to occur in the protected area; (2) which of these stages is most important (e.g., in terms of threats to target species, undermining ecosystem services provided by the protected area etc.); and (3) what tools and techniques exist to help managers and others stakeholders to respond.

The baseline differs widely; in some ecosystems or some parts of the world there are already some fairly detailed projections about what is likely to happen under climate change while in other areas we are still just beginning to learn more. The following chapter looks at some of the things that need to be in place to help capacity building with respect to managing climate change.

The internal process: Equipping protected area managers to respond

Best Practice: Assemble a baseline of information from a wide variety of local, national and academic sources

Capacity starts with understanding, which in turns relies on knowing as much as possible about what is happening and what is likely to happen. Protected area managers need access to the best available information, including climate observations and changes over time, projections of future changes and any resulting impacts. But people managing protected areas – whether they are government employees or members of a community looking after an ICCA – are usually short of time. They are not generally researchers and in most cases will not have funds to buy technical manuals and papers or the resources to attend meetings and conferences; they may

All protected areas need more scientific information that can be used to mitigate the effects of climate change. Researchers at Kogelberg Nature Reserve, South Africa. Death Valley National Park (USA) participates in the Global Network of Mountain Ecosystem Climate Change Monitoring Sites.

not even have good access to the internet. On the other hand, they and other local stakeholders will probably know more about what is actually happening in the protected area than anyone else. The first stage of capacity building is therefore to be smart about assembling information that explains what is happening. Several different kinds of information — from both external and local sources— can help:

- **Databases:** there are a growing number of online databases that provide detailed descriptions of likely climate changes and their effects, trends in climate over time, access to tools and manuals for responding to climate change and news of the latest research. These can also provide a quick way of keeping up to date with the latest understanding for people rushed for time. But most require access to the internet (and increasingly on having a reliable, fast connection); this is still not the case for many protected areas. Sometimes databases can be downloaded onto CDs or memory sticks. Some key sites are listed in the box below.
- **Scientists and researchers:** universities and other research groups can help protected areas in a number of ways: by carrying out research at a broad scale that explains what is likely to be happening in a region, by narrowing research efforts down to the location of the protected area itself to provide more detailed data, through direct capacity-building efforts with staff, and as a source of information for managers. Taking the last first: many protected areas remain desperately short of information; researchers working in or visiting the protected area (or people who are simply interested and supportive) can help enormously by sending electronic copies of relevant data, papers and toolkits, particularly when these are unlikely to be available (for example expensive papers from peer-reviewed journals). Unfortunately, many scientists fail even to send material back to protected areas when they have been carrying out research there. Research projects themselves can provide invaluable information, both to the protected area being studied and to others that are nearby or facing similar climate challenges. Natural and social scientists all have something to contribute. Studies are likely to be most useful if they are planned in collaboration with managers and other relevant stakeholders. As is the case with the opinions of local stakeholders mentioned next, results of scientific research studies should be examined critically by managers rather than being taken immediately and simply at face value. Future projections in particular can be way off target.
- **Local stakeholders and traditional ecological knowledge (TEK):** to build more detailed information about likely changes to a particular protected area, it is probably best to start at home, with a critical analysis of what people have observed about changes in their immediate environment: seasonality, population levels of species of interest, frequency and seriousness of extreme weather events, etc. Such traditional ecological knowledge (TEK) is increasingly recognised as a critical source of information for planners and managers, and an increasing number of researchers trained in the western science tradition are now also usefully incorporating elements of TEK into their studies. Input from older members of the community who have witnessed changes over several decades is particularly useful, as is anything that has been recorded and provides concrete information on changes (some communities may have oral or even written records of particular fruiting times, fish spawning times or the like). But such information must be handled with caution. Climate change is sometimes

Climate change databases

- CAKE site
- More to come — suggestions welcome
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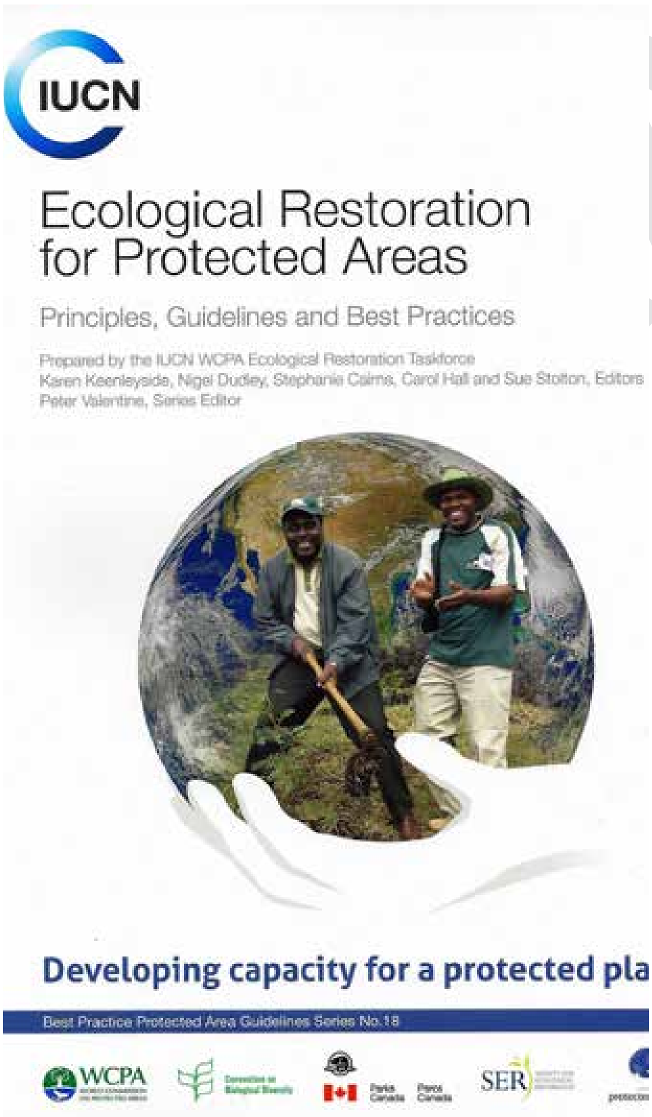
Universities are valuable potential partners in monitoring. A university student uses radio equipment to track hibernating dwarf lemurs in Marojejy National Park, Madagascar.

used, consciously or unconsciously, as a scapegoat for other drivers of change such as unsustainable use of natural resources, and opinions about the scale of climate impacts needs to be treated from a critical perspective. Conversely, TEK is often undervalued or taken for granted; use of such knowledge needs to be properly recognised and if necessary paid for. Including local stakeholders in monitoring schemes can be particularly valuable, because they are often the best placed to collect information on things such as species numbers, but also due to their ability to pass information on widely within the community. People involved in monitoring should also be included in discussions about how monitoring is conducted and what indicators are most suitable, often in collaboration with other specialists.

Best Practice: Ensure that everyone involved in protected area management understands the implications of climate change

It is not enough for one person in the protected area to understand about climate change; knowledge needs to filter up and down to all levels of management, which implies an internal capacity-building process. Everyone involved in management decisions needs to know what climate change is and what it is likely to mean in general terms, what it implies for their own protected area in particular and what should be done to monitor and respond. Much of the latter will be similar to other forms of management: ecosystem-based adaptation or community-based adaptation often means implementing traditional management options in new ways or for new purposes. For example, actions such as restoration of mangroves, control of invasive species and maintenance of biological corridors are all good conservation practices that take on a new urgency under a changing climate. Other potential actions, such as relocation of species whose habitat has shifted, are less likely to be encountered in everyday management. Explaining why something is being done can be as useful as telling staff how to carry out a particular management technique.

Of particular importance is a thorough understanding of how best to translate the basic facts about climate change into practical action and reaction. Rangers and other people involved in management need to know what they should be looking out for in terms of ecosystem changes (and what they should be quizzing other stakeholders about) and in particular how to spot things that need an immediate response. Control of an invasive species is far more likely to be successful if done efficiently when the newcomer is first spotted than if action is delayed until it is well established. Rangers may also need practical skills in management techniques, such as those involved in restoration, that are becoming increasingly important under climate change, as well as having a thorough understanding of the potential and pitfalls of connectivity conservation. Staff capacity should not be limited to technical issues but also needs to cover social perspectives, such as the likely reactions of human communities to changing environmental conditions, what their needs are likely to be and how the protected area can contribute.



Protected area managers and field personnel may also need practical skills in management techniques, such as those involved in restoration, that are becoming increasingly important under climate change.

In some situations protected area staff may be the only source of technical information on climate change for a much wider community, making it doubly important that people from the protected area understand as much as possible about what is happening.

Best Practice: Plan for adaptive management, backed by all stakeholders, supportive policies and financial resources

As noted above, we are often feeling our way; trying to manage for biodiversity and other ecosystem services in rapidly changing conditions and with tools and resources that are far from fully developed. An important part of capacity building is learning to manage under conditions of uncertainty and establishing a system that allows this to occur without descending into anarchy. Setting ten-year goals and pursuing them no matter what is increasingly unlikely to secure very effective conservation results. Instead goals need to be set more tentatively, progress monitored along with other trends in and around the protected area, and actions modified if the results of monitoring indicate that things need to change. These principles of adaptive management are integral to any management system but, like many other responses identified in this manual, acquire a new urgency due to rapid climate change.
There are two key components of flexible management: (i) a management framework that allows and encourages a reflective approach and, even more importantly, (ii) a mindset among managers, rangers or communities that recognises and embraces an adaptive approach.

A flexible framework can be integrated with standard management planning (indeed some elements should already be part of such a framework). Along with specific conservation targets to be monitored, a, climate-savvy plan should include monitoring of key climate-related variables, including agreed “triggers” for action. So, for instance, if managers of a marine protected area 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. Evidence of sea-level change of a pre-determined amount would for instance then trigger a response plan that might involve relocating some young mangrove trees and/or acquiring higher land for the reserve to move into as the coastline alters. These climate variables would sit alongside more conventional conservation targets in providing the overall skeleton of the management plan. In addition, the plan should be re-examined regularly throughout its life (for example once yearly) so that its overall direction and purposes could be discussed according to changing environmental conditions.

Changing mindsets is more subtle. It will be helped by a better understanding of likely climate impacts and the degree of professionalism of protected area staff. Younger staff may already start the job expecting that climate change will be an inevitable component of their work. In community-run reserves, people's longer-term involvement with the ecosystem in question may mean that they recognise the level of change (and are likely responding within their own lifestyles) so that there is already a pragmatic understanding of the need for adaptation. But there are costs in adaptation-friendly approaches, including the need for greater effort, a less familiar working pattern and greater uncertainty; some managers and staff may be less open to such a system. If this happens in the case of protected area systems run by governments or NGOs, policy directions may need to come from a higher level.

Social, political, intellectual, and financial resources to support adaptation activities

All these changes need resources, including financial resources. There is only a certain amount that protected area managers can achieve on their own. Four types of support are important:

- **Political support:** some level of political support is very helpful: countries that recognise the significance of climate change are more likely to enact supportive policies, make funding available and control damaging activities. (But it should also be noted that protected areas are successfully implementing policies aimed at building climate resilience even in countries or sub-national areas governed by parties who deny the existence of climate change.) Protected

In community-run reserves, people's longer-term involvement with the ecosystem in question may mean that they recognise the level of change (and are likely responding within their own lifestyles) so that there is already a pragmatic understanding of the need for adaptation. Harmony Flats Nature Reserve, South Africa.

area agencies can help build support from sympathetic policy-makers by highlighting the roles of protected areas in mitigating and adapting to climate change, and by providing living laboratories for learning about adaptation.

- **Intellectual support:** the need to build knowledge has been discussed above. More generally, intellectual support includes people prepared to stand up and offer data-supported, rational arguments in public against climate-deniers, and to provide a broader intellectual understanding of what is likely to occur under as climate changes.
- **Social support** comes in various ways. At the most immediate level, the kinds of adaptation to be carried out in protected areas often depend upon understanding and support from local stakeholders, adding fresh impetus to the need for good relations between protected area staff and people nearby and for the use of participatory approaches in management decisions. More generally, social support from the broader population can be built through education and outreach programmes aimed at people visiting the protected area, people vaguely interested in conservation and, particularly, for those stakeholders who may be uninterested in conventional conservation goals but nonetheless gain from a protected area in terms of ecosystem services or similar benefits. Reaching out to oblivious or potentially antagonistic stakeholders is a key part of any programme.
- **Financial support:** finally, adaptation often takes money. Through the suite of activities described in the preceding three paragraphs, protected area managers need to build a broad enough base of supporters to attract funds, through judicious application to donor agencies (who will often be attracted by projects with a strong social component), through payment for ecosystem services (PES) schemes, or through donations from private individuals or corporations. The wider the benefits that can be demonstrated, the greater to potential pool of sponsors is likely to become.

The external process: Passing information on

Best Practice: Develop an effective outreach programme to tell local communities and visitors about managing for climate change

One result of a more inclusive approach to protected area management is a growing realisation about the importance of telling people what is happening. This is particularly true in the case of climate change; where there may already be a high level of uncertainty, confusion and concern about what people have observed themselves or heard about at second hand.
Communication has a number of roles in adaptation: telling people about likely or observed changes in the environment and their implications; informing people of proposed management changes so that they have the opportunity to react and comment; giving information about new opportunities for adaptation (e.g., by relating case studies from similar places); providing training on issues related to adaptation; and giving basic information about times of meetings, contact details of protected area staff etc. It can range from a few sentences on a notice board to detailed training in some particular conservation technique.

The most effective communication is by direct personal contact; this will be easiest when at least some of the protected area staff are members of local communities and talk about their work as a matter of course, but can also include group meetings and one-to-one meetings of varying degrees of formality. Some basic principles about workshops are laid out in the box below.

Other ways of informing people should be chosen with regard to the commonest methods of communication used in particular communities and include:

- Posters explaining about climate change or describing observed changes or management responses within a particular protected area

Running a workshop

A workshop is one standard way of spreading information. Aside from staff, this might include local communities living in or near a protected area; those individuals or companies with a direct commercial interest, such as tourism operators; conservation organisations; and government officials. Running a participatory workshop, in which all voices are heard and respected, is always challenging. The only chance of reaching a genuine consensus is if all interest groups have an opportunity to make their opinions heard, but there are many practical barriers to this and sometimes several separate meetings will be needed. The poorest members of society can be inhibited from speaking out, for instance; local community members may be nervous about criticising protected area staff employed by the government; in some cultures women are not accustomed to speak in meetings dominated by men; and so on. Even if all these hurdles are cleared there is no assurance of reaching common ground. It is important to be clear about what the meeting can and cannot achieve, and particularly not to raise unrealistic expectations. Where most people are literate a record can be kept by writing on a document or projected PowerPoint slide so people can see immediately what is being recorded.

The type of workshop is important. A simple discussion around a meal or drink may gain more insights than a structured workshop, although if training is the aim then a more formal setting may be needed. It is also important to set meetings at a time that does not preclude certain stakeholder groups from attending (e.g. when fishing boats are out at sea or when children are likely being fed and put to bed). Evening meetings are probably best if the attendees are mostly within a small radius of the meeting place. Ideally the meeting should take place in or very near the protected area, both because it will make it easiest for local stakeholders to attend and because being on site will help focus discussion, bring examples to mind and act as a reality check on ideas and proposals. Specialists from outside the area can be invaluable, but it is important that their views do not dominate the meeting: local "experts" will almost certainly know more about at least some aspects of local conditions than people from outside. With regard to recording the meeting, at the least there needs to be a list of participants and probably a short record of what took place.

- Letters to key stakeholders
- Email messages
- Setting up a web site that carries information open to any community members who can access the internet (this can carry films, interviews and photographs in addition to text)
- Use of social media such as Facebook and Twitter
- Programmes and interviews on local radio and television stations: efficiency can be increased by working in partnership with local journalists, who are often grateful for a good story and can access communication tools faster and better than the average protected area employee or community manager
- Text messages

These methods are often changing quite quickly so communication needs to be reviewed periodically. Clearly if many people cannot read then options are more limited; messages in the local language(s) are also important but carry costs if they must be translated from another language. In addition, lessons learned from adaptation approaches within protected areas need to be communicated to other protected areas: staff exchanges and visits between protected areas can be a good way of teaching and learning. What did not work is as important, sometimes more important, than what worked.

Public involvement

Communication and outreach efforts around climate change provide an opportunity for practitioners to create partnerships with other organizations and surrounding communities. Through these partnerships, parks can reach larger audiences and form deeper relationships with their constituents while fostering a sense of environmental stewardship within their communities. Communicating the importance and urgency of managing for climate change to these audiences builds crucial support and capacity for climate adaptation activities. This section focuses on key strategies for engaging with outside audiences through partnerships and programs, strategic messaging, and making climate change local, relevant, and urgent.

Best Practice: Know your audience and frame your message accordingly

In order to design effective, compelling education and communication programs, practitioners must first understand the needs and interests of their target community. Often the primary concerns and motivations of a community can be easily misunderstood if the due diligence of seeking out their perspectives is not done. Successful communications hinge upon allocating project time to thoroughly connect with the target audience in order to determine its social identities, common values, priorities, and knowledge base.

Gaining this understanding takes effort and outreach. Strategies for engaging and learning about a community's priorities include:

- Holding listening sessions
- Seeking out and involving community leaders

The urgency of cllimate change must be effectively communicated.

Public involvement case study 6.1 ***City of Chattanooga, Tennessee, United States***

In 2006, Mayor Ron Littlefield of Chattanooga signed the U.S. Conference of Mayors' Climate Protection Agreement, which led to one of the nation's first processes with the goal of having citizens set specific long-range goals and create a climate action plan. During the visioning sessions, in which all residents were invited to participate, citizens determined that trees were an effective way to offset the city's heat island effect while improving energy efficiency and carbon sequestration. Trees were also recognized for their ability to mitigate the effects of more frequent climate-induced violent weather events, including severe drought and storms .

The Citizen Forester educational initiative, born out of this process, hosts educational programs for homeowners and gardeners on the value, benefits, and care of trees. In addition to learning about climate change interpretation, energy, and cost savings related to tree planting, residents receive tree seedlings and further instruction on tree management. According to Gene Hyde, city forester for Chattanooga's Department of Public Works:

My primary hope of our Citizen Forester educational initiative is to engage and educate the populace in the many valuable benefits and ecosystem services of trees. In Chattanooga, trees provide $1.2 billion of storm water detention services, sequester 15,943 tons of carbon annually, and absorb 4,500,000 pounds of air pollution. The value of the ecosystems services provided by our trees for the absorption of air pollution is estimated to be $12 million.

Considered one of the most polluted cities in America in 1969, National Geographic Magazine has now named Chattanooga one of the 50 best places to live in the country and the self-expressed community value of trees is recognized as central to the city's climate change initiatives.

- Going into communities to speak with people on their own terms
- Seeking out existing successful strategies and finding common themes
- Inviting the community to participate in the design process
- Asking for community feedback and adapting accordingly at every stage

Once practitioners have identified what drives their audience, they can then adapt their messaging to focus on the concerns and values that are relevant. For one group it may be the health of its children, for another it could be the cost savings that accompany energy efficiency. Framing the messaging in terms of key drivers is crucial to engaging communities and effectively facilitating behavior change.

Additionally, practitioners should use these strategies to tap into the leadership of a community. In doing so, they can identify and enlist trusted sources of information to help spread their message. These trusted voices can help shape and disseminate education messages and other communications that are in language that is clear and easy to understand for the target audience.

Best Practice: Focus on solutions-oriented messaging and make actions manageable

Rather than focusing on providing the public with more climate science and data, communicators should orient their message to focus on potential solutions and individual actions that can make an impact. These solutions work best when they are easily done and can be integrated into your audience's daily lives and decisions.

It is important to make actions manageable

Public involvement case study 6.2 ***City of Rotterdam, The Netherlands***

In the low-lying delta city of Rotterdam, a looming threat from flood waters and rising sea levels has resulted in the need to reengineer public spaces to protect the city. As part of this effort, city parks and greenways are being used as platforms to communicate Rotterdam Climate Initiative (RCI) efforts, local public health threats associated with a warming climate, and civic infrastructure changes in response to climate-oriented threats.

Established in 2007 and implemented by the Departments of Public Works and Urban Development, the RCI is part of the Clinton Climate Initiative and a partnership between the City of Rotterdam, Port of Rotterdam, Environmental Protection Agency, and Deltalinqs (the city's port industries association). With the aim to reduce carbon dioxide emissions by 50% (compared with 1990 levels) and to "climate-proof" the city by 2025, the RCI helps the public understand that a particular climate adaptation, mitigation, or sustainability effort is due to intentional practices. RCI-branded signs can be seen on the city's green roofs, green ports, public vegetable gardens, and water squares which provide public spaces for recreation during dry periods and serve as water storage areas during times of heavy rainfall. This effort has helped create a new social norm related to climate action, unify the city's climate activities, and communicate civic actions to the public in a comprehensive, engaging manner.

The RCI collaborates with the city's public health and recreation departments, water boards, government partners, NGOs and schools. The Regional Public Health authority communicates information on climate-related health threats in public spaces while signage in parks and green spaces focuses on positive messages that connect directly to people's daily lives.

For some groups, children's health, and how protected areas can contribute to it, may be the issue that them into a concern about climate change.

Public involvement case study 6.3 ***The Jane Goodall Institute and Gombe National Park, Tanzania***

The Jane Goodall Institute (JGI), with financial support from the Royal Norwegian Embassy, has teamed up with Gombe National Park and surrounding communities in Tanzania to address the local effects of climate change. In conjunction with the United Nations' Program on Reducing Emissions from Deforestation and Forest Degradation (REDD) and the technology firms Esri, DigitalGlobe, and Google Earth Outreach, JGI is employing technology that enables park staff and community members to take the lead in gathering forest data in the area surrounding the park. Using high-resolution satellite images and Geographic Information Systems technology, specially trained community forest monitors map the forest, chimpanzee habitat, and human land use. Because of its close working relationship with communities, JGI is uniquely positioned to share with them the information it gathers and to engage them as partners.

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

Gombe National Park, Tanzania PLACEHOLDER PHOTO

by offering examples of solutions that have a quantifiable impact and that your target audience can do immediately. Practitioners should focus on specific behaviors rather than overarching goals. Asking an individual or community to conserve energy is very different than asking them to program their thermostat to a lower temperature when they are not in the house. By providing the tools, actions, and models necessary to accomplish a specific goal, practitioners can help their audience take action in a way that is easily integrated into their existing habits.

Changing behavior is easier for people when they feel that others are participating as well. Creating new social norms is a valuable way to integrate specific solutions into people's lives. Rewarding and showcasing model behavior and communicating that certain climate-related actions are being taken at the community level is a great way to begin to create a new social norm around a specific issue or behavior. Visual, well-placed messages with unified themes remind community members of the larger goals and actions that they are being asked to take.

Best Practice: Illustrate how climate change has already impacted your area

With other pressing needs and concerns in the forefront, for many audiences climate change feels like a distant issue. As a result, highlighting examples of how climate change is already impacting a community or protected area brings the audience closer to the issue, increasing their level of perceived risk and subsequent motivation. Rather than featuring the future effects and long-term view, demonstrating current effects can reduce the psychological distance between your audience and climate change.

Suggestions for localizing your messaging include drawing connections to local plants, animals, physical elements, cultures, communities, and extreme weather events. Are there specific health effects, adaptation requirements, or changes in agricultural production that are already affecting your community? Perhaps seasonal changes are lengthening the local allergy season, or perpetuating a drought which influences crop yield in your area.

Rather than focusing only on the effects on nature, climate change communications should connect the issues to the audience's daily lives. The more imminent, concrete, and

Public involvement case study 6.4 ***Klimaguide, Jungfrau World Heritage Region, Switzerland***

The Jungfrau Klimaguide is a multimedia climate application for Apple's iPhone and Google's Android mobile-device platforms, exclusive to the Jungfrau World Heritage Region of Switzerland. The guide was compiled to mark the 175th anniversary of the University of Bern in 2009, and was updated and re-launched in 2014. It was produced by Texetera with the financial support of BKW Energy Ltd. and the backing of the Swiss communes of the region. The guide creatively highlights the university's climate science research for visitors to the World Heritage Site.

"The Climate Guide allows visitors to witness climate impacts while hiking," says its producer, Erik Thurnherr. "We include bonus materials such as comparisons of historic paintings and photos to present photography, television programs, and interviews. The guide also ties in climate actions tips and addresses strong local renewable energy initiatives in Jungfrau towns such as Grindelwald." Visitors who download the app are educated about Jungfrau glaciers as they walk along one of seven interpretive trails. "In this app you'll find a wealth of information on the subject of climate change. You are receiving this information in an area where you only need to look around you to see the consequences of climate change." www.jungfrau-klimaguide.ch

Public involvement case study 6.5 ***Embracing media as a partner for climate change communications in Southeast Asia***

In Thailand, Cambodia and Viet Nam, IUCN works closely with the media to raise public awareness, focusing particularly on building coastal resilience to climate change impacts. In Thailand, IUCN established a partnership with Thai Public Broadcasting Service (Thai PBS), the first and only public broadcaster in the country, which has been operating since 2008.

The partnership involves capacity building for broadcasters, in which IUCN provides training to Thai PBS reporters, editors, producers, media researchers and trainers. The aim is 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 results are of a professional 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 can help raise public awareness on climate change immensely. In addition, stories aired on TV indirectly bring the issues to the attention of national policy-makers.

Contributed by Dararat Weerapong, Senior Communications Officer, IUCN Southeast Asia Group

personal stories are, the more compelling they will be to the community.

Best Practice: Develop new partnerships and programs

The challenges and goals inherent in climate communications can lead to the development of innovative programming opportunities with new and existing partners. Leveraging these partnerships can result in connections with broader audiences as well as new lenses through which to look at the issues. Whether reaching out to new sectors, decision-makers, or media partners, it is important to think creatively about who should be at the table and how these partnerships can be cultivated to yield fruitful results.

The scope of the problem and solutions required to mitigate and adapt to climate change are best addressed by including diverse perspectives and a broad range of people, sectors, and allies.

Key points to consider when developing new partnerships include:

- Listen and be prepared to meet your partners where they are—take the time to define your engagement strategies around the specific priorities of your audience
- Ensure that all partners have the same understanding of the language you are using
- Define a clear structure, delegate activities, and create mutual goals to secure continued participation in the partnership from all parties
- Provide opportunities for all partners to participate fully in the process
- Leverage the unique strengths that everyone brings to the table, and build upon your partners' relevant experiences

Communicators should think about which perspectives are missing from the table and work to include new voices and stories. Do existing partners match the demographics and represent the diversity of interests within the target community? The importance of collaboration among artists, scientists, and communicators is also crucial. Artists can be effective public programmers, and act in concert with scientists to bridge the gap between technology, art, and conservation.

Youth education

Engaging youth and the education sector in communication about the impacts of climate change on protected areas helps to build the next generation of environmental stewards. Through partnerships with educational organizations, parks are able to incorporate youth perspectives while students are able to build

Youth education case study 6.6 ***Climate Change Youth Initiative, National Park Service, United States***

The George Melendez Wright Climate Change Youth Initiative was sponsored by the US National Park Service (USNPS) Climate Change Response Program in partnership with the University of Washington's College of the Environment. This program provided opportunities for young people to work on diverse issues related to climate change and its effects in national parks. The opportunities took two forms: competitive fellowships awarded to advanced graduate students (Masters and Doctorate levels) to support their independent research, and paid internships in which undergraduate or beginning graduate students work for 12 weeks on projects in research, interpretation, park operations, policy development, or other fields.

Some examples of internships included: creating an web application that combines photos, phenology data, and climate data so students can explore changing plant phenology at Sequoia National Park; collecting and analyzing tide gauge data for several coastal parks in the northeastern US to inform adaptation projects; surveying unique Paleo-Indian archaeological resources threatened by sea level rise at Bering Land Bridge National Preserve; and creating high-quality videos about climate change impacts on parks to educate the public and meet USNPS staff training needs. Unfortunately, the program lost funding and is now dormant; USNPS is trying to revive it.

emotional and intellectual attachments to parks as they learn more about climate change impacts on specific areas. Connecting climate change impacts in the parks to the ability of young people to take action in their own lives not only boosts the capacity of parks to adapt to the future, but creates a sense of empowerment and fosters future leaders. The following principles can help youth educators deepen and increase the impact of their climate change programming as well as the connection their audiences feel to the issue.

Best Practice: Incorporate joy, humor, play, storytelling and role models

Rather than framing communications around the gravity and intensity of the problem, kids need to be engaged through hope, fun, and adventure. Fortunately, protected areas and public lands provide a wealth of these crucial elements. Communicators need to think creatively about engaging with a serious subject by providing empowering experiences.

Youth education case study 6.7 ***Glacier National Park Teacher Training, United States***

For the last three years, Glacier National Park has partnered with the Glacier Institute, a nonprofit organization, to host a week-long climate change teacher workshop for educators from across the United States. Workshop participants attend presentations from agency researchers, participate in brainstorming sessions around crafting lesson plans and developing service learning projects, and hit the trail with park staff and researchers. A featured speaker is also highlighted each year. The park and institute staff found that collaboration goes a long way and that sometimes the best way to get started is by being around others attempting to do the same thing. In the months that follow the training, lesson plans, field trip ideas, and collaborative projects flood in to the workshop's shared online classroom, truly showing the impact a week-long workshop can have in building camaraderie and climate change literacy with teachers around the country.

Contributed by Melissa Sladek, Science Communication Specialist, Glacier National Park

Teacher training session, Glacier National Park, USA PLACEHOLDER PHOTO

Youth education case study 6.8 ***Johannesburg City Parks, South Africa***

At city parks in Johannesburg, community leaders and educators are taking a proactive role in building public understanding of climate change effects and engaging civic participation in the search for solutions. The Environmental Education Unit of Johannesburg City Parks (JCP) is responsible for the facilitation of climate change education in the city and focuses on three broad program areas: school programs, environmental awareness-raising initiatives, and capacity building programs.

Over 9,000 students from 150 schools attend JCP climate change education programs annually. The curriculum is linked to activities such as planting drought-tolerant indigenous gardens and growing food gardens on school grounds. The gardens are also used for science-based activities and lessons. "Through garden-based education workshops, the children learn about principles such as the value of indigenous trees or plants as opposed to alien plants, and their role in biodiversity preservation and climate change control," says Sinah Magalo, Manager of JCP's Environmental Education Unit.

JCP also hosts climate change workshops, exhibitions, and tree-planting events for the public. At the workshops, members of the community are encouraged to participate in dialogue on climate change and strengthen community leadership. Activities and discussion are tailored for each type of group. "During workshops we do an activity that analyzes the current practice of each community member with regard to waste, energy, and green issues," continues Magalo. "Thereafter, each community member looks at his or her behavior and plans what they will be doing to change their behavior. Through these workshops community members have started recycling and have developed food gardens in their homes and schools."

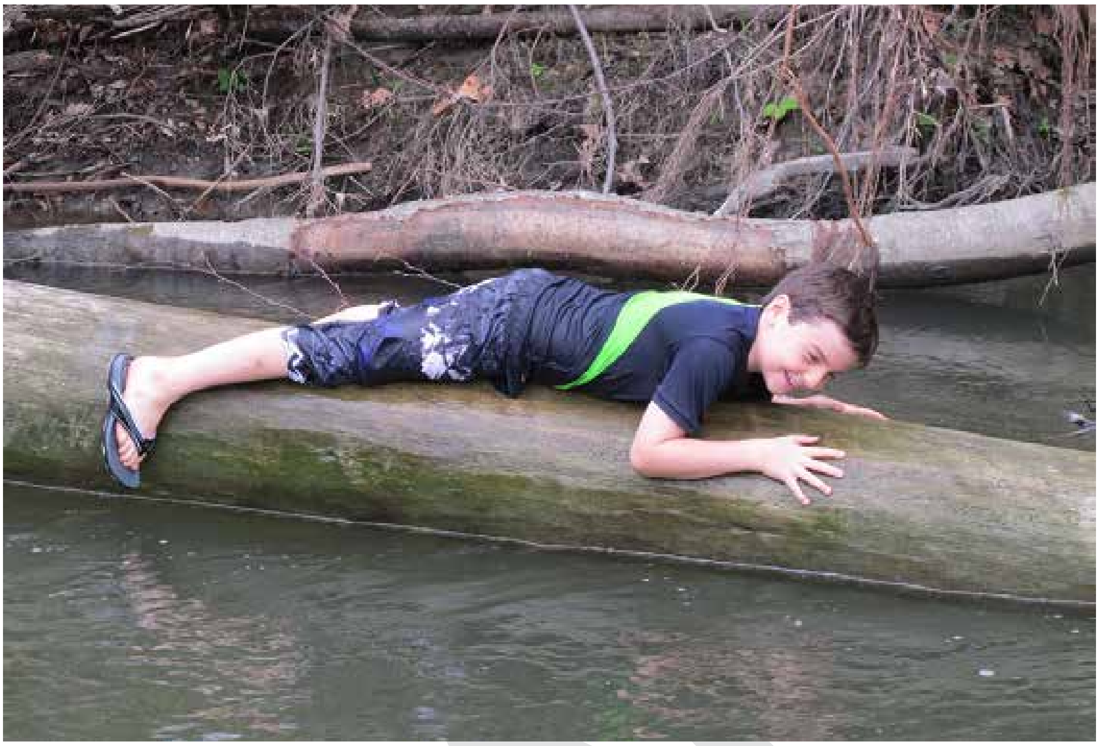
Parks are great places for kinesthetic learning – running through fields, interacting with animals, and playing in water. Educators have an opportunity to focus on these positive activities while at the same time addressing the issue of climate education. Weaving treasure hunts, puzzles, or other games that include information about climate change into the activity can engage youth in the issue in new and positive ways.

Storytelling and metaphors can be excellent ways to reflect, reference, and access positive motivations and help youth (or even adults) feel that they can overcome the large challenges presented by climate change. When learning about climate change, young people especially can feel overwhelmed by the scope of the problem. Empowering stories show that people have overcome obstacles before and that through innovation, perseverance, and engaging with their community, youth can contribute to overcoming this obstacle as well.

Showing youth how to integrate pro-environmental habits into their daily lives can also help them feel that they are contributing and their voices and actions make a difference. Focusing on solutions that are attainable and rewarding resonates with young people. Games, contests, and interactive learning can provide opportunities to reward positive behaviors and are natural elements of protected area programming and communications for young people. Wherever possible, communicators should incorporate these aspects into climate change education.

Best Practice: Include young people in the communication design process

Integrating youth into the development of climate change interpretive and educational



Parks are great places for kinesthetic learning – running through fields, interacting with animals, and playing in water.

experiences helps to ensure that the information around climate change is presented in a way that is compelling and relevant. The more relevant and tailored the message, the greater the potential interest and knowledge uptake will be for young people. As with all audiences, providing relevance can also ensure that young people are able to access the scientific information in a way that allows them to participate fully and equitably.

The exchange between young people, educators, and program designers has the potential to create powerful, transformative experiences based on needs and interests that are unique to young people.

Best Practice: Inspire youth engagement through experiential learning opportunities

Offering experiential learning opportunities in the form of volunteer, service-learning, and citizen science projects can help familiarize young people with climate science, highlight local issues, and provide students with a blueprint for new actions. Volunteering can also foster civic engagement and personal responsibility. By offering longer, more in-depth educational opportunities, youth are able to engage on a deeper level and more fully process the complex issues around climate change.

Integrating hands-on science through research projects or citizen science initiatives allows youth to feel that they are part of a larger movement. Understanding that their work is contributing to a broader effort can increase their sense power to combat climate change. Additionally, by learning on their own, youth have a greater sense of ownership over their work and their connection to climate change.

Protected areas and public lands are the ideal locations to provide this type of relevant, hands-on experience.

Best Practice: Create networks of formal and informal educators

With the breadth of the challenges that climate change presents, there is a growing need for networks of educators to support the promotion and dissemination of best practices. Protected areas can be natural gathering places and hubs for building these communities. They provide practitioners working in both formal and informal education with a physical space to connect youth emotionally and physically to the land and the impacts of climate change.

Informal educators in parks and partner organizations have experience designing place-based educational opportunities and using

Protected areas can abuild capacity for future leaders by connecting young professionals to internships and field opportunities. Redwood State Park, California, USA.

the land and its stories to foster relationships between the community and nature. Teachers and other formal educators understand the needs of their students and the mandated curriculum requirements. Protected areas provide the perfect opportunity to combine the strengths of the two groups and to connect them around climate change.

Additionally, communicators and educators can benefit greatly through sharing best practices as well as the roadblocks and successes that they have experienced. Climate change education is relatively new, and it is crucial that practitioners share experiences, best practices, and lessons learned. Protected areas can also build capacity for future leaders through new and existing networks and by connecting young professionals to internships, job opportunities, mentors, and role models for success.

Chapter 7
Monitoring, evaluation, and adaptive management

Most protected areas are just beginning to plan for or implement climate adaptation and we have much to learn. We don't fully understand how ecosystems will respond and what management actions might be most effective. In cases of high uncertainly, the best course of action is "learning by doing", which is the essential element of adaptive management (Walters and Holling 1990). As the future unfolds, we will identify successful efforts and learn from mistakes only by specifically directing attention to learning what worked and what didn't (Spearman and McGray 2011). The need for "learning by doing" is thus more imperative than ever and adaptive management is a key strategy to a future of effective PA management. Monitoring and evaluation (M&E) are the basis for identifying successful adaptation processes and management actions, and thus for adaptive management.

Many funding sources now specifically target climate adaptation. Successful projects are required to clearly illustrate linkages between adaptation activities and a reduction in climate impacts and vulnerability. A well designed M&E program shows how management actions address climate vulnerability, and measures how actions contribute to adaptation.

An adaptive management approach in protected areas requires a carefully designed monitoring and evaluation program, which has many goals and benefits:

- determining trends in key indicators of ecological conditions to inform decisions,
- evaluating the results of management actions,
- improving management through learning (adaptive management),
- providing a reference or baseline for comparison to other (more altered) areas,
- informing decisions on effective resource allocation (prioritization),
- promoting accountability and transparency, and
- involving the community, building constituency, and promoting protected area values.

Protected areas have important roles in the broader conservation community that require coherent monitoring and reporting. PAs often include the least altered ecological communities, and as such they are important as benchmarks for other areas. Monitoring in PAs provides a reference for comparison to more disturbed areas, and information from relatively unaltered reference areas are necessary to identify and evaluate the interactive effects of climate impacts and other stressors.

Climate change and adaptation pose special challenges to the design and implementation of monitoring. M&E for climate adaptation can differ from that for more traditional resources in these ways (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 tradeoffs in achieving short and long objectives.
- **Monitoring objectives need to address multiple disciplines**. Many monitoring programs 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, there is additional uncertainty in estimating rates and trends in climate drivers, and the responses of species, ecological processes, and surrounding communities to climate changes. Currently distant species may colonize PAs, while long-established species and ecological relationships can disappear. The timing of key ecological events is already changing (Parmesan 2006) , and all projections are based on models. These factors can challenge the design and implementation, of monitoring, and the evaluation of the resulting data.
- **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, the success of adaptation activities is frequently to prevent negative consequences from a future event. This requires use of a "counterfactual" – comparison to something that might have happened in the absence of action.
- **Absence of universal metrics for success**. Unlike mitigation to reduce greenhouse gases, there are no indicators or metrics that can be universally applied and measured to detect and report progress towards successful climate adaptation. Indicators need to be relevant to the project, its objectives, and other high-priority considerations.

Traditional Ecological Knowledge

In most protected areas an invaluable source of knowledge, including monitoring, comes from traditional ecological knowledge (TEK). TEK has been defined by many authors but generally follows that proposed by Berkes et al (2005):

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

Angas Downs IPA (Australia) provides opportunity for elders to impart cultural and environmental knowledge to younger generations.

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

TEK may be held within aboriginal peoples, or other people that have resided adjacent to or within national parks for many years, and have pursued land-water based lifestyles. Although TEK is generally qualitative, there is real value in that it has been collected over a much longer time period than science-based monitoring, and there is important information in the observations and understanding that it encompasses (Nakashima et al. 2012). Possibly the greatest contributions to a protected area monitoring program are the antecedent ecological conditions it can describe for understanding ecological baseline conditions, and in the meaningful engagement with those that hold this knowledge.

Local knowledge may also held in park volunteer groups that have conducted formal and informal surveys in and around parks. For example, bird watching groups, eco-tourist organizations and naturalist societies often have observing biota for many years and this knowledge can inform the development of protected areas monitoring and the interpretation of monitoring results.

Best Practice 1: Use established principles and support adaptive management

Benefits of effective monitoring and evaluation apply equally to management for climate adaptation and more traditional goals. Established principles for designing and implementing monitoring or research for climate adaptation are generally consistent with those that address monitoring for other conservation purposes. Key features of all successful monitoring programs include early engagement of partners, good data management, clearly documented protocols, use of statistically credible sampling designs, robust and documented methods for analysis data, and regular reporting of results in formats appropriate to primary audiences.

The Biodiversity Indicators Partnership (2011) guide is a particularly clear articulation of the key steps to designing and implementing natural resource monitoring for protected areas. This guide describes the basic steps that all monitoring programs will need to address, and provides examples, worksheets and other tools to facilitate development of an effective monitoring and evaluation program. The IUCN Best Practice Guide for Evaluating Effectiveness (Hockings et al. 2006; Figure 1) 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. While the IUCN guide does not address the challenges of M&E that are specific to climate adaptation, the practical advice, examples, and tools are relevant and exceptionally clear, practical, and comprehensive.

Most detailed guidance that specifically addresses monitoring and evaluation of climate adaptation is directed towards international development projects, mostly at regional to national scales. But many principles apply to adaptation and they can be modified to better address PA needs at the site level. Over the past decade, a series of informative and evolving guides to designing and implementing M&E have been produced. Bours et al. (2013) concisely reviewed and summarized the key features of 16 prominent studies, and identified key benefits and challenges of each approach.

Monitoring and evaluation are a core component of adaptive management (Figure 2). Adaptive management embraces an experimental approach where management actions are used to evaluate assumptions and hypotheses about how an eco-

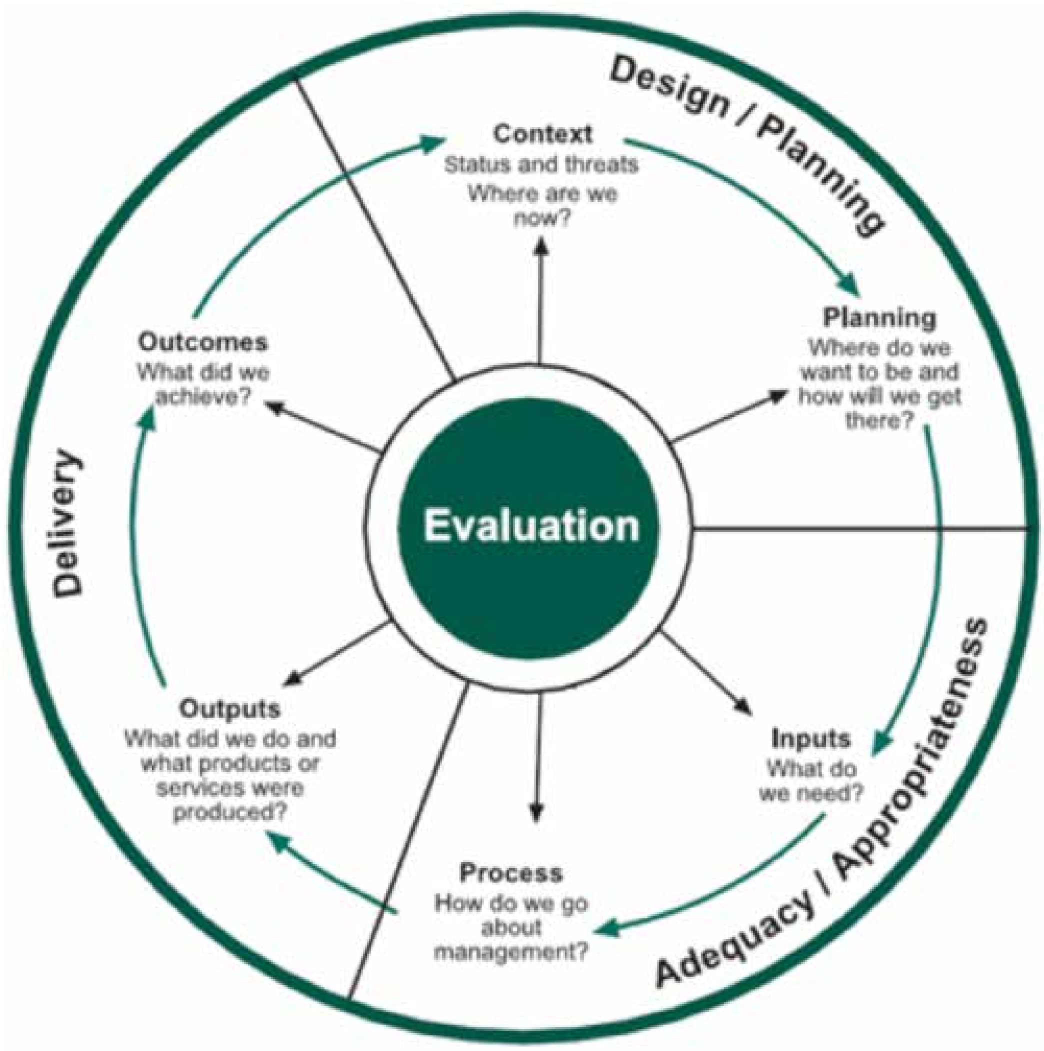


Figure 1. IUCN framework for evaluating management effectiveness (Hockings et al. 2006). An understanding of management effectiveness is an important component of an adaptive management.

system, park, community, or other system operates. These are monitored and examined in a systematic manner that explicitly supports learning about how the system responds to management actions (Walters and Holling 1990). Adaptive management is learning-based and decisions are designed to contribute to achieving management goals while increasing understanding of the system.

There is no uniform definition of “adaptive management” (Canter and Atkinson 2010), but there are six characteristics that describe most adaptive management situations (NRC 2004). These can be summarized as:

- **Regularly revisited management objectives.** Agreed-upon goals are regularly examined in light of emerging data, learning, and insights.
- **There is an explicit and testable model of the system being managed.** Depending on the system and state of knowledge, the system model may be a relatively simple conceptual model, or it may be a highly complex and computationally intensive simulation model.
- **Participants have described and evaluated a range of management choices.** Multiple management choices have been identified to address the management issue. Each management choice has been evaluated to estimate the likelihood of achieving the management objectives and for the opportunity to learn about the system.
- **Monitoring and evaluation of outcomes.** Monitoring results and testing alternatives is the core of adaptive management. Sampling designs and analyses need to be designed so the monitoring results can detect differences between hypotheses and improve understanding. It can be very difficult to design and implement a practical, cost-effective monitoring program that is able to detect management-relevant differences between alternative management actions.
- **An explicit mechanism 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 between 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 implemented.

Adaptive management is best suited to situations where there is substantial uncertainty about the consequences of management actions, where reducing uncertainty can improve management, and where there’s a genuine likelihood of reducing uncertainty through experimental management (Williams and Brown 2012). Learning and flexible organizations are essential to implementing adaptive management, and to effectively

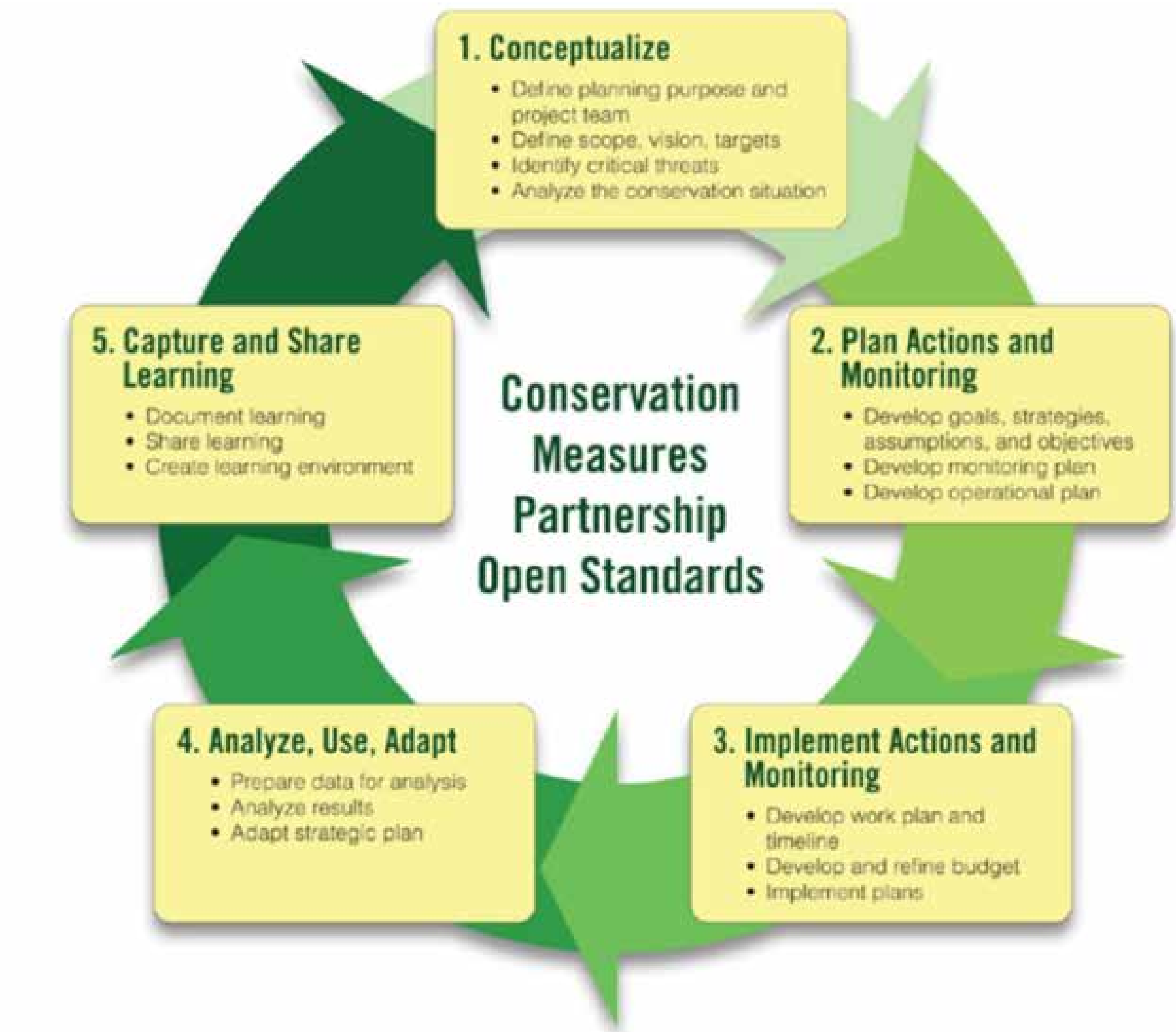


Figure 2. Best Practice management cycle for conservation projects. This cycle incorporates adaptive management principles and clearly shows the need to monitor, evaluate and learn from monitoring results, and modify management actions to improve practices (Figure from CMP 2013; www.ConservationMeasures.org).

responding to climate changes. Monitoring and evaluation that is designed from the outset to contribute to learning and that facilitates exploration of emerging issues will improve adaptation practices (Villanueva 2011).

Best Practice 2: Identify how M&E will contribute to adaptation

A critical principle for effective climate adaptation is to clearly link adaptation actions to goals and impacts. Monitoring can benefit the path to climate adaptation by measuring progress towards long- and short-term goals and objectives. For a major project, monitoring can effectively measure and report on the stages of implementation, changes in management actions, management effectiveness, resource conditions or trends, infrastructure that supports adaptation, or other relevant metrics of interest.

Three key aspects of adaptation that can be monitored to show progress towards success adaptation are (Oliver et al. 2013):

- Building institutional adaptive capacity,
- Reducing identified risks and vulnerabilities, and
- Successful management despite climate change.

Building institutional adaptive capacity. Adaptive capacity refers to the ability of organizations and individuals to respond to climate changes in ways that reduce impacts or effects. In the context of PAs, capacity building reflects the development of skills and abilities that enable a better response to climate variability, directional changes, and extreme events. In effect, building adaptive capacity increases the potential for effective adaptation to climate change (Oliver et al. 2013).

Institutional capacity is extremely important to effective climate adaptation. Inflexible management, outdated policies, and inadequately trained staff severely limit the ability of most protected areas to design and implement climate adaptation. Managers at all levels are now being asked to make decisions that require expertise in climate science, ecology, economics, risk management, and other special topics. 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.

Climate changes are amplifying management challenges from other environmental changes. Flexible and adaptive ‘learning institutions’ will be needed to identify and respond to rapidly evolving and novel situations precipitated by climate changes. Effective climate adaptation will increasingly require synthesizing and evaluating technical and non-technical information from diverse sources outside the areas of expertise of most

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 Gayte.

managers. Additional training will generally be needed to educate staff about climate changes, adaptive management, and new on-the-ground management actions. To deal with complex issues, adaption may require better access to topical experts, improved tools to support management, and supportive institutional organizations. All these characteristics are important to climate adaptation and preparedness.

Figure 3 illustrates the UK National Indicator that addresses "hallmarks of adapting organizations". While developed for local governments, the indicator is relevant to a PAs and measures preparedness to manage risks to service delivery, the public, local communities, local infrastructure, businesses and the natural environment from a changing climate. Each hallmark in Figure 3 can be measured by indicators at the scale of a site, network of sites, or broader (regional, national) level. These hallmarks are consistent with climate adaptation frameworks, targeting key activities and associated accomplishments.

Reducing identified risks and vulnerabilities. Most PAs are threatened by many factors, some related to climate changes and some not. Common threats to PAs include land use intensification, invasive species, altered patterns of disturbance, habitat loss and fragmentation, pollution, poaching, and resource degradation from overuse. Some of these threats will interact more strongly with projected climate changes, and immediate action to reduce these threats – especially those that interact strongly with climate – can be part of effective climate adaptation.

Climate vulnerability assessments are and important source of information on threats, as are other existing sources of information including site and resource-specific management plans, other assessments, broader reviews, and research reports. Adaptation actions that address specific threats or elements of vulnerability –exposure, sensitivity, or adaptive capacity - of a conservation target constitute elements well suited for monitoring.

Successful management despite climate change. Most conservation practices currently used by well-managed PAs will be effective with or without climate change. However, there will likely be goals or strategies that are or will become maladaptive, or are simply not achievable under a highly likely future climate. Some practices will become maladaptive. For example, hardening shorelines may temporarily protect against sea level rise. But over a slightly longer term, the hardening structures may inhibit or prevent movements of plants, establishment of adapted plant communities, and be an impediment to implementing more nature-based adaptation actions. In the planning process, each action needs to be evaluated for the current climate, and the range of likely climates that may eventuate over the life of the project. Plans that acknowledge and accommodate projected climate changes, and that favor strategies and actions that are robust to a variety of possible futures, are more likely to be successful. Scenario planning, for example, can help identify potential management actions likely to generate favorable results across a range of possible (uncertain), climate-driven futures. In the long term, successful management of PAs will involve progress in building institutional adaptive capacity, and actively addressing threats and vulnerabilities.

Best Practice 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

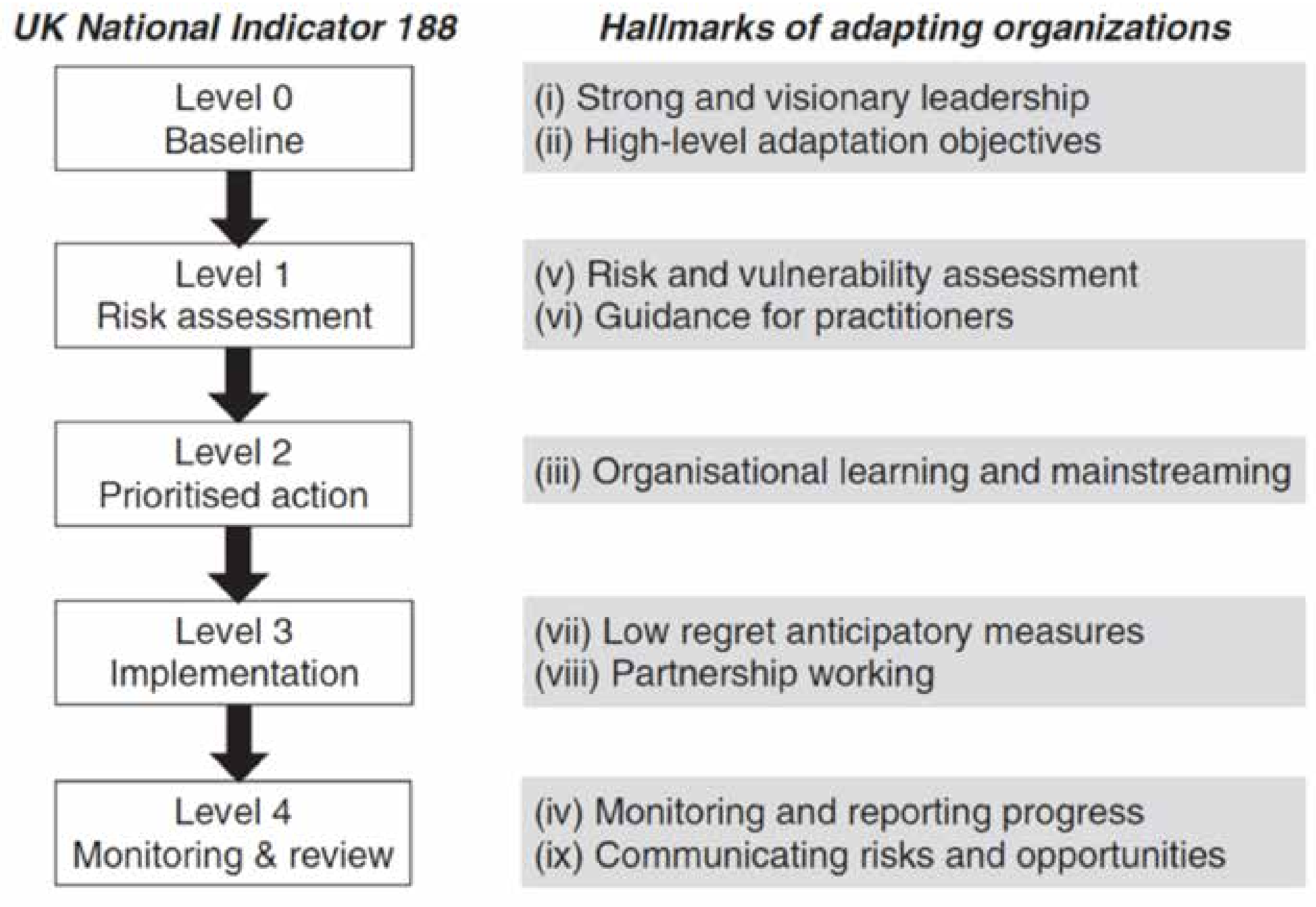


Figure 3. Field-based climate adaptation is most effective when supported by institutions and governance processes that are forward-looking, flexible, cooperative, and that promote learning at all levels. Hallmarks, or indicators, of adaptive organizations can be focused more process, rather than outcomes. A more detailed description and list of indicators for each level of adaptation are in the technical guidance to the indicator (LRAP 2010; Figure from Wilby and Vaughn 2011).

almost certainly 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 specifically target areas or systems subject to threshold events, where abrupt and dramatic changes ("pulse" events) will force an adaptive monitoring design. Other changes may be gradual ("press" events) that require periodic adjustments 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 particular species (Jump et al. 2010).

The increasingly likelihood of climate-related 'threshold' events poses a particularly important challenge to monitoring. Threshold events will likely be infrequent and very important, with long-term ecological consequences. Examples are coral bleaching, massive plant death, insect infestations, intense fires, or major floods. These sorts of events typically occur over a relatively short period, and the magnitude and extent of impact is very difficult or impossible to characterize through routine, ongoing monitoring. Without advance planning, it may be impossible 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.

Best Practice 4: Include adaptation-specific indicators into existing monitoring practices

As a general principle, climate adaptation activities should be incorporated into existing planning, management practices, and tools. If possible, monitoring for climate adaptation should become a routine part of existing monitoring of status and trends in natural resources, and monitoring and reporting of management and organizational effectiveness.

Because it is a foundation of learning institutions and knowledge-based management, virtually all PAs require routine monitoring, evaluation, and reporting. Additional indicators will usually be needed to specifically evaluate adaptation activities and progress towards adaptation goals. To address the monitoring challenges described at the beginning of this section, a broad range of indicators may be needed.

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

- Specific: the indicator is precisely, accurately, and concisely described. All important characteristics are unambiguously defined.

- Measurable: the indicator can be quantified precisely and repeatedly.
- Achievable: measurements are practical with available resources.
- Relevant: the indicator is an appropriate and interpretable metric of the state, condition, or process of interest.
- Time-bound: there is a complete temporal reference

Climate adaptation constitutes a long-term, mulit-dimensional process. In many situation, key bottlenecks to implementing climate adaptation are related to policy, administration, or other factors that are not directly related to on-the-ground action. Table 1 lists thematic areas suitable for monitoring, and general climate adaptation indicators that may be appropriate. The process of selecting indicators is generally far more complicated than described here, and there are many tools to assist in the identification and selection of suitable indicators. Table 2 lists tools and references that are particularly relevant to identifying and selecting indicators for climate adaptation. More detailed tools and lists of indicators can be found elsewhere (see especially Bours et al. 2014, and tables 9 and 10 in Ervin et al. 2010).

Table 1. Indicators useful for measuring progress during design and implementation of climate adaptation

Thematic area	Indicator or action
Capacity	Leadership support for climate adaptation clearly articulate and communicated to staff
	Training conducted to educate staff and community to understand importance and implications of climate change
	Staff members have adequate skills and knowledge to manage for climate adaptation
	Access to necessary data and information on climate projections, hydrological impacts
	Climate awareness incorporated into necessary policy documents
	Inventories and baseline data available for conducting assessments and measuring change
	Key management goals are climate-informed
Threats	Vulnerability assessment for key natural resources at appropriate levels and scales (species, communities, ecosystems
	Vulnerability assessment for infrastructure, archaeological, geological resources
	Vulnerability assessment for operations and visitor impacts
Planning	Adaptation options identified for at-risk resources
	Climate is a routine consideration in all resources and infrastructure planning and management plans explicitly incorporate likely impacts of climate change; all plans examined and climate-maladaptive actions avoided
	Planning process is flexible and response to climate related change and uncertainties
	Climate adaptation actions incorporated into work plans
Resource monitoring	Indicators of key vulnerabilities identified and measured
	Indicators of physical climate variables measured and routinely reported
	Measures and metrics developed and reported for leading and sensitive indicators of climate impacts (e.g., phenology, runoff, seasonality)
	Monitoring of climate-sensitive ecosystems implemented
	Monitoring of climate-sensitive processes implemented

Table 2. Selected tools and guidance for designing climate adaptation monitoring, identifying and selecting indicators, and effectively using results to inform decisions.

Topic	Description	Reference
Review of adaptation M&E tools and frameworks	Reviews 16 tools and frameworks for climate adaptation, mostly from the international development community. A key resource from SEAChange.	Bours 2013
Selecting indicators	Short guide with an emphasis on logframes.	Bours 2014
Conservation monitoring and adaptive management	Clear, practical, and mature guide to designing and implementing monitoring within an adaptive management process. Includes excellent definitions, worksheets and other practical tools. Specifically addresses climate adaptation.	CMP 2013
M&E of climate adaptation	Guide to designing results-based monitoring of climate adaptation of community-based development projects.	Oliver et al. 2013
Biodiversity indicators	Exceptionally clear and practical description of methods for identifying and developing indicators, reporting results, and effectively using information, with many examples. Covers all steps in the process.	Biodiversity Indicators Partnership 2011
PA management	Comprehensive compilation and synthesis of lessons from UNDP GEF projects with strong consideration of resilience and climate effects.	Ervin et al 2010
Organizations adapting to climate change	Identifies and describes key characteristics of organizations that are effectively addressing climate adaptation	Wilby and Vaughn 2011
Adaptation monitoring and evaluation	Comprehensive approach based focused on disaster risk reduction. Presents ADAPT principles.	Villanueva 2011
Effectiveness monitoring	IUCN framework and guide to PA management effectiveness monitoring	Hocking et al. 2006

Chapter 8
Designing resilient protected area networks

Climate change is having, and will continue to have, profound and unpredictable impacts on protected areas around the world. At the same time, protected areas are increasingly expected to provide an expanding set of ecological, social and economic benefits, including preventing biodiversity loss under increased intensity and frequency of threats and pressures; sustaining the productivity of managed ecological systems such as farms, forests and grasslands; contributing to national sustainable development goals such as food security, water security, and livelihoods; and contributing to societal climate change resilience, including through mitigating the impacts of natural disasters on human communities (Bergh and Couturier, 2013; Kettunen, M. and P. ten Brink, 2013; Ervin, 2010, 2013).

The far-reaching and unpredictable nature of climate change impacts means that business-as-usual practices for protected area design, planning and management are no longer an option. Preparing for change at the protected area site level by fostering adaptive management, strengthening critical capacities, and increasing ecological integrity are all critical first steps. However, these steps are insufficient for ensuring that a protected area network as a whole can deliver on increased societal expectations, while simultaneously facing more shocks and stresses from climate change as well as greater anthropogenic pressures. A new set of principles and guidelines at the level of protected area networks and of human-ecological systems is required in order to meet these new and complex expectations.

The three elements of resilience

Organizations define resilience in different ways (see Moberg and Simonsen, 2013; UNDP 2014; Hughes 2013; UNU, 2014). However, there are three elements common to most organizations' definitions of resilience,: a) an ecological design component – the degree to which the protected area network design allows ecological systems to resist, recover from and adapt to shocks, stresses and changing conditions; b) a network management component – the degree to which management interventions enable or inhibit ecological systems to cope with shocks, stresses and changing conditions; and c) a learning and adaptation component – the ability of human societies to anticipate, prevent, prepare for, recover from and learn from shocks and stresses. These three elements provide a basis for developing a set of guiding principles for applying the concept of resilience to human-ecological systems and to protected area networks (see Table 1). The remainder of this chapter explores implications for each of these resilience principles, and offers recommendations for how they might be applied to protected area network design, planning and management, in order to more fully realize changing societal expectations.

Network design principles to enhance resilience

The principles of effective protected area network design are well documented. They include ensuring representation, redundancy, connectivity and integrity, among others (Dudley, 2006). To a large extent, these principles provide de facto steps toward fostering network-level ecological resilience to climate change. However, by adding the specific aims of ecological resilience to each of these steps, planners can progress even further toward the goals of establishing protected area 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.

Ensure ecological representativeness: The vast majority of protected area networks around the world do not adequately

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.

Network design principles to enhance resilience	
Ensure ecological representativeness	Wilson et al., 2011; Hannah et al., 2007; SRC 2014
Build ecological redundancy	Wilson et al., 2011; Hannah et al., 2007;
Restore ecological integrity	Keenleyside et al., 2013;
Expand the network	Hannah et al., 2007;
Balance the portfolio	Game et al., 2008; Saxon, 2008
Predict the future	Groves et al., 2010; Wilson et al., 2011;
Protect the stage	Anderson and Ferree, 2010; Lipsett-Moore et al., 2010;
Strengthen landscape connectivity	SRC, 2014b; Ervin et al., 2010; Keller, 2009
Network management principles to enhance resilience	
Decrease landscape threats	Gunderson et al., 2010; Hannah et al., 2007
Manage negative synergies	Walker and Salt, 2006. Hannah et al., 2007; Ervin et al., 2010
Manage across boundaries	Walker and Salt, 2006. Hannah et al., 2007; Ervin et al., 2010
Maintain ecosystem services	Biggs et al., 2012; Ervin et al., 2010
Promote diverse governance	SRC, 2014; Boyd and Folke, 2012; Moberg and Simonson, 2013
Foster sectoral mainstreaming	Pleininger and Bieling, 2012; Chapin et al., 2009
Learning and adaptation principles to enhance resilience	
Foster complex thinking	Folk et al., 2010; Moberg and Simonson, 2013
Increase societal capacity	Moberg and Simonson, 2013; Folk et al., 2010; Ervin et al., 2010
Encourage adaptive learning	Moberg and Simonson, 2013; Folk et al., 2010; Craig et al., 2011
Increase societal relevance	Ervin, 2013 and Ervin et al., 2009

Table 1. Principles of resilience applied to protected area networks and human-ecological systems.

represent the diversity of species, habitats, ecosystems or even ecoregions. Major gaps in protection persist, particularly for ecologically productive systems, such as riparian areas, low-elevation forests and grasslands, and coastal areas (UNEP/WCMC, 2014). A protected area network that fully captures intact examples of species, habitats and ecosystems is more likely to be able to withstand shocks and stresses than one heavily dominated by a small sub-set of ecosystems, such as mountain, desert and alpine ecosystems (Wilson et al., 2011; Dunlop et al.,2008).

Build ecological redundancy: Because the intensity and distribution of impacts that climate change will have on biodiversity and ecosystems is uncertain, planners should consider building in a high level of redundancy into protected area networks, particularly for ecosystems and their associated services that are vulnerable to climate change. This means ensuring that there are sufficient examples of intact ecosystems, habitats and populations, widely distributed across the protected area network, in order to provide insurance for and spread risks from unpredictable shocks and stresses, and to mitigate uncertainty from climate change and its interactions with other stresses (Wilson et al., 2011).

Restore ecological integrity: A large percentage of protected areas across the globe contain degraded ecosystems. For example, a recent study of nearly 1800 protected areas 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 protected area maintains key characteristics of a reference natural community, is a key goal of restoration. It can be measured through the loss of species, the status of indicator species, the complexity of trophic levels, the degree of patchiness and variability in age classes, the balance of primary productivity, and the maintenance of nutrient cycling (Woodley, 2010). 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 protected area network, planners should pay particular emphasis on those areas that are in danger of a undergoing a fundamental shift in their ecology. To do so may require using reference natural communities from the past, as well as possible future communities that would arise under various climate scenarios. Planners should also consider focusing restoration efforts on areas important as refugia (places that hold isolated remnant populations of species that were once more widespread), and on areas important for species adaptation, including disperal along altitudinal, latitudinal and sometimes longitudinal gradients, as well as riparian and other connectivity corridors (Mackey et al., 2012; Ervin et al., 2010).

Expand the network: In a recent survey of over 100 articles, the single most frequently cited measure for strengthening resilience at the landscape level was the expansion of protected area networks (Hannah et al., 2007). Although there have been great strides in the global extent of protected area coverage (UNEP/WCMC, 2014), these gains are still not enough to ensure a landscape that is resilient to climate change. Parties to the Convention on Biological Diversity agreed in 2010 to protect 17% of terrestrial and 10% of marine areas globally, yet many studies of landscape- and seascape-level resilience suggest that up to 30% or even more may be required to ensure a fully resilient landscape (Wilson et al., 2011). When expanding their protected area networks, planners should focus on ecosystems that provide critical services (especially those that provide climate-sensitive services, such as food, water and disaster mitigation).

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.

Balance the portfolio: A protected area network that contains a balanced portfolio – focusing on protected areas that include species and ecosystems that are both vulnerable and resistant to climate change – is likely to have greater success in ensuring resilience. Some researchers call this approach “protect[ing] the strongest of the weak, and the weakest of the strong” (Game et al., 2008). Designing protected areas to help vulnerable species and ecosystems adapt can help to minimize and even avoid extinctions. At the same time, designing protected areas to capture resilient habitats and ecosystems can help ensure persistence by providing refugia for species with narrow environmental ranges, temporary habitat for dispersal species, and source populations for future colonization (Saxon, 2008; Mackey et al., 2012).

Predict the future: Most protected area gap assessments are based on the current state of biodiversity and ecosystems, without fully incorporating how these patterns will shift under various climate change scenarios (Ervin et al., 2010; Ervin and Parrish, 2006). Although many climate change impacts are unpredictable, many impacts can be reasonably predicted, and these forecasts should be incorporated into protected area network designs. For example, planners designing marine protected areas can incorporate likely patterns of sea level rise into their plans for inland, coastal and near-shore ecosystems (see for example Groves et al., 2010). As planners incorporate predictive scenarios and models for climate change, they may discover that they will also be faced with new trade-offs and difficult decisions about which ecosystems warrant increased investment in protection, and which may not (Carpenter et al., 2009). Clear guidance on how to incorporate the implications of climate scenarios into network-level decision-making will therefore become increasingly important.

Protect the stage: When designing a protected area 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 radically shift under most scenarios (Parry et al., 2007). Therefore, planners should design networks to represent and connect the underlying, enduring features of biodiversity across a landscape — the “stage” of evolution. These enduring features — which include, for example, bedrock types, soils, aspect, slope and elevation — largely determine past, present and future distribution of species, habitats and ecosystems, and will not change in a shifting climate (Anderson and Ferree, 2010). For example, protected area policy-makers conducted a gap assessment in Papua New Guinea that incorporated climate-related shifts in habitat but also focused on underlying features across the landscape (Lipsett-Moore et al., 2010).

Strengthen landscape connectivity: Despite the wide recognition of the importance of species or habitat connectivity in maintaining species across landscapes and seascapes, few protected area gap assessments explicitly include it (Keller, 2009; Ervin et al., 2010). Protected area planners should, as an urgent priority, identify options to increase the number of connectivity corridors, while at the same time incorporate climate considerations into their siting, design and management. Some specific steps to do so include incorporating predictive models of species and habitat ranges, using underlying enduring features when designing connectivity corridors; including resilient patches within corridors; identifying bottlenecks that would likely be exacerbated by climate change; orienting corridors to facilitate likely species movements; and locating corridors in environmental transition zones (Ervin et al., 2010). Some researchers add a note of caution that connectivity may also exacerbate climate impacts, including the acceleration of the spread of invasive species, disease and fire, and encourage planners to explore negative aspects of connectivity (SRC, 2014).

Network management principles to enhance resilience

The second side of protected area network resilience is the management of the network itself. This includes understanding and addressing threats that extend beyond individual protected areas (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.

Decrease landscape threats: Most assessments of site-level protected area management effectiveness include some form of threat evaluation (Leverington et al., 2010). However, although a large number of threats facing protected areas originate from outside of their borders, and many extend across multiple protected areas, the majority of landscape-scale threat assessments have major gaps. These gaps include an assessment of the spatial and temporal distribution of threats across the landscape; the specific impacts on individual biodiversity elements; the cumulative and synergistic impacts; the underlying causes; and the degree of future impact (Ervin and Parrish, 2006). This is particularly troubling, given the close relationship between ecological threats and pressures, ecological integrity and climate resilience. In order to minimize threats at the landscape level, planners can conduct larger-scale assessments that incorporate elements of resilience, including a) focusing on those threats that exacerbate or have negative synergies with climate change impacts; b) incorporating maps with spatial overlays between the distribution and intensity of multiple threats, and the climate vulnerability of key species and ecosystems; c) incorporating climate scenarios and their impacts on biodiversity; d) developing conceptual models for the underlying causes of threats and their drivers, as well as for the potential tipping points of ecosystems; and e) prioritizing the results into national sustainable development, biodiversity, climate adaptation, and protected area plans, as well as other key plans that tackle threats (Ervin et al., 2010).

Manage negative synergies: The vast majority of assessments do not consider how landscape-level threats interact with one another or with those at the site level threats, and more importantly, how they interact with climate change impacts. This is a major shortcoming, since the synergistic relationship between a variety of threats and climate change has been widely documented (Travis, 2003). Some threats create negative feedback loops with climate impacts, some magnify the impacts of climate change, and some accelerate extinctions and ecological regime shifts. When assessing network-wide threats, planners should pay particular attention on those threats that have negative synergies with climate change, including, among others, acidification of soils and waters (Keller, 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 (Laurance and Williamson, 2001); draining and mining of peatlands (Joosent et al., 2012); and overharvesting of biological resources (Lough, 2007; de Young et al., 2012).

Manage across boundaries: Creating transboundary protected areas 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. However, the majority of transboundary protected area initiatives do not adequately account for climate resilience issues (Ervin et al., 2010). This is unfortunate, given the important role of large transboundary protected areas in enabling climate adaptation at large scales (Thompson et al., 2009), strengthening overall landscape integrity and resilience (Carroll et al., 2010), and maintaining ecosystem services (Groves et al., 2001). When there are opportunities for creating new transboundary areas, some specific ways that planners can infuse these plans with climate resilience thinking include: a) collaboratively assessing climate impacts and vulnerability; b) developing cross-boundary climate adaptation plans; c) incorporating the maintenance of critical ecosystem services, particularly those that are vital to human wellbeing and are

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

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.

vulnerable to climate impacts, such as water provisioning; and d) taking joint actions to promote climate resilience, including tackling regional threats, promoting sustainable management across boundaries, promoting multiple pathways for species movement, and collaborating on translocation of species (Ervin et al., 2010).

Maintain ecosystem services: As noted earlier, protected area networks are increasingly expected to provide social and economic benefits by delivering ecosystem services, in order to help mitigate the impacts of climate change on communities around the world. This is especially important for the more than one billion people who depend upon the biodiversity and ecosystems within protected areas for their livelihoods, and the more than two billion people who depend upon ecosystem services for their basic necessities (SCBD, 2009). Therefore, planners will need to more explicitly incorporate issues related to the interface between ecosystem services and climate resilience. The most important step is to identify those areas that provide critical ecosystem services, and ensure that they are included in the protected area network. Among protected areas that include critical ecosystem services, planners can strengthen resilience by prioritizing a) prevention of new threats; b) restoration of existing degraded areas; c) mitigation of ongoing threats, such as illegal logging, poaching, mining and encroachment; and d) research and monitoring to avoid ecological regime shifts.

Promote diverse governance: The world's governments have widely embraced more diverse protected area governance – the Convention on Biological Diversity's Programme of Work on Protected Areas includes an entire section on this need (CBD, 2006), and numerous countries around the world have promoted a range of governance models across their protected area systems. Diverse governance models may include 'other conserved areas,' such as community no-take zones and voluntary easements. Multiple governance models are likely to lead to a more resilient landscape by enabling broader participation, improving connectivity, improving diversity of responses to climate impacts, and increasing redundancy of protection (SRC, 2014). Planners can capitalize on these benefits by ensuring that participants representing various governance models are involved in the design, planning and management of the national protected area network.

Foster sectoral mainstreaming: In the context of protected areas, mainstreaming is the integration of the aims and objectives of various economic sectors into the design and management of ecological systems. Mainstreaming in this sense is well established, with specific steps including the identification of stakeholder interests, mutually beneficial outcomes, potential conflicts and trade-offs, mutually satisfactory strategies, and pathways for embedding these strategies into plans, policies and practices (Ervin et al., 2009; Petersen and Huntley, 2005). Examples of sectoral mainstreaming into protected area networks, with an emphasis on strengthening climate resilience, include a) reducing road construction and infrastructure development that will create new bottlenecks and restrict the movement of wide-ranging species; b) reducing habitat fragmentation; c) reducing 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; d) reducing activities such as underwater sonar testing that affect migratory species; and e) reducing activities that have negative impacts on species vulnerable to climate change.

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 var-

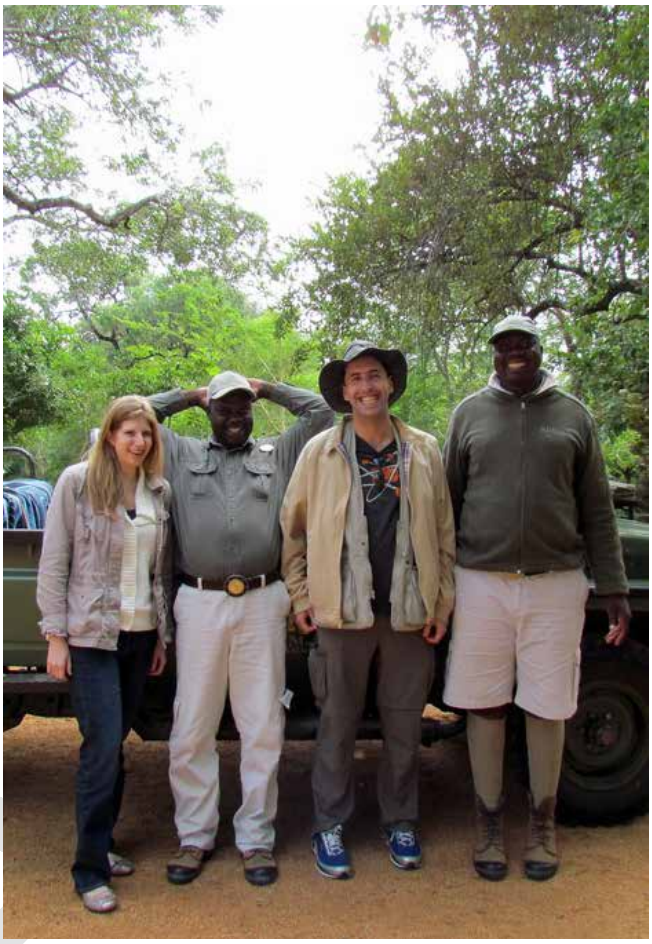
Conservation easements are part of a suite of diverse protected area goverrnance models that can be deployed. Paint River conservation easement, Keweenaw Land Trust, USA.

ious shocks and stresses. This includes the ability the think, organize and learn in new ways, at individual, institutional and societal levels.

Foster complex thinking: In order to understand the complexities of climate change impacts on biodiversity within and across protected areas, planners must be willing to embrace models of systems-level thinking that incorporate unpredictability, uncertainty, nonlinearity and scenario planning, among many other departures from traditional reductionist thinking (SRC, 2014). Three key concepts are: a) ecological regime shifts – a switch in an ecosystem, typically irreversible, from a relatively stable, complex state to another usually less diverse one; b) resilience thresholds – the point at which an ecosystem experiences a regime shift; and c) tipping points – a point along a continuum, such as temperature extremes, or forest fragmentation, at which an ecosystem crosses an ecological threshold and experiences a regime shift (Gunderson et al., 2010). Planners can use these fundamental resilience concepts to further elaborate scenarios that incorporate the unpredictability and uncertainty of climate change impacts, and to prioritize actions across the protected area network.

Increase societal capacity: Capacity gaps have long plagued protected areas around the world – fewer than a third of all protected areas have management plans (Ervin et al., 2010), for example, and in some countries, there is an average of only one permanent staff per protected area (Lisle et al., 2004). With the need to strengthen resilience of the protected area network, and to manage it in order to enable resilience in human communities, the need for increased capacity is only compounded. Key climate-related capacities that are likely to be required across a protected area network include knowledge and skills related to: a) laws, policies and incentives related to resilience-related strategies; b) the economic valuation of the protected area network in order to be able to make the economic case for increased investment; c) the updating of existing, or creation of new, management plans that fully incorporate climate resilience issues; d) an analysis of, and strategies for to address, system-wide threats that exacerbate or accelerate climate impacts; e) the incorporation of resilience issues in system-level management effectiveness assessments; f) an upgrade of the national monitoring system to account for resilience issues; g) an updated protected area gap assessment that incorporate resilience thinking; h) a re-evaluation of opportunities for trans-boundary protected areas, in light of climate resilience (Ervin et al., 2010).

Encourage adaptive learning: The accelerating pace of climate impacts, coupled with the immaturity of science regarding the impacts of climate on biodiversity, ecosystems and protected areas, means that planners must accelerate their own pace of learning and adaptation. Indeed, adaptive learning is one of the cornerstones of climate resilience (SRC, 2014, UNU, 2014); UNDP, 2014). In order to accelerate learning about climate and biodiversity relationships, and to embrace lessons from across individual protected areas, planners may need to upgrade knowledge systems within the protected area system, including: a) establish new monitoring protocols and feedback mechanisms; b) prioritize learning-related activities as part of staff objectives and performance appraisals, with an emphasis on climate-related issues; c) establish clear climate-related learning objectives and priorities across the protected area network; and d) establish a database of evidence-based climate learning regarding the interactions between management interventions and outcomes. In order to capitalize on the wealth of knowledge outside of protected areas, planners may also need to: a) radically expand their



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.

ability to communicate with key stakeholders, including with indigenous and local communities who have long histories of adaptive management; b) create and incorporate a community-based early detection and warning system for climate-related issues; and c) establish user-friendly communication mechanisms, forums and vehicles that enable societal learning regarding the interface between protected areas and climate change.

Increase societal relevance: Protected areas have long been viewed as a societal cost, rather than as a societal investment. Protected areas have also largely existed outside of national economic and development plans and policies. Because of the major shift in how societies are beginning to view protected areas, protected areas planners must now ensure that the protected area networks within their country are properly positioned to receive the investment and policy support required to deliver on new expectations. There are numerous opportunities to reposition protected area networks as a societally relevant investment that can strengthen resilience and foster national development. One of these is within national sustainable development goals and plans. Fewer than 15% of all national development plans specifically mention protected area networks, yet protected areas can have a major role in enhancing national food and water security, generating employment and sustaining livelihoods, buffering vulnerable communities from disasters, fostering healthy populations, and reducing border-related conflicts (Ervin, 2013). To properly position protected areas as a societally relevant investment, planners must a) draw the link between the multiple social and economic values of the protected area network, and their direct relevance to the goals and objectives of national plans;

A Fast Start for Natural Solutions:
A Canadian/Kenyan Partnership for Climate Change Adaptation in Protected Areas

John Waithaka[1], Mike Wong[1], Karen Keenleyside[1], Edwin Wanyonyi[2] and Erustus Kanga[2]
[1]Parks Canada, [2]Kenya Wildlife Service

> I believe we can work together, learn from each other, develop creative solutions, and produce better results for our organizations, our people and the global community (Letter of Alan Latourelle, CEO, Parks Canada, to [NAME], Kenya Wildlife Service director, June 3, 2009)

This case study describes how protected areas agencies in Canada and Kenya are working together to implement ecosystem-based approaches to climate change adaptation and briefly reports on one of the projects undertaken to enhance the resilience of protected areas and human communities to climate change impacts. This work has been facilitated through an existing Memorandum of Understanding (MoU) between the Park Canada Agency (Parks Canada) and the Kenya Wildlife Service (KWS).

Protected areas as natural solutions to climate change adaptation

Climate change is having far reaching consequences for Kenya's biodiversity, a country that relies mainly on biodiversity resources for sustenance of livelihoods and generation of wealth. Agriculture, livestock, forestry, nature based tourism and fisheries account for most of the employment, economic output and export earnings, and biomass energy accounts for a high proportion of total energy consumption. To a large extent, biodiversity resources are crucial for political and economic stability, and national security. Kenya's protected areas are crucial for conserving this biodiversity, reducing poverty, generating employment and creating wealth. They support 90% of wildlife tourism and contribute to other sectors of the economy such as energy, water, agriculture, security, forestry and horticulture. But these protected areas are under serious threat from climate change.

Today, over 70 per cent of natural disasters affecting the country are climate-related. Rising temperatures, frequent, intense and prolonged droughts, unpredictable weather patterns, declining levels of water in rivers and lakes, unexpected floods, unprecedented spread of invasive species, increased incidences of fires, and occurrence of strange diseases are becoming significant threats to biodiversity conservation (GoK, 2010). The changing climate is responsible for the melting of glaciers on Mount Kenya which has lost eleven of the 18 that existed in 1900 (GoK 2007). The combined effects of these impacts are affecting Kenyan's wildlife, the economy and livelihoods of millions of people.

Through an MoU that exists between Parks Canada and the KWS, the two agencies developed and implemented several projects to mitigate the impacts of climate change on park ecosystems and neighbouring communities. The initiative was supported by the Government of Canada through the 'Fast Start Financing' Programme.

Six KWS flagship protected areas that were facing significant climate change-related threats were identified and prioritized for action. They included Tsavo East, Tsavo West, Amboseli, Mount Kenya, Aberdare and Lake Nakuru National Parks. These are among Kenya's top tourist destinations as well as important biodiversity hotspots. Project interventions were aimed at enhancing the ecological integrity and adaptive capacity of the park ecosystems, habitats, wildlife and neighbouring human communities to climate change impacts. Activities included restoration of degraded forest habitats in Mount Kenya and Aberdare National Parks, restoration of wetlands and savannah habitats in Amboseli, Tsavo East and West National Parks, and management of invasive species in all the six parks. Local communities and other stakeholders participated in a wide range of activities, including establishment of modern tree nurseries, planting of seedlings, mechanical removal of invasive species, and protecting riparian zones.

The projects were implemented in collaboration with local community groups, park visitors, education institutions and other organized groups. Participants were made aware of the role of protected areas in of biodiversity conservation, sustainable tourism, climate change mitigation as well as providing natural solutions to a range of ecological and livelihood challenges. The projects provided opportunities to connect people to nature, build support for restoration efforts and raise awareness about the broad impacts of climate change. The lessons learned are transferable to other parks in Kenya and the East African region, and demonstrate how multiple benefits of national parks can be obtained by simple actions that simultaneously address ecological issues and the needs and values of local people.

Canada's and Kenya's institutional capacities to adapt to climate change have grown through these projects. Both Parks Canada and the KWS have developed a better understanding of protected areas' response to change.

Parks Canada and KWS staff with community leaders outside Amboseli National Park

The Memorandum of Understanding

The governments of Canada and Kenya signed a Memorandum of Understanding at the November 2006 United Nations Climate Change Conference in Nairobi with the aim of sharing experiences in the management of national parks. The MoU, to be implemented by Parks Canada and the Kenya Wildlife Service (KWS), was established in recognition of the strongly shared interests and responsibilities of both agencies in the management, planning, conservation and enjoyment of national parks as reflected in the mandates for the two organizations. In addition, it was a response to the appeal by the Convention on Biological Diversity's Programme of Work on Protected Areas for members of the Convention to improve protected areas planning and management through cooperation, capacity building and technology transfer (CBD 2004). The MoU facilitates support to KWS in areas such as protected area management planning, ecological monitoring and reporting, stakeholder engagement and provision of memorable visitor experiences.

Implementation strategy

The MoU was to be implementation in three phases. The first two phases were exploratory, and involved reciprocal exchange visits between staff of the two organizations. The activities of the third phase were to be determined based on the outcome of the first two phases. The phased implementation approach was to enable the partnering agencies to understand each other's culture, values, management style and priorities, and operational procedures. The exploratory phases, implemented between 2006 and 2008, helped to create realistic expectations.

Degraded habitats in Amboseli National Park that are being rehabilitated.

Following the reciprocal exchange visits, it became clear that both agencies were facing similar challenges despite differences in geographical location, social-economic disparity and technological capacities. These challenges included ecosystem fragmentation, species and habitat loss, climate change impacts, and the spread of invasive alien species. Other common management challenges included ensuring that parks were valued and appreciated by the public, and that they provided opportunities for learning, recreation and fun, while contributing to the well-being of people, remaining relevant to them, and touching both their hearts and minds.

In developing the MoU, Parks Canada was not seen as a donor. However, being the oldest national park agency in the world, it was in a good position to provide technical and professional assistance, and a standard for benchmarking. As part of its participation in the MOU, Parks Canada also sought funding opportunities such as the Fast-Start financing to support conservation activities in Kenya. When such opportunities materialized, the existence of the MoU facilitated the development of financial tools and processes for successful implementation of activities. The MoU was formulated so as to keep it open-ended to enable collaboration whenever an opportunity arises.

As exemplified by the Fast-Start climate change adaptation project, formal partnership mechanism such as MoUs can be important to sustain partnerships between protected area agencies without establishing a donor-recipient relationship. Through the Parks Canada-Kenya Wildlife Service MoU and the Fast-Start Financing opportunities, the two protected areas agencies have built their capacities to manage their protected areas. In addition, by sharing knowledge and experiences through local, regional and global forums, they are providing information that can inspire other protected area agencies to work together to address global challenges such as climate change.

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Community members participating in destroying invasive species in Tsavo East National Park.

b) ensure that these values are recognized and incorporated into national accounting frameworks and decision-making processes; and c) ensure that the specific policies and practices that flow from these national plans continue to place protected areas as an efficient and effective strategy to strengthen national resilience and achieve national development goals.

Climate change will continue to have unfolding, cascading and unpredictable impacts on protected areas and the human and natural communities that depend upon them for decades if not centuries to come. However, planners and policy-makers responsible for protected area networks can respond now by incorporating some of the basic principles of climate resilience into protected area design, management and adaptive learning outlined in this chapter.

Chapter 9

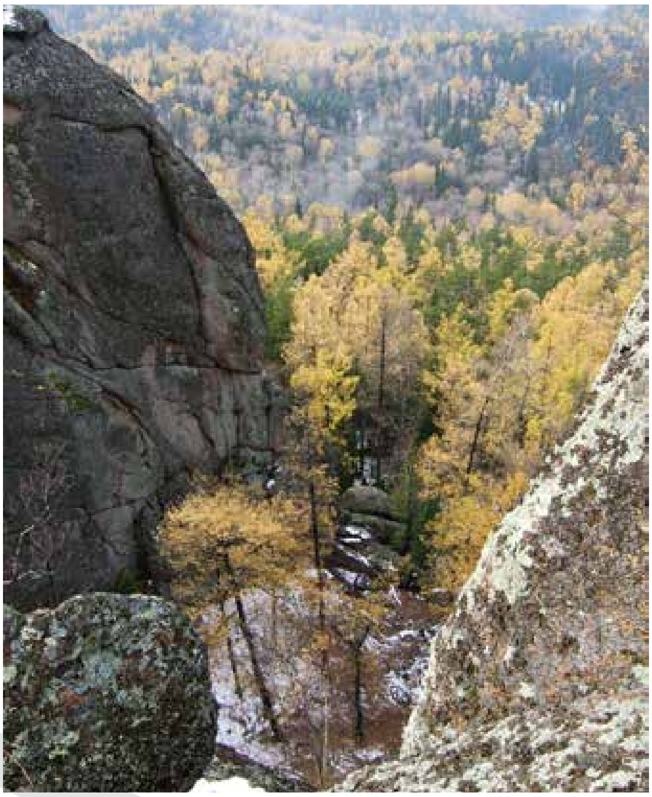
Combined with other parts of document — chapters to be re-numbered in final version

Chapter 10
Mainstreaming protected areas as a natural solution to climate change

This guide has focused on the best practices protected area managers can take when considering the short and long-term impacts of climate change. As discussed throughout, there is now no room for managers to assume that climate change will not have some impacts on their protected area and that is essential that future planning is climate savvy.

It is essential to recognize that protected areas have important — and often underappreciated — roles in addressing climate change from local to global scales. The World Commission on Protected Areas calls protected areas one of the “natural solutions” to climate change (Dudley et al, 2010) and urges them to be seen as mainstream solutions by nations. The often intact ecosystems found within PAs contribute to climate change mitigation by sequestering and storing huge amounts of carbon. In some places, protected areas offer disaster relief for vulnerable human communities, and many provide essential ecosystem services (e.g. fibre, food, medicine, water) for basic human needs (Figure 10.1).

All protected areas are reservoirs for carbon, and conserving these stocks in trees, soils, peat and other ecosystem components reduces the generation of greenhouse gases and can contribute to storing carbon that would otherwise be released into the atmosphere (Mackey et al. 2014). Deforestation and vegetation degradation are recognized as one of the most important sources of greenhouse gas emissions (IPCC 2013), and PAs – through their virtue of stopping destructive activities - have an essential role in mitigating some of these emissions. When a PA is degraded via anthropogenic activities (e.g. inappropriate fire regimes, establishment of invasive species),



All protected areas 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.

Figure 1. Climate mitigation and adaptation benefits and ecosystem services that accrue from intact protected areas. (Dudley et al. 2010, p. 28).

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

good PA management can change a carbon source into a carbon sink. The converse is also true – PAs can often start to be a source of GHG emissions if not effectively managed in a climate smart way. It is therefore essential when considering adaptation goals that the activities that are identified either are at least 'carbon neutral' or a net positive when considering the PAs overall storage and sequestration potential. This is an essential component of mainstreaming and what many call 'ecosystem-based mitigation'.

Furthermore, some protected areas are critical for providing ample clean water, lessening the impacts of floods, filtering sediments, protecting coasts and estuaries, and providing a multitude of other key ecological functions for human needs. In many places, climate change are going to affect these ecological and physical processes and the role of protected areas will be increasingly important in buffering the negative impacts. To address these issues, protected areas have a number of the distinct advantages. These can be broadly categorized as (Dudley et al. 2010): (1) Governance and safeguards; (2) Permanence; (3) Effectiveness; and (4) Monitoring, verification, and reporting. Table 10.1 summarizes these advantages. In addition to the attributes described in Table 10.1, in many regions PAs contain the only remaining large tracts of natural habitat and may support native biodiversity found nowhere else. The combination of defined boundaries, established governance, commitment to the long term, a proven ability to deliver benefits, and a means for accountability make PAs ideal candidate locations for climate mitigation and adaptation projects that also support conservation goals.

There is an important communication message that protected area managers need to apply in these situations because as nations struggle to implement adaptation and mitigation strategies, protected areas are frequently overlooked simply because the key decision-makers do not appreciate the relevance of ecosystem-based approaches, or they are uncertain how these approaches can be used. A current challenge is to ensure that PAs are fully integrated with broader environmental policies and other approaches to climate adaptation. Including protected areas considerations into the full spectrum of societal decisions and activities that will be influenced by climate change is known as "mainstreaming." Changes in temperature, water availability, seasonal patterns, and weather extremes will affect virtually every sector of society, from energy needs to health, recreation, security, agriculture, and transportation. Protected area mainstreaming is the informed inclusion of protected areas into the climate adaptation decisions made by society that drive management policy in all these sectors.

Table 1. Advantages of protected areas for implementing climate mitigation and adaptation actions (modified from Dudley et al. 2010).

Governance and safeguards
Defined borders and area with recognized protection.
Operate under government, self-declared community, policy or trust, or other effective framework.
Agreed-upon governance structure to meet social and cultural requirements.
Are supported by a variety of international conventions and agreements (CBD, REDD, World Heritage, Ramsar, Man and Biosphere, CITES, etc.).
Recognise cultural and social values of protected areas and have experience in implementing accessible, local approaches involving people in a legitimate and effective way in management.
Permanence
Based on a commitment to permanence and long-term management of ecosystems and natural resources.
The focus on local, national, and international attention on areas with protected status adds to the area's protection.
Effectiveness
Established record as effective in retaining natural ecosystems and services, especially through PA systems at landscape/seascape scale.
Supported by management plans. Plans can facilitate rapid responses to emerging climate information.
Staff, equipment, and infrastructure that support management expertise and capacity, including how to manage ecosystems to generate ecological services for climate adaptation.
Opportunity to use protected area planning and management experience to bear on broader landscape and seascape scale approaches to climate mitigation and adaptation.
Can draw on existing funding mechanisms, including government budgetary appropriations, and funding from GEF and LifeWeb.
Backed by established networks of experts that can provide advice and assistance, including IUCN World Protected Areas Commission and NGOs.
Monitoring, verification, and reporting
Are supported by government commitments under the CBD to establish ecologically-representative protected area systems.
Have organised and populated data sources to set baselines and facilitate monitoring, such as the IUCN management categories, governance types and Red List, and the UNEP World Conservation Monitoring Centre (UNEP-WCMC) World Database on Protected Areas (these systems would need some strengthening to meet UNFCCC needs).
Defined borders greatly facilitate measuring, monitoring and reporting e.g. carbon sinks, storage, and ecosystem services.

The overall goals for mainstreaming protected areas as adaptation solutions are to:

- Identify integrated approaches that avoid 'development vs. environment' arguments or that foster institutional tensions and associated costs;
- Promote efficient planning of environmental resources and environmental hazard management;
- Support technological and cultural innovation that is informed and inspired by nature;
- Inform policy decisions on major issues, thereby improving the productivity, resilience and adaptability of local, sectoral, and national systems.

A systems perspective and ecosystem-based management will help integrate PAs into broader policies and plans. PAs are integrally connected with local communities and surroundings, and many benefits from well-managed PAs, such as flood mitigation, will be realized by communities distant to the PA.

Ecosystem-based adaptation

Ecosystem-based adaptation (often called EBA) to climate change is very frequently part of broader national goals, particularly those related to natural hazards and provision of nature-based goods for humans (Figure 10.1). It is important to note that EBA solutions are focused on reducing the vulnerability of human communities so it is not a conservation strategy per se. In some places, EBA strategies have failed to explicitly consider protected areas as part of solutions. A key step to mainstreaming protected areas into climate adaptation is to recognize and publicize the roles of intact natural systems to provide human communities protection from and resilience to hazardous events. Intact natural systems are critical to maintaining water yields and quality floodplains provide natural flood controls; forests hold snow for spring-time water yield and prevent avalanches; estuaries are important breeding grounds for fish and protect coastal areas from floods.

Examples of protected areas' mitigation role in responding to climate change

- **The Amazon Region Protected Areas programme** (ARPA) in Brazil provides a good example of the mitigation role of protected areas. ARPA has created 22.28 million ha of new protected areas, strengthened management of 8.65 million ha of existing protected areas and created a mosaic of state, provincial, private and indigenous reserves with a total area of 30.93 million ha. ARPA thus conserves a carbon stock estimated at 4.5 billion tons, which, if cut down, would emit approximately1.8 billion tons of carbon.
- **Protected areas in Bolivia, Mexico and Venezuela** contain around 25 million hectares of forest, storing over 4 billion tons of carbon, whose worth in terms of global damage costs avoided is estimated to be between US$45 and US$77 billion. Bolivia: Tropical forests in Bolivia's protected areas are estimated to store around 745 million tons of carbon, worth between US$3.7 billion and $US14.9 billion at international carbon market prices (US$5 minimum and US$20 maximum). Deforestation poses a real threat, with almost 10 per cent of forest cover already lost through logging, conversion to agriculture and settlement, and fire damage.
- **Mexico:** Over 2.2 billion tons of carbon is locked up in Mexico's federal and state protected areas. Even at a very conservative price, this service is worth at least US$34 billion. In addition, low-lying coastal areas of Mexico are vulnerable to sea-level rise; particularly the Rio Bravo Delta, Alvarado Lagoon and lower reaches of the Papaloapan River, the Grijalva-Mezcapala-Usumacinta Delta Complex, Los Petenes and Sian Ka'an Chetumal bays. Protected areas have been established in four of these sites to safeguard coastal settlements, minimise coastal erosion and help to reduce damage from storms and tidal surges.
- **Venezuela:** Carbon storage is currently estimated to be worth US$1 billion in Canaima National Park, US$94 million in Imataca Forest Reserve, and US$4.5 million in Sierra Nevada National Park. Almost 20 million hectares of forest have been identified by the government as being available for mitigation – potentially storing more than 1.4 billion tons of carbon worth between US$7 billion and US$28 billion. Yet between 1990 and 2005 Venezuela lost 7.5 per cent of its forest and woodland habitat.

Sources: MacKinnon et al. 2012; Dudley et al. 2010: 32; TNC

Left: Sian Ka'an Biosphere Reserve, Mexico. Right: Canaima National Park, Venezuela.

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

Furthermore, intact ecosystems provide enormous benefits by stabilizing soils and preventing landslides, preventing avalanches, and mitigating other hazards. Table 10.2 describes climate-related hazards than can serve as adaptation opportunities that benefit communities while contributing to broader protected area conservation goals.

Watershed protection is an almost universally important ecological benefit of protected areas. Projected climate changes will increase the variability of water supplies in many regions, with follow-on consequences for the quality and amount of water provided to communities. Actions that protect forested catchments can provide biodiversity benefits, especially for aquatic biota, and help secure reliable, clean water in rivers and streams. Goals that will facilitate mainstreaming adaptation, while promoting both water and biodiversity include:

- Protect forested catchments. Reduce/restore degraded areas, promote native vegetation that holds soils. Expand protected areas to include upstream watersheds.
- Manage wetlands to maintain their functions to filter sediments, remove toxins, absorb flood waters, and support diverse biological communities.
- Integrate forest management and water supply. Coordinated, collaborative approaches between environmental agencies, state and private protected areas, water companies, and NGOs are needed to most effectively manage and expand protected areas in catchments, and use the resulting water supply in environmentally appropriate ways.

Table 2. Examples of the role of protected areas in preventing or mitigating against natural hazards. Source: Dudley et al. 2010: p. 49.

Hazard	Role of protected area	Key areas or habitat types	Examples
Flooding	Providing space for overspill of water / flood attenuation	Marshes, coastal wetlands, peat bogs, natural lakes	The two reserves which form the Muthurajawella Marsh, in Sri Lanka, cover an area of 3,068 ha near Colombo. The economic value of flood attenuation (converted to 2003 values), has been estimated at US$5,033,800 per year.
	Absorbing and reducing water flow	Riparian and mountain forests	Benefits from forest protection in the upper watersheds of Mantadia National Park, in Madagascar, in terms of reduced flood damage to crops were estimated at US$126,700 (in 1991 Madagascar had per capita GNP of US$207).
Landslip, rock fall and avalanche	Stabilising soil,- loose rock and snow	Forest on steep slopes	Floods and landslides are frequent hazards in Nepal, claiming around 200 lives a year. Shivapuri National Park is the main source of water for domestic consumption in Kathmandu. Landslide protection measures have been implemented in 12 localities in the park.
	Buffering against earth and snow movement	Forests on and beneath slopes	150 years ago the Swiss government recognised that forest loss was linked to serious avalanches, landslides and flooding. 17 per cent of forests are managed to protect against landslides and avalanches, providing services worth some US$2–3.5 billion per year.
Tidal waves and storm surges	Creating a physical barrier against ocean incursion	Mangroves, barrier islands, coral reefs, sand dunes	The indigenous communities living in the Rio Plátano Reserve in Honduras are reforesting the shore of the Ibans Lagoon with mangrove and other species to improve fish habitats and counter the erosion of the narrow coastal strip.
			Following the 2004 Tsunami, studies in Hikkaduwa, Sri Lanka, where reefs are in a marine park, noted that damage reached only 50 m inland and waves were only 2-3 m high. At nearby Peraliya, where reefs have been extensively affected by coral mining, the waves were 10 m high, and damage and flooding occurred up to 1.5 km inland.
	Providing overspill space for tidal surges	Coastal marshes	The Black River Lower Morass is the largest freshwater wetland ecosystem in Jamaica. The marsh acts as a natural buffer against river flood waters and incursions by the sea and is an important economic resource for 20,000 people.
Drought and desertification	Reducing grazing and trampling	Particularly grasslands but also dry forest	In Djibouti the Day Forest is a protected area, with regeneration projects initiated to prevent further loss of this important forest area and further desert encroachment.
	Maintaining drought-resistant plants	All dryland habitats	In Mali, the role of national parks in desertification control is recognised, and protected areas are seen as important reservoir of drought resistant species.
Fire	Maintaining management systems that control fire	Savannah, dry and temperate forests, scrub land	In Mount Kitanglad National Park, Philippines, volunteers from different ethnic communities in the area undertake fire watching duties. Being members of volunteer guard initiatives fits well with traditional ideas of land stewardship and a council of tribe elders endorses their appointment.
	Maintaining natural fire resistance	Fire refugia in forests, wetlands	Studies in and around Kutai National Park, Indonesia, found that the 1982-3 forest fires killed more trees in secondary forest than in protected primary forests, where fire swept through undergrowth, only affecting larger trees when fire crept up lianas. Similarly recent studies in the Amazon found the incidence of fire to be lower in protected areas relative to surrounding areas. Forest fragmentation also leads to desiccation of ground cover, increasing the fire hazard
Hurricanes and storms	Buffering against immediate storm damage	Forests, coral reefs, mangroves, barrier islands	The protected mangrove system known as the Sundarbans in Bangladesh and India helps to stabilise wetland and coastlines and contributes to the Sundarbans' role in buffering inland areas from cyclones. Mangroves can break up storm waves that can exceed 4 m in height during cyclones, and result in the coastal areas protected by these forests suffering less from wind and wave surges than those areas with little or no mangrove cover.

Other climate-related adaptation targets that are particularly relevant to broader goals include coastal management to address flooding from storms and sea-level rise, fisheries management, and programs to address drought (Table 10.3).

Mainstreaming protected area adaptation: Policy and financing

Protected areas already contribute substantially to climate adaptation and mitigation, but these contributions can be greatly increased through better integration into regional and national programs. Two key challenges are policy and financing (Dudley et al. 2010).

With regard to policy, at every opportunity protected area management needs to be integrated into wider efforts to address climate change, such as National Adaptation Programmes of Action (NAPAs). NAPAs have a clear link to the national budget and key decision-making processes. Relevant examples of climate-smart adaptation are often based on regional-scale projections of climate impacts. This focus at a sub-national level is relevant to broader-scale protected area planning and management. In India, for example, the climate change response strategy has eight elements: research and development, energy, sustainable agriculture, solar power, disaster relief, sustainable habitat, national water programme and "Green India". Trying to fit protected areas into a diverse programme such as this is challenging.

Valuing the role of protected areas

To build an effective case for integrating protected areas in broader agendas, it is necessary to clearly communicate the many benefits that protected areas provide for both mitigation and adaptation, which can occur simultaneously (Table 10.4). A more complete picture of the value of a country's response to climate change can be gained by considering the total mitigation and adaptation impacts (consequences and tradeoffs and co-benefits of various responses). Natural ecosystems often provide numerous benefits at lower costs than engineered actions, yet the valuation of these benefits are often based on a single one. For example, conserving coral reefs and mangroves, rather than constructing sea walls, provides coastal protection and societal resilience but can also provide additional benefits ranging from enhanced fish stocks to economically beneficial ecotourism. Conserving a forest will contribute to carbon storage and climate mitigation, while

Table 3. Adaptation targets for protected areas, and their potential opportunities and costs (adapted from MacKinnon et al. 2012: p. 16).

Target	Potential opportunities	Potential risk/costs
Water supplies	Watershed protection • erosion control • invasive species control • fire protection • flood mitigation • water filtration • water yield	Impoundments (dams) Canals/drainage Diversions and off-channel usage
Agriculture and food security	• protection of wild crop relatives (genetic diversity) • maintain nutrients (fertile soils) in landscape • promote sustainable agro-ecological practices • promote alternative, ecosystem-based livelihoods	Expanded agricultural footprint • Pressure on protected areas • Release of climate tolerant cultivars and GMOs into environment • Drift and leaching of agrochemical pollutants in to soils, air, and water
Support fisheries aquaculture productivity and security	Protection through marine protected areas Restoration, especially of: • Coral reefs • Mangroves Promote alternative, ecosystem-based livelihood strategies	Increased pressure to access resources in MPAs and sanctuaries Overharvest Pollutants from aquaculture
Manage water flows and floods	Protection and restoration of riverine and floodplain habitat, and of montane cloud forests	Inter-basin transfers Hard infrastructure for flood control
Manage for disaster reduction	Design approaches to disaster risk reduction (DRR) that combine hard infrastructure with soft green approaches	Replacement of green with hard infrastructure within protected areas
Address sea-level rise and storm surges	Coastal ecosystem protection and restoration	Replacement of green with hard infrastructure in protected areas
Alien invasive species	Incentive to address one of the key challenges causing biodiversity loss	Possible spread of invasive species with crop improvements, biofuels, aquaculture, and other production activities

Mangroves and coastal ecosystem integrity


Mangroves in West Bali National Park, Indonesia.

Mangroves cover only a small part of the globe, but they are critically important to coastal ecosystem integrity. Despite their small spatial extent, they may contribute as much as 10% of the carbon released due to global deforestation (Hutchison et al. 2014). Mangroves sequester approximately four times more carbon per hectare than tropical forests but deforestation rates are three to five times greater than global rates forest loss (FAO 2006). Maintenance and/or restoration of mangroves can reduce the vulnerability of coastal areas to fooding while increasing fisheries and food security. In Vietnam, communities have been planting and protecting 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 per cent greater than revenues from shrimp farming and aquaculture on lands cleared of mangroves (MacKinnon et al. 2012).

Table 4. Adaptation and mitigation targets relevant to mainstreaming, and methods used to assess them (from MacKinnon et al. 2012).

Target	Description / methods	References
Carbon	Storage and standing biomass can be measured, with methodologies available from Woods Hole, University of East Anglia, etc, Sequestration potential is more complicated.	Hoover, C.M. (ed.) (2008); Field Measurements for Forest Carbon Monitoring A Landscape-Scale Approach. XVIII. Springer, 242 pp; GOFC-GOLD (2009); A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in remaining forests and deforestation, GOFC-GOLD report version COP15-1. Alberta, Canada
Food	Wild crop relative methodology in Peru involving participatory research	Altieri, M.A. and P. Koohafkan (2008); Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities, Third World Network, Penang, Malaysia
Fisheries	Household studies and industrial research into fish banks and spawning aggregations.	Cochrane, K.; C. De Young, D. Soto and T. Bahri (eds.) (2009); Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. FAO, Rome
Mangroves	Many methodologies available	Ellison, J.C. (2012); Climate Change Vulnerability Assessment and Adaptation Planning for Mangrove Systems, WWF, Washington, DC
Pollination	Hundreds of crops require pollination and there is currently a crisis but little coordinated research.	Allen-Wardell, G., P. Bernhardt, R. Bitneret et al. (1998); The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conservation Biology 12 (1): 8-17
Non timber forest products	Including harvest of wildlife, medicinal and food plants.	
Recreation	Including tourist attractions. A major value in many cases.	
Water	At local to international levels; there are at least 14 economic studies for water in just Latin America.	Dudley, N. and S. Stolton (2003); Running Pure, WWF and The World Bank, Gland and Washington DC
Disaster risk	Sri Lanka and Bangladesh have disaster studies and there has been an important study of the role of mangroves in DRR in Vietnam	
Biodiversity conservation	Sustaining natural habitats and biota; providing places where species persist and adapt.	

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

The International Context for Adaptation: REDD+

A bewildering number of international agreements, programs, and NGOs provide opportunities and incentives to design and implement climate responses that benefit protected areas, particularly for developing countries. The focus of many international agreements is on mitigation, hazards, or human welfare – issues that are also relevant to protected areas. The UN-REDD Programme (Reducing Emissions from Deforestation and forest Degradation) is one of the largest and best-supported efforts (UN-REDD 2014). REDD operates in 53 developing countries in Africa, Asia-Pacific, and Latin America, and it supports projects to design and implement UN-REDD National Programmes and complementary projects that address common approaches, analyses, methodologies, tools, data and best practices. REDD+ includes the core activities of REDD to create financial value for carbon stocks aned offer incentives to reduce emissions from forested lands. REDD+ extends the focus to more fully include conservation and sustainable management of forests and enhancement of forest carbon stocks. Additional multilateral REDD+ initiatives include the Forest Carbon Partnership Facility (FCPF) and Forest Investment Program (FIP), hosted by The World Bank. Forty-seven tropical or subtropical countries are signatories to the FCPF, with explicit goals to support REDD+.

IIED (http://www.environmental-mainstreaming.org/links.html) provides internet links to about 25 programs, agencies, groups, and initiatives relevant to mainstreaming environmental concerns.

at the same time maintaining the integrity of watersheds and reducing the risk of floods, landslides or siltation, and sustain native fish and aquatic biodiversity. While there are currently relatively few total valuation studies of protected areas and/or systems that address this level of complexity, Table 10.4 lists common adaptation and mitigation targets and assessment methods.

Reducing vulnerability

At the national level, a government needs a thorough understanding of the likely impacts of climate change on society and the environment to make rational choices about land use planning. Vulnerability assessments and targeted communication campaigns can increase awareness of the expected impacts from climate change. Vulnerability assessments (chapter 3) should be an early priority when developing adaptation strategies, and at broader scales it is particularly important to address both ecological and social issues. A key goal in many countries is to reduce risk from climate-related hazards. In these cases, it may be most effective to consider climate in the context of a hazard or risk assessment. Regardless, results of the assessment will feed into the process of identifying national adaptation priorities. There is an important distinction between identifying hazards or vulnerabilities, and setting priorities for action.

To conduct a credible and effective assessment, some issues will invariably require local, participatory input (e.g., assessments of food security, identifying critical habitats or sites of cultural significance) while others are more suitable for an expert-driven analysis (e.g., carbon storage). Protected area managers can play a role in helping to identify the types of impacts expected under climate change. Assessments will also help to identify how, and where, protected areas can address specific concerns, and how the protected area system might need to be modified (in terms of expansion, design and management) to meet these new social needs. Water security for agriculture and domestic use is likely to become more critical with climate change (IPCC 2014). The role and value of protected areas in providing both quantity and quality of water supplies is established from a large body of evidence (Dudley and Stolton 2003), yet wetlands are currently amongst the least protected biomes and, paradoxically, many new mitigation and adaptation measures may actually reduce water flows through wetlands.

The process of mainstreaming

There is clearly 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 principles and steps that are common to

Table 5. Six key steps in mainstreaming.

	Step	Activity	Result
1.	Start up	Evaluate 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 range of priorities, including benefits and costs, and links between adaptation and other national-level issues.	Identify stakeholders to consult. Present proposals and engage stakeholder to refine desirable and credible outcomes with 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 mechanism.	Evaluation of program efficacy; continuous improvement of process

most situations. Six key steps (modified from IIED 2010) are described in Table 5 (above).

The steps described in Table 5 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 (Figure 10.2). See Dalal-Clayton and Bass (2009, 2010) for much more detailed descriptions of this process, the actions at each step, and the many tools and practices available to accomplish the actions.

Two-way mainstreaming

The focus on this section has been on better integrating climate adaptation into other processes and institutions, but the mainstreaming process is best viewed as a two-way street. Protected areas climate adaptation projects can simultaneously achieve other goals that are of great societal value. As an example, securing indigenous rights to forests is an incredibly effective and economical means to sustain forests and reduce deforestation, preserve biodiversity, mitigate greenhouse gas emissions, and provide for the well-being of indigenous forest

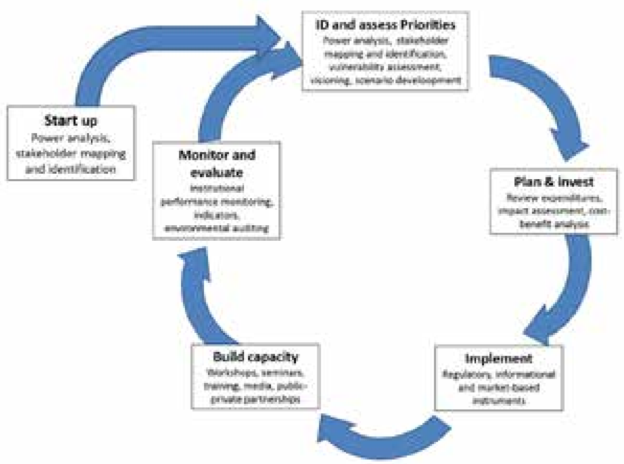


Figure 2. Cycle of key steps towards mainstreaming climate adaptation (modified from IIED 2010; See UNDP 2008 for a related 8-step process).

groups (Stevens et al. 2014). These co-benefits can likewise help achieve adaptation goals of protected areas.

Tools to Assess Mainstreaming Protected Areas in Climate Change Strategies

Tool 1(b): Potential of protected area systems

The results of individual protected area assessments, or of a group assessment of a protected area system, could also be collected to provide an overall regional or national assessment of benefits. Tabulated data might be presented as in Table 6.

Tool 2: Enabling factors to develop potential of protected areas as instruments to address climate change

A number of enabling factors are either essential or greatly helpful in developing protected areas as climate change response strategies (see Table 7).

Tool 3: Principles and best practices for mainstreaming PAs in CC strategies (mitigation and adaptation)

[The guidance will need to include some principles and best practice. A very preliminary list follows; this will need further development before being field tested.]

Principle 1: Management responses that address climate change do not undermine the primary protected area objective of nature conservation.

- All mitigation and adaptation projects involve a careful environmental impact assessment
- Monitoring and adaptive management both form integral parts of any mitigation and adaptation project
- Whenever possible, climate change adaptation and mitigation projects have multiple benefits, for both climate and biodiversity (e.g., mangrove restoration to aid marine life, local fisheries and coastal protection)

Principle 2: Climate change mitigation and adaptation values in and around protected areas are maximised within the limitations imposed by principle 1.

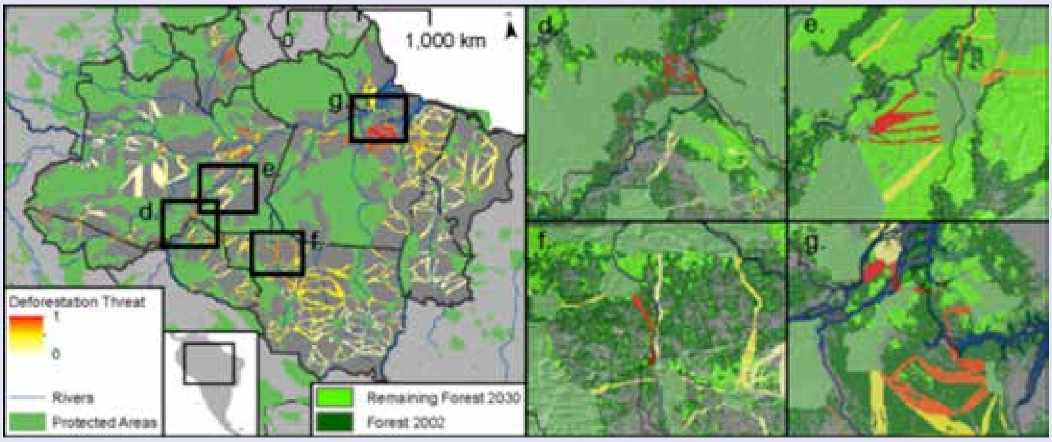
Mainstreaming protected areas into national adaptation planning

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

The United Nations program on Reducing Emissions from Deforestation and Forest Degradation (REDD+) can help reduce the gap between needs and available funding. REDD+ funds land-use-based climate change mitigation activities that simultaneously reduce greenhouse gas emissions and support nature conservation and sustainable management. REDD+ is a component of the UNFCCC (United Nations Framework Convention on Climate Change) promoting coordination of goals and financial resources to protect forest carbon, maintain biodiversity, and minimize loss of ecosystem services
Within the Legal Amazon, Jantz, Goetz, and Laporte (2014) identified potential new conservation areas as high-value biodiversity corridors connecting existing protected areas, fulfilling REDD+ goals to preserve habitats with high vegetation carbon densities. They mapped corridors that traverse the highest biomass areas (i.e., areas with the greatest density of carbon stored in vegetation) between protected areas as a way to identify forests where conservation could help maintain protected area connectivity while preventing CO2 emissions from deforestation (see figure below). By including data on rare species and human activities, they identified corridors that are a high priority for habitat connectivity, species conservation and climate mitigation, while also meeting cost-benefit requirements (i.e. having low economic opportunity costs). Across a range of biomass densities that included forested and non-forested vegetation types, there were large numbers of corridors that stored as much carbon in vegetation as the protected areas they connect. These corridors are strong candidate areas to support traditional biodiversity conservation, contribute to climate adaptation goals for protected areas, to preserve ecosystem services, and contribute to national and international climate change mitigation programs.

The high-priority corridors were identified using data that can be freely downloaded from the internet. Key data sets included high-resolution maps of vegetation biomass density (i.e., carbon stores; Baccini et al. 2012), the IUCN protected areas and Red List databases, and maps of human activities (WCS 2005, Soares-Filho et al. 2006). The extent of human activities provided a connection to economic analyses, and they were used to estimate the economic opportunity cost of corridors (WCS 2005, Nepstad et al. 2009).

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



Left panel: Corridors mapped between protected areas in the Amazon. Yellow (low) to red (high) gradient indicates threat of deforestation. Insets: Corridors between protected areas 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.

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Protected areas as water towers

Protected areas are usually established for biodiversity conservation, but many have a much broader relevance to sustainable development and climate change adaptation. Many mountain protected areas can be justified through provision of ecosystem services, such as clean water, soil conservation, and protection of downstream and vulnerable communities from natural hazards such as floods and unstable hillsides.

A number of Bank biodiversity projects have provided funding to protected areas in forest watersheds, which safeguard the drinking supplies for some of the world's major cities. Panda reserves in the Qinling Mountains, China, protect the drinking water supplies for Xi'an. The Gunung Gede-Pangrango in Indonesia safeguards the drinking water supplies of Jakarta, Bogor, and Sukabumi and generates water with an estimated value of $1.5 billion annually for agriculture and domestic use. Similarly, Kerinci N.P. in Sumatra safeguards water supplies for more than 3.5 million people and 7 million hectares of agricultural land, while two of the Andean protected areas in Ecuador provide drinking water supplies for 80 percent of Quito's population. The La Visite and Pic Macaya national parks in Haiti safeguard water supplies for the cities of Port au Prince and Les Cayes respectively. In Mexico, the Monarch Butterfly Reserve protects an amazing biological phenomenon and the drinking water of Mexico City. The Aberdare Mountains and Mount Kenya national parks in Kenya provide critical water to Nairobi, while the Udzungwas in the eastern arc mountains of Tanzania supply Dar es Salaam. In South Africa, the recognized value of the mountains of the Cape Peninsula and Drakensberg in providing water supplies for Cape Town, Johannesburg, and Durban has led to serious national investments to address invasive species through the Working for Water programs, as well as biodiversity investments through the World Bank.

La Visite National Park, Haiti

Source: World Bank 2008

Table 6. Possible presentation of tabulated data for an overall regional or national assessment of benefits.

Benefit	Number of PAs involved	Total area of all PAs involved	Names of relevant PAs	Estimated value of benefit	Restoration potential	Notes
Carbon storage						
Carbon sequestration						
Wild food						
Fisheries						
Agro-biodiversity						
Water quality						
Quantity of water						
Soil stabilisation						
Coastal protection						
Flood prevention						
Pollination services						
Non-wood products						
Wood products						

Enabling factors	Mainly present	Mainly absent	Notes
Political support			*Is this from the government? Is support cross-party or subject to sudden electoral or other changes?*
Community support			*How widespread is support from communities? Is it dependent on financial or other incentives?*
Functioning protected area system			*What % of the country's total area is protected? Which biomes are best protected?*
Functioning natural ecosystems or potential for restoration within the protected area system			*Are natural flood plains or coastal barriers intact? Are there identifiable restoration projects that could improve ecosystem services?*
National protected areas agency or NGO/ community equivalent			*Does the agency have expertise or capacity on climate change and ecosystem services?*
National climate change mitigation strategy			*Does the strategy have wording that opens up options for integrating protected areas? Is it finished or under development. Can it be influenced?*
Agreed methodology for calculating carbon storage and actual or potential carbon sequestration			
Methodology for identifying and quantifying ecosystem services			
National carbon accounting or equivalent			*Does the counting consider both current and potential carbon storage in ecosystems?*
Capacity to carry out calculations			*Is the capacity already within the protected area institution or would it have to be brought in?*
Legal and policy framework for PES schemes			*Are there PES schemes already in operation?*
Legal and policy framework for REDD+ schemes			*Are there REDD schemes already in operation?*
Availability of funding from donors, government, industry, communities or private sources			*How much funding? Can any of this be directed towards protected areas?*
Agreed but flexible protected area aims			*Do these include climate change mitigation and adaptation? Could they?*
Secure tenure for protected areas under any governance type			

- Climate change response projects include full assessment of carbon storage, carbon sequestration and potential, and ecosystem services
- Restoration potential is included within the assessment
- Scenario-building tools are used within planning and adaptive management of mitigation and adaptation projects
- The full range of IUCN protected area management categories and governance types are used within mitigation and adaptation projects
- Protected areas are considered as options in wider landscape/seascape planning for climate change, e.g., if lowland areas are to be abandoned to seasonal flooding

Principle 3: Climate change mitigation and adaptation strategies within protected areas are sustainable in the long term.

- Projections of future climate change impacts are included within the planning of adaptation and mitigation projects
- New partners (e.g., industry, local communities, other government departments) are brought into the projects to maximise expertise and potential
- Payment for Ecosystem Services options are investigated and developed where practical
- Impacts on land and water outside the protected area are also considered

Principle 4: Affected stakeholders, including beneficiaries and those bearing the costs of protection, are involved in planning and decisions relating to climate change mitigation and adaptation in protected areas.

- Local needs for ecosystem services are investigated during planning stage and incorporated into projects wherever possible
- There is full transparency about all potential and current mitigation and adaptation projects
- Costs and benefits are distributed equitably
- Projects are whenever possible developed jointly
- Knowledge gained from projects run within protected areas is used in extension projects to help communities living nearby

The full range of IUCN protected area management categories and governance types should be used as part of mitigation and adaptation projects. Researchers in Kogelberg Biosphere Reserve, South Africa.

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