CHAPTER 17

CLIMATE CHANGE AND PROTECTED AREAS

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CONTENTS

IUCN WCPA World Commission on Protected Areas
Convention on Biological Diversity

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TITLE PAGE PHOTO

The Athabasca Glacier with the Columbia Icefield behind, Banff National Park, Canada: the 1890 peg identifies a historical location of the snout of the glacier and the extent of the terrain across which it has receded over the past 120-plus years. In general, glaciers are retreating almost worldwide as average global temperatures rise. Source: Graeme L. Worboys

Introduction

In the early part of the 21st century, evidence for the overall warming of the Earth's climate system due to human-generated greenhouse gas pollution of the atmosphere is unequivocal. The leading international body for the scientific assessment of climate change, the Intergovernmental Panel on Climate Change (IPCC), has reported that 'changes in climate have caused impacts on natural and human systems on all continents and across the oceans' (IPCC 2014a:6). The average of global surface temperatures for land and ocean increased by 0.85°C between 1880 and 2012, and the global mean surface temperature increased by 0.12°C per decade between 1951 and 2012 (IPCC 2013a). Sea-levels are also rising. 'The rate of sea rise since the mid-19th century has been larger than the mean rate during the previous two millennia' (IPCC 2013a:11).

The findings of the IPCC present a grim picture. Regrettably, greenhouse gas emissions continued to grow in 2014. After considering a broad range of future development and greenhouse gas emission scenarios, the IPCC has reported that global surface temperatures are likely to be more than 1.5°C higher in 2100 than the average surface temperatures in the period 1850–1900. Some development and emission scenarios are, however, worse. Global mean surface temperatures in 2100 are likely to increase by more than 2°C compared with 1850–1900, and could exceed 4°C surface warming under the scenario described as 'business as usual with no mitigation action' (IPCC 2013a).

More frequent high temperature extremes are virtually certain over most land areas on both the daily and the seasonal scales. Ocean temperatures will increase at all depths and will affect ocean circulation. The volume of glaciers will continue to decrease; sea-levels will continue to rise. The IPCC forecasts that changes to precipitation will not be uniform. 'The contrast between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions' (IPCC 2013a:20). Ecosystems are already being affected by climate change: 'Many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change' (IPCC 2014a:4).

It is clear that these effects will be profound for protected areas. Climate change represents one of the greatest threats to species and ecosystems that people of Earth face, and this includes protected area organisations and communities responsible for protected areas. In this chapter, we focus on climate change in relation to the governance and management of protected areas. To set the scene, we introduce key climate change research findings for current trends and forecast changes and describe the implications. We introduce a 'nature-based solution' approach and present possible mitigation and adaptation responses for climate change, with a focus on climate-ready responses by protected area managers. The chapter then focuses on being 'climate-ready', and we provide explanatory information about this important concept as well as a range of governance and management considerations that consequently may be important for managers to assess.

Climate change research findings

In 2013, the Fifth Assessment Report of Working Group I of the IPCC synthesised recent research on the physical science basis for climate change (IPCC 2013a). This included both the situation in 2013 and the projections of possible future climate conditions. We summarise some of the key findings here.

Climate change findings

The climate system

'Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea-level has risen, and the concentrations of greenhouse gases have increased' (IPCC 2013a:4).

Human influence

'Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system' (IPCC 2013a:15).

The atmosphere

'Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 … In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years (medium confidence)' (IPCC 2013a:5).

Chaotically leaning pine trees, Golden Mountains of Altai World Heritage Property, Altai Republic, Russia: warmer temperatures have melted the permafrost that previously provided support for these normally upright trees

Source: Graeme L. Worboys

The oceans

'Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (high confidence). It is virtually certain that the upper ocean (0–700 m) warmed from 1971 to 2010 … and it likely warmed between the 1870s and 1971' (IPCC 2013a:6).

Snow and ice-covered landscapes

'Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent' (IPCC 2013a:9).

Average sea-level

'The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (high confidence). Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] metres' (IPCC 2013a:11).

Carbon and other biogeochemical cycles

> The atmospheric concentrations of carbon dioxide (CO2), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. CO2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic CO2, causing ocean acidification. (IPCC 2013a:11)

In 2014, the effects of climate change and warming may be readily seen in protected areas and elsewhere around the world including the melting of glaciers, ice caps and permafrost; the enhanced energy and behaviour of storms; catastrophic fire conditions (Chapter 26); record-breaking summer heatwaves; the changed behaviour of wildlife; rising sea-levels; and changes in the increased acidity of oceans. Given such adverse trends, the IPCC was very clear about its advice to limit the effects of climate change by stating: 'Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions' (IPCC 2013a:19).

Climate projections: Temperature

While climate change impacts are pervasive, the nature and scale of impacts may differ greatly between regions, or even within regions. It is important for protected area managers to gain an appreciation of potential future climate conditions that may affect their areas. Specifically, for future projected temperature changes, the IPCC based its projections on four 'representative concentration pathways' (RCPs) and stated:

> Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 for all RCP scenarios except RCP2.6. It is likely to exceed 2°C for RCP6.0 and RCP8.5, and more likely than not to exceed 2°C for RCP4.5. Warming will continue beyond 2100 under all RCP scenarios except RCP2.6. Warming will continue to exhibit inter annual-to-decadal variability and will not be regionally uniform. (IPCC 2013a:20)

Box 17.1 Glossary of some acronyms used by the Intergovernmental Panel on Climate Change

AR5

The IPCC Fifth Assessment Report.

CMIP5

Couple Model Inter-comparison Project Phase 5 of the World Climate Research Programme. This is a multi-model context for better assessing climate models, including poorly understood feedback between the carbon cycle and clouds, examining climate predictability and examining the different models.

RCP

Representative concentration pathways. These are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth assessment report. They describe four possible climate futures and are described as RCP2.6, RCP4.6, RCP6 and RCP8.5.

RCP2.6

This RCP assumes small constant net negative emissions after 2100 and implies net negative carbon dioxide emissions after about 2070 and throughout the extension; carbon dioxide concentrations slowly reduce towards 360 parts per million volume (ppmv) by 2300.

RCP8.5

This RCP assumes stabilisation with high emissions between 2100 and 2150, then a linear decrease until 2250. RCP8.5 stabilises concentrations only by 2250, with carbon dioxide concentrations of approximately 2000 ppmv—nearly seven times the pre-industrial level.

SPM

Summary for policymakers.

Sources: IPCC (2012, 2013a, 2013b)

Box 17.2 Projections for climate change phenomena other than temperature

Some broad projected changes have been illustrated by the two climate scenarios (Figure 17.1).

The water cycle

'Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions' (IPCC 2013a:20).

Oceans

Reflecting an overall warming trend, the IPCC stated for oceans that '[t]he global ocean will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation' (IPCC 2013a:24).

Cryosphere (places where the Earth's water is in a solid form as snow or ice)

'It is very likely that Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises. Global glacier volume will further decrease' (IPCC 2013a:24).

Sea-level

'Global mean sea level will continue to rise during the 21st century … Under all RCP scenarios, the rate of sea level rise will very likely exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets' (IPCC 2013a:25).

Carbon and other biogeochemical processes

'Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO2 in the atmosphere (high confidence). Further uptake of carbon by the ocean will increase ocean acidification' (IPCC 2013a:26).

Climate stabilisation

'Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond … Most aspects of climate change will persist for many centuries even if emissions of CO2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO2' (IPCC 2013a:27).

The language of the IPCC is acronym rich. To assist the reader, we have prepared a glossary of some of their abbreviations (Box 17.1), and this is especially relevant for interpreting the supporting information for two of the IPCC's figures presented in this chapter (Figures 17.1 and 17.2).

Two temperature projections prepared by the IPCC are illustrated in Figure 17.1. The RCP of 2.6 identifies reductions in carbon dioxide concentrations towards 2100 (Box 17.1). Both scenarios show gradual warming, with the greatest warming for the curve approximating a future scenario titled 'business as usual with no mitigation action' (RCP8.5) (Figure 17.1). Greater levels of warming are projected for the northern hemisphere than for the southern hemisphere, with landmasses warming more quickly than the oceans.

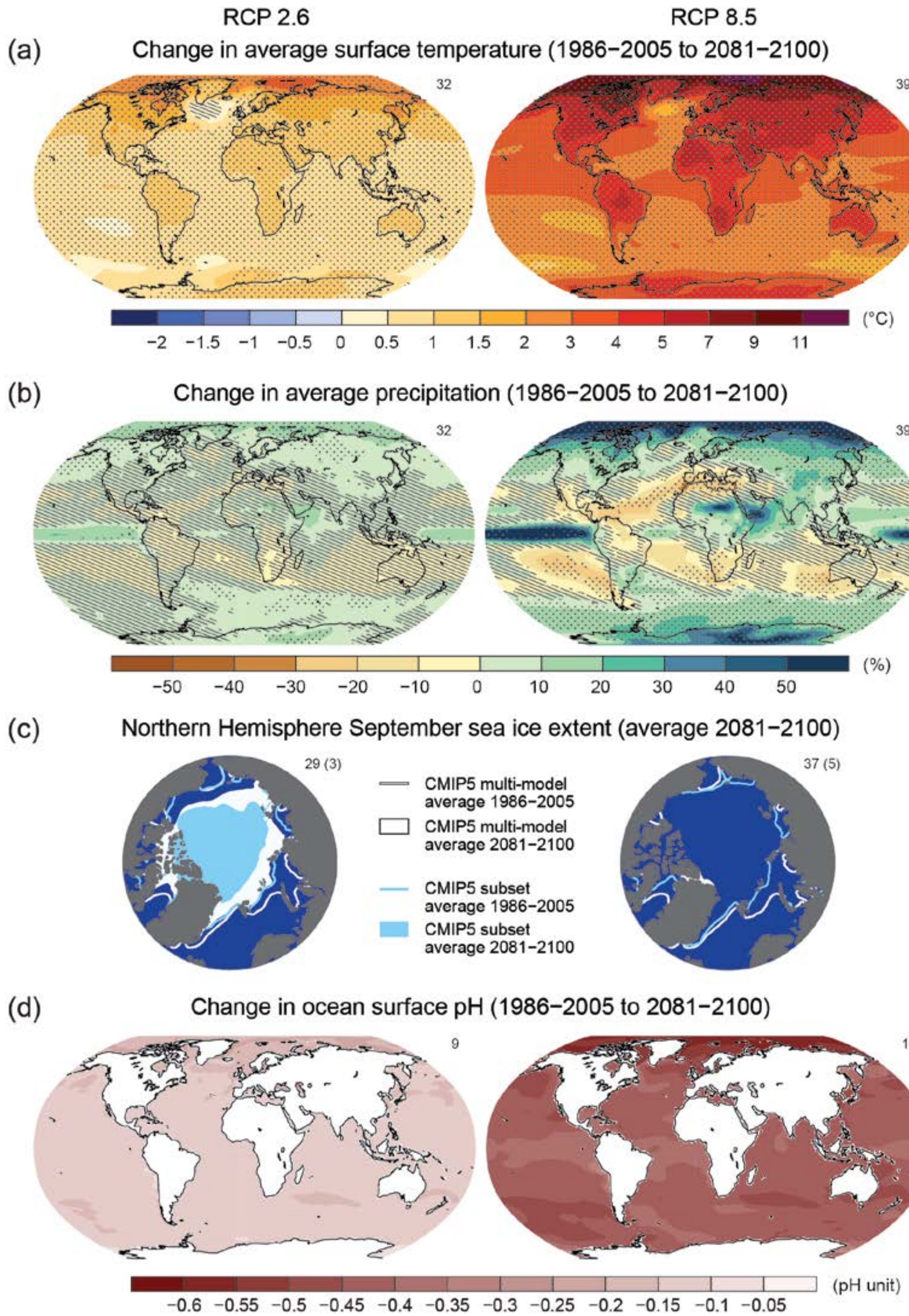


Figure 17.1 IPCC climate change projections for two carbon dioxide concentration levels for temperature, precipitation, sea-ice extent and ocean surface pH

Notes: Maps of CMIP5 multi-model mean results for the scenarios RCP2.6 and RCP8.5 in 2081–2100 of: a) annual mean surface temperature change, b) average percentage change in annual mean precipitation, c) northern hemisphere September sea-ice extent, and d) change in ocean surface pH. Changes in panels (a), (b) and (d) are shown relative to 1986–2005. The number of CMIP5 models used to calculate the multi-model mean is indicated in the upper right-hand corner of each panel. For panels (a) and (b), hatching indicates regions where the multi-model mean is small compared with natural internal variability—that is, less than one standard deviation of natural internal variability in 20-year means. Stippling indicates regions where the multi-model mean is large compared with natural internal variability (that is, greater than two standard deviations of natural internal variability in 20-year means) and where at least 90 per cent of models agree on the sign of change. In panel (c), the lines are the modelled means for 1986–2005; the filled areas are for the end of the century. The CMIP5 multi-model mean is given in white; the projected mean sea-ice extent of a subset of models (number of models given in brackets) that most closely reproduce the climatological mean state and 1979–2012 trend of the Arctic sea-ice extent is given in light blue.

Source: IPCC (2013a:10), reproduced with the permission of the IPCC; see IPCC (2013a:10) for the complete figure caption.

Cooling off in a central Moscow park, 21 July 2010, during the record-breaking great Russian heatwave of 2010 that included 28 consecutive days of temperatures above 35°C from 14 July. The extreme heat was unprecedented and led to forest and peat fires, heat-related deaths and drownings.

Source: Graeme L. Worboys

Other climate projections

The IPCC Fifth Assessment Report also provided projections from 2081 to 2100 for phenomena other than temperature and these are summarised in Box 17.2.

Extreme events

The changing occurrence and nature of extreme events form the most challenging climate change trend. This is because the relationship between the climate mean and extreme events is not linear (IPCC 2013b), and these nonlinear relationships are shown schematically (Figure 17.2). As the mean surface temperature increases, the proportion of days over a defined temperature threshold will increase exponentially and there will be a marked increase in the number of extreme hot periods (days or several days). These extreme hot periods, for example, are what will drive some of the most important changes in biological systems and will impact on protected areas and their management. The occurrence of extreme climate events could change in frequency, intensity, spatial extent, duration and timing. Extended years of droughts, hotter or extended heatwaves, larger floods or more extreme storm events are some of the potential implications. The graphs in Figure 17.2 illustrate how small average changes in temperature between present and future climates could affect the potential for extreme events.

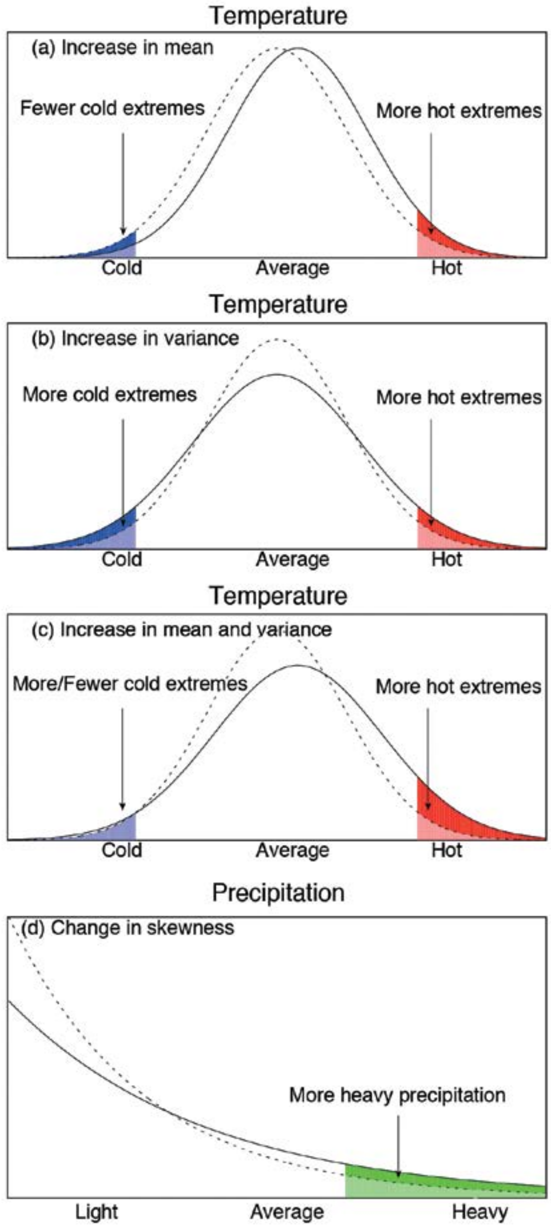


Figure 17.2 Climate extremes: probability schematics

Notes: Schematic representations of the probability density function of daily temperature, which tends to be approximately Gaussian, and daily precipitation, which has a skewed distribution. Dashed lines represent a previous distribution and solid lines a changed distribution. The probability of occurrence, or frequency, of extremes is denoted by the shaded areas. In the case of temperature, changes in the frequencies of extremes are affected by changes: a) in the mean, b) in the variance or shape, and c) in both the mean and the variance. d) In a skewed distribution such as that of precipitation, a change in the mean of the distribution generally affects its variability or spread, and thus an increase in mean precipitation would also imply an increase in heavy precipitation extremes, and vice versa. In addition, the shape of the right-hand tail could also change, affecting extremes. Furthermore, climate change may alter the frequency of precipitation and the duration of dry spells between precipitation events. (Parts a–c modified from Folland et al. 2001, and d modified from Peterson et al. 2008, as in Zhang and Zwiers 2012.)

Source: IPCC (2013b:134), reproduced with the permission of the IPCC; see IPCC (2013b:134) for the complete figure caption.

Box 17.3 Definitions: climate change mitigation and adaptation

There are two broad responses to climate change. Mitigation is about avoiding or reducing greenhouse gas emissions as well as increasing the sequestration of greenhouse gases, and adaptation is about coping and responding to climate change. The IPCC has defined both of these terms.

Mitigation definition

'Mitigation is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system: it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks' (IPCC 2007:878). This can been defined more simply as a human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2014b).

Protected areas can help mitigate climate change by storing carbon (preventing the loss of carbon that is already in vegetation and soils) and capturing carbon by sequestering carbon dioxide from the atmosphere in natural ecosystems.

Adaptation definition

Adaptation is:

> [t]he process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects. Adaptation may be incremental (where the central aim is to maintain the essence and integrity of a system or process as a given scale) or transformational (adaptation that changes the fundamental attributes of a system in response to climate and its effects. (IPCC 2014c:1)

Protected areas can adapt to climate change by protecting or maintaining ecosystem integrity, buffering local climate and reducing the risks of and impacts from extreme events. Protected areas can also provide essential ecosystem services that help people cope with change.

Sources: IPCC (2007); Dudley et al. (2010)

Nature-based solutions

All nations of Earth need to reduce anthropogenic greenhouse gas emissions and to employ every advantage possible to reduce atmospheric carbon dioxide and other greenhouse gas concentrations. The natural terrestrial and marine environments of Earth play a substantial role in mitigating the effects of climate change and in assisting adaptation responses (Box 17.3). Protected areas are a key part of this natural world and exist over a substantial part of the Earth's surface, with 15.4 per cent of the Earth's terrestrial surface area and 3.4 per cent of its oceans protected in 2014 (IUCN and UNEP-WCMC 2014). A protected area's vegetation can help to sequester carbon from the atmosphere through photosynthesis and the carbon is stored in the ecosystem as living and dead biomass and soil. These important roles have been recognised as a 'nature-based solution' to climate change.

The benefits of protected areas as a nature-based solution were highlighted in 2010 by the publication of *Natural Solutions*, prepared by a consortium of organisations including the International Union for Conservation of Nature (IUCN), The Nature Conservancy (TNC), the UN Development Programme (UNDP), the Wildlife Conservation Society, the World Bank and the World Wide Fund for Nature (WWF) (Dudley et al. 2010). The *Natural Solutions* text presented cost-effective response options that could contribute to the mitigation of and adaptation to climate change (Box 17.3).

Mitigation

Almost all natural and semi-natural ecosystems, including areas designated as protected areas, capture and store carbon by sequestering carbon dioxide from the atmosphere through photosynthesis (Dudley et al. 2010). The UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) has estimated that 312 gigatonnes of carbon are stored in the world's protected area network and this is 15 per cent of the world's terrestrial carbon stock (Dudley et al. 2010). Such protected status reduces the likelihood of loss of carbon that is already present in vegetation and soils, and some protected areas may be actively managed to maintain or increase their sequestration potential. Actively managed protected areas promote mitigation by:

- avoiding conversion to other land uses and avoid habitat destruction and the loss of carbon
- providing opportunities for the ecological restoration and protection of degraded, carbon-rich sites such as disturbed peatlands and the regrowth of disturbed forests
- providing opportunities for helping to sequester carbon including for inland water areas, estuaries and peatlands (Dudley et al. 2010).

Adaptation

Protected areas reduce the impact of climate change on local communities and provide ecosystem support services. With protection, this ecosystem-based adaptation helps to maintain ecosystem integrity, buffer local climate, and reduce risks of and impacts from extreme events such as storms, floods, droughts and sea-level rise (after Dudley et al. 2010). Protected areas directly help to:

- deal with floodwaters by providing space for water dispersal and through natural absorbing impacts of vegetation
- minimise landslides with natural vegetation stabilising soil and snow to prevent slippage and to absorb impacts if a slip does occur
- minimise the impacts of coastal storm surges through the presence of mangroves, coral reefs, barrier islands, dunes and marshes
- reduce grazing pressure and consequently improve catchment protection, soil water retention and minimising the effects of drought and desertification
- actively manage for fire through fuel-reduction programs and initial response capability (Dudley et al. 2010).

Maintaining essential ecosystem services in protected areas helps people cope with changes caused by climate change to water supplies, fisheries, incidence of disease and agricultural productivity (Dudley et al. 2010). Active protected area management helps increase the resilience of essential natural resources and services and helps reduce the vulnerability of livelihoods including:

- for water, helping to retain water quality, flow regimes and yield through well-managed and non-eroding catchments
- for marine and freshwater fish resources, helping to conserve and rebuild fish stocks
- for food resources, helping to conserve crop wild relatives to facilitate crop breeding and pollination services and helping to provide sustainable food for communities
- for health, helping to slow the expansion of vector-borne diseases that thrive in degraded ecosystems and for retaining access to traditional medicines (Dudley et al. 2010).

Protected areas also help to improve the resilience of ecosystems to climate change.

Investments that respond to climate change

When considered in their totality, protected areas have been established over a substantial area of Earth, and consequently, how they are managed for climate change is important. Nature-based solution approaches form an integral part of an international response to dealing with climate change threats. With this larger context in mind, this chapter further develops what is possible for responding to (mitigation) and working with (adaptation) the effects of climate change and for achieving such actions. Scientists advise us that the world of the future will be different—very different—and protected areas will change. We assess the implications of climate change for protected area managers in the following sections.

Healthy reef environment, Great Barrier Reef Marine Park, Queensland, Australia: coral reef systems around the world (including the Great Barrier Reef) are being impacted by coral bleaching through higher temperatures and rising acidity levels

Source: © Great Barrier Reef Marine Park Authority

Implications for biodiversity

Changes to ambient temperatures, concentrations of carbon dioxide, availability of water (for terrestrial organisms) and the nature of extreme events are serious impacts of climate change on natural systems. These changes will affect protected areas both directly and indirectly, and the responses to changes in climate parameters or events will vary between species and ecosystems. Some impacts on biodiversity are described in Table 17.1.

Table 17.1 Examples of impacts on biodiversity from changes in climate and atmospheric parameters

Parameter	Impacts and responses
Temperature and solar radiation	'Increasing temperatures will interact with water stress for both plants and animals, and will affect the timing of important life cycle events such as reproduction and diapause (a quiescent period during a life cycle). Advances in spring events and delays in autumn events are probable for many species' (Steffen et al. 2009:73) Temperature during organism development affects the sex ratios for many reptile species, while temperature extremes will influence fundamental geographic ranges of many plant and animal species, with some species seeking higher and cooler elevation refugia and/or sheltered and cooler aspects. Increasing ambient temperatures will contribute to increasing risk of extreme weather events such as storms and lightning activity, leading to greater fire and flood impacts on species and communities. In high mountain areas, reduced cloud cover will contribute to extended exposure of the biota, particularly plants, to ultraviolet light, with subsequent impacts on flowering, seed setting and germination percentage. This will be particularly noticeable for species currently protected by semi-permanent snow cover
Carbon dioxide concentrations	Increased carbon dioxide levels in the atmosphere and/or water will result in higher photosynthetic rates until the carbon dioxide concentrations or another factor (such as light or nutrients) become limiting. Higher carbon dioxide levels also increase water-use efficiency by reducing stomatal conductance. Carbon dioxide-driven changes in productivity are usually accompanied by changes in plant chemical composition and plant structure. The increased plant growth, for example, will contribute increased fire fuel accumulations in many grassland and forest situations. Oceans and freshwater bodies will become more acidic as they absorb more carbon dioxide. This will increase the solubility of calcium carbonate, which is a principal component of skeletal material of aquatic organisms
Water yields and supplies	'Water is critical for all terrestrial organisms, and water—together with ambient temperatures—ultimately sets the fundamental distributional limit for all species' (Steffen et al. 2009:73). Water stress from extended droughts and floods, as well as seasonal rainfall regimes, may increase; however, increasing atmospheric carbon dioxide may also mitigate water stress for some plants. Reduced snow occurrence and extent may have considerable impact on water yields from catchments and runoff regimes into major river systems. Reduced snow cover duration may impact on many plant and animal species that otherwise survive extreme cold protected by an insulating layer of snow cover
Extreme events (storms, floods, wildfire and droughts)	'Extreme weather events such as floods, droughts, storms and fire can affect population dynamics, species boundaries, morphology, reproduction, behaviour, community structure, composition, and ecosystem processes. Changes in the frequency, intensity and seasonality ["seasonal drift"] of extreme events are likely to have larger impacts on many species, communities and ecosystems than individual, directional shifts in temperature and changes in rainfall patterns' (Steffen et al. 2009:73). The extreme events may provide an ecological advantage to many invasive species that (consequently) will threaten the survival of some native species. In marine environments storm surges and sea-level rise will threaten the continued existence of natural communities/ecosystems that currently are natural barriers to coastal storm damage (coral reefs, mangroves and seagrass beds, fore-dune communities and coastal wetlands). The loss of communities such as mangroves and wetlands will result in carbon dioxide being released, further enhancing atmospheric greenhouse gas levels

Source: Modified from Steffen et al. (2009)

Some major taxonomic groups of plants and animals may be especially vulnerable or more adaptable than others to the impacts of climate change. Using the Australian situation as an example, some of these vulnerabilities are described in Table 17.2. The effects identified would be indicative of the effects to taxonomic groups elsewhere.

Severe mainland-bound ocean storm, southern New South Wales, Australia

Source: Graeme L. Worboys

Table 17.2 Factors that will increase the vulnerability of Australian taxonomic groups to climate change

Taxonomic group	Potential vulnerability
Mammals	Generally, mammals are mobile and able to disperse Some 'narrow-ranged endemics particularly in montane or alpine regions that are susceptible to rapid climate change in situ' will be vulnerable (Steffen et al. 2009:93) There may be 'changes in competition between grazing macropods (plant eating Australian marsupial mammals that include kangaroos and wallabies) in tropical savannahs mediated by changes in fire regimes and water availability; herbivores affected by decreasing nutritional quality of foliage as a result of CO2 fertilisation' (Steffen et al. 2009:93)
Birds	Generally, birds are highly mobile and able to disperse There will be phenological changes including to migration and egg laying Increased competition for breeding grounds Breeding sites of waterbirds and coastal species will be susceptible to reduced freshwater flows into wetlands, rising sea-levels and storm surges, and saltwater intrusion Top predator species will be vulnerable to changes in food supply and earlier or later migrations in response to seasonal shift movements
Reptiles	For reptiles, there is a range of mobility but generally there is poor dispersal The warming temperatures may alter sex ratios; some species may be able to modify their use of microhabitats Shore-nesting species will be susceptible to rising sea-levels and storm surges
Amphibians	Amphibians have a high habitat specificity and a range of mobility and dispersal characteristics Frogs may be the most at-risk terrestrial taxa. The effect of the pathogenic Chytrid fungus (*Batrachochytrium dendrobatidis*) may change with changes in host susceptibility and pathogen activity Drying and burning of bogs and peaty soils will affect breeding sites for some species
Fish	There is limited capacity for freshwater fish species to migrate Freshwater species will be vulnerable to reduced water flows and water quality (including acidity), increased water temperatures and reduced shading from riparian vegetation; all species will be susceptible to flow-on effects of warming on the phytoplankton base of food webs Marine species will generally be mobile but species confined to rocky or coral reef habits may be less mobile and so vulnerable to loss of habitat Species are vulnerable to changes in ocean currents that otherwise provide nutrients and disperse young There are sea temperature thresholds for reproduction and most species are susceptible to the effects of increasing acidity on the development of bony structures

Taxonomic group	Potential vulnerability
Terrestrial invertebrates	Invertebrates are 'expected to be more responsive than vertebrates due to short generation times, high reproduction rates and sensitivity to climatic variables … Flying insects such as butterflies may be able to adapt by shifting ranges if they are not limited by host plant distributions; non-flying species with narrow ranges are susceptible to rapid change *in situ*' (Steffen et al. 2009:93) Invertebrates of restricted wet forests and montane environments may be threatened as these habitats disappear Genetic changes already observed in some widespread species such as *Drosophila* spp. and invertebrate herbivores also affected by reduced foliar quality under elevated carbon dioxide concentrations (Steffen et al. 2009:93) Aquatic invertebrates will be affected by altered flows, water quality and temperatures. It is likely that surface waters will become more acidic and this will erode exoskeletons All marine species with calcium carbonate in shells, plates, spicules and tubes will be affected by increased acidity of the ocean. The most notable group affected are the corals but the impacts of increased acidity will be pervasive; corals will also bleach with rising temperatures
Plants	Longer-lived plants such as trees may be highly vulnerable if climate change affects recruitment and establishment opportunities Narrow-ranged endemic plants will be vulnerable if their required conditions are rare; elevated carbon dioxide will increase photosynthetic rates where other factors, such as water and nutrients, are not limiting Productivity may be increased in some regions by a combination of increased carbon dioxide and longer growing seasons; higher carbon dioxide levels will increase water-use efficiency but total water use may not decrease due to decreased total leaf area and increased evaporation from the soil Competition between C3 and C4 plants (C3 and C4 refer to evolutionary traits for the way plants capture carbon dioxide, with C3 plants being more primitive) may be affected by elevated carbon dioxide, but soil moisture may be a stronger influence than photosynthetic pathways Changes to fire regimes will have significant impacts on vegetation Changes in plant phenology and insect life cycles will affect pollination and some forms of dispersal; hybridisation and speciation may increase as plants suffer increasing pressure and stress Aquatic and marine plants may be affected by increasing acidity; algae with calcium carbonate crusts, rinds, blades and shells will be particularly vulnerable

Source: Modified from Steffen et al. (2009)

Shifts in plant and animal distributions

The present distributions of most living organisms (with the notable exception of *Homo sapiens*) are defined by climate parameters—conditions that define their niche (along with other features). As these parameters change locally, species population dynamics play out, with the combination of dispersal and colonisation of new habitats and local extinctions giving the impression that the species and communities are moving across the landscape, although the apparent 'movement' of species is a result of complex dynamic processes. As a general rule, species will tend to move along the thermal gradients that run from the Equator towards the poles, and from low elevations towards higher elevations. For example, a meta-analysis of data for more than 1700 species (Parmesan and Yohe 2003) found an average shift of 6.1 kilometres per decade polewards but an increase of only metres per decade in elevation, with key spring events advancing by an average of 2.3 days per decade.

This general rule is, however, complicated by dispersal capacity (species and taxonomic groups differ in their capacity to disperse in response to stimuli), obligate requirements (some species have narrow requirements for soil type, pollinators, food sources or seasonal climate conditions) and habitat types (habitats may not be continuous and may not support dispersal even for the most mobile species—thus the requirement for greater connectivity; see Chapter 27). Protected area managers can use bioclimatic models to gain insights into how species and assemblages may be redistributed, but these analyses are limited by uncertainty about future climate conditions (Yates et al. 2010). In addition, species are often affected most significantly by combinations of climate factors, and information about critical climate-induced factors such as drought, heatwaves and fire is

The mountain pygmy possum (*Burramys parvus*) of the Australian Alps: this endangered marsupial is found in snow country in the highest parts of Australia's Alps. It is a true hibernator and is highly likely to be impacted by rising temperatures and a future snow-free environment of the Alps.

Source: NSW Office of Environment and Heritage, reproduced with permission

not included in most current bioclimatic modelling. Even if very good climate projections were available, there is limited knowledge about the interaction between key climate-related factors and important species and interspecies relationships.

Further complicating the prediction of climate change impacts on ecosystems is that each species making up an identified assemblage (an ecological community) or contributing to the character and function of an ecosystem will respond differently to changes in climate conditions. Provided there is a source of new species with equivalent functionality to those that are forced out or move away from the assemblage or ecosystem, that ecosystem can maintain its overall function. This process may result in new assemblages and ecosystems, with combinations of species not previously existing. The potential degree of change in assemblages of vascular plant species that might be expected for Australia, for example, by 2030 under severe climate change has been assessed, with green representing least difference in composition and red the most difference (Figure 17.3). A key point here is that change is forecast and needs to be expected.

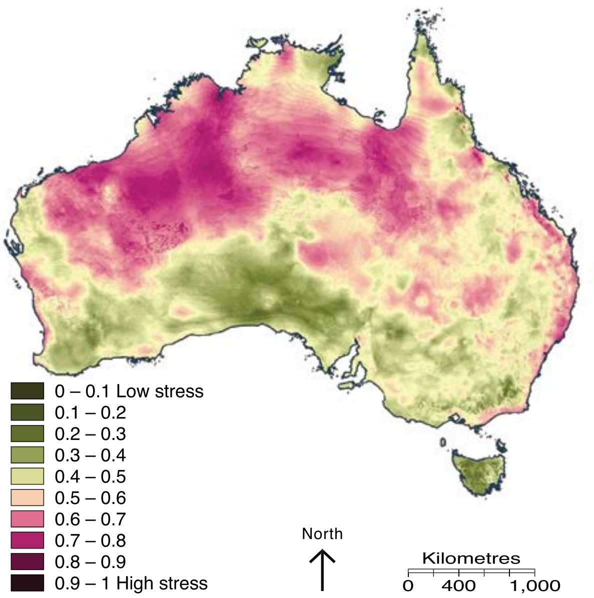


Figure 17.3 Modelling of impacts of climate change on vascular plants in Australia where red identifies greatest change and green, least change

Note: Predicted dissimilarity in composition of 1-kilometre grid cells from 2010 to 2030 under the IPCC 'business as usual' (A1FI) climate scenario.

Source: Adapted from Ferrier et al. (2010)

Biome shifts

Where modelling at the biome level indicates the likelihood of a change from one biome to another, a major plant physiological threshold can usually be identified. The loss of tundra due to increasing surface temperatures

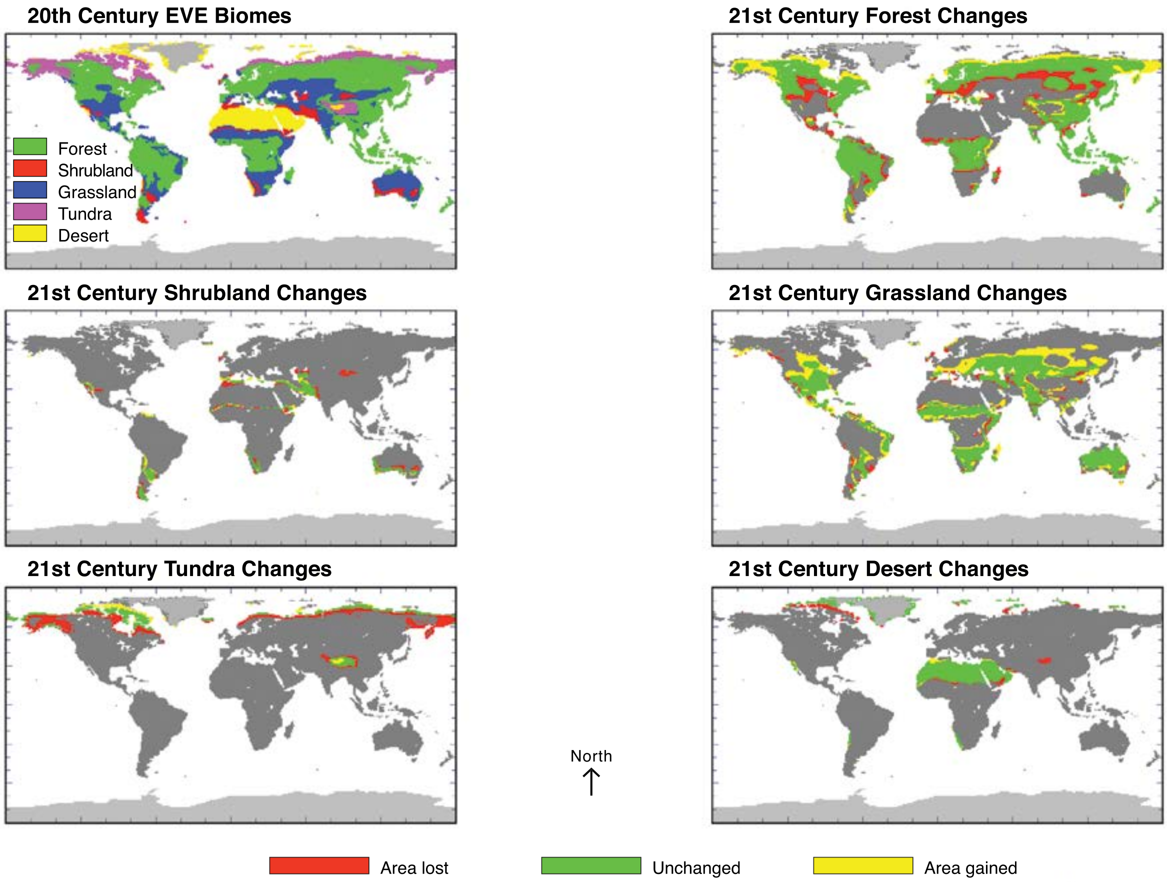


Figure 17.4 Forecast changes in the distributions of five major biomes to the end of the 21st century

Note: Derived from the Equilibrium Vegetation Ecology (EVE) model's 110 life-form fractional cover maps, as determined using EVE variables for the IPCC 'near-to business as usual' scenario, on a 1° × 1° grid.

Source: Adapted from Bergengren et al. (2011)

and the associated lengthening of the growing season, for example, results in invasion by slower-growing boreal forest tree species. For this reason, identifying physiological thresholds through laboratory research or monitoring is very important. While research from other biomes may provide guidance, it is challenging to apply research findings from relatively less complex ecosystems to relatively more complex ecosystems (McKellar et al. 2010). Anticipated changes, for example, for five major biomes—forests, shrubland, grassland, tundra and desert—are illustrated in Figure 17.4.

Implications for values people and communities obtain from protected areas

> Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability … Impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. For countries at all levels of development, these impacts are consistent with a significant lack of preparedness for current climate variability in some sectors. (IPCC 2014a:6)

Climate change will affect the values people and communities obtain from protected areas. The overall value of the natural world to humans consists of economic values and broader cultural and other non-economic values and can be captured by a typology presented in Chapter 6, and a suite of cultural values that has been recognised in Chapter 4. Indicative impacts of climate change on these values are described in Table 17.3.

Table 17.3 Examples of impacts from changes in climate on values held by humans for natural and cultural phenomena

Protected area natural values (Chapter 6)	Description	Example climate change impacts
Direct use values	These values refer to the direct use we make of natural values and ecosystem services, which may include harvesting of some resources and fishing	Ecosystem function may remain unchanged through active management, but traditionally used species may no longer be available in the wild with climate change
Indirect use values	These values tend to be in a more diffuse form such as clean water from catchments, forests that help prevent avalanches and vegetation that prevents soil erosion on steep slopes	Extreme weather events, droughts and catastrophic fire events may impact forests and catchments and affect the indirect values; restoration management may be implemented
Non-use values (future use values)	These values may be option values, which relate to maintaining an area in case it is needed for its natural resources in the future; bequest values of leaving things in place for future generations; and existence values that we consider important even though we do not benefit ourselves	The specific values of an area may change with time though the overall natural value will be retained given there is active management to minimise non-natural threats
Protected area cultural values (Chapter 4)		
Aesthetic value	These values include sensory perceptions such as form, scale, colour, texture and material of the fabric or the smells and sounds associated with the place and its use	The cultural landscape setting may change and this may impact on the aesthetics
Historic value	The place has influenced, or has been influenced by, a historic figure, event, phase or activity; site of an important event	The context and setting of a historic event or place may change
Scientific/research value	Importance of the data; rarity, representativeness, degree to which the place may contribute further substantial information	A scientific reference site may become more important for its baseline role in measuring change
Social value	Qualities for which a place has become a focus of spiritual, political, national or other cultural sentiment to a majority or minority group	Climate change may change the things that you used to do such as a coastal beach transformed to a wetland. The social values of a site may change
Spiritual value	Used to capture the attachment between humans and the natural environment/place, being more specific than social or aesthetic values	The spiritual values of a place may be diminished, such as the permanent drying up of a waterhole

These changes to human natural and cultural values may mean that in the future, in some circumstances, there are tense environmental challenges accompanied by social and political pressures for responses. To illustrate this, we have described some climate change impacts that will affect people and communities in the future and the types of responses with which protected area managers could be associated (Table 17.4). There is a very clear underlying message here. Working with local people and as part of a local community will be needed more than ever before, for this will help communities fully value and support the special qualities and intergenerational benefits of protected areas.

Most protected area managers will be fully aware of the need to work with communities (Chapter 12). In addition, the natural resource management expertise of protected area managers may be especially valuable to local communities, particularly in rural and remote areas: 'protected area agencies have the potential to be major facilitators of natural resource management in the wider landscape, thereby contributing to sectoral and community-based adaptation' (Dudley et al. 2010:93).

Table 17.4 Examples of climate change impacts and working with communities

Climate impact	Potential impact on region and communities	Working with communities in managing protected areas
Marine inundation	Coastal communities, industries and infrastructure are gradually displaced as sea-levels rise and the effects of storm surges impact further inland	There is a need for ongoing cooperative work with communities to retain support for the conservation of local remnant (non-inundated) protected areas. Protected area managers would work with communities to help with the functional re-establishment of settlements, industries and infrastructure
Extreme and prolonged drought	Existing food and water supply sources and systems are disrupted and short-term alternative arrangements may be needed	Managers will need to work with local communities to assist with support needs. Long-term effective education and information programs will be needed to help local communities understand and respect that drought-stressed protected areas and their wildlife also need special protection during times of drought
Migration from other regions	Displaced people will mean increased local population numbers that could result in increased illegal use of natural resources from protected areas	Managers will need to work closely with State, national and aid organisations and local officials to help with the welfare needs of displaced people as well the special protection requirements of reserves. Partnerships could be established with the military to achieve short-term protection needs until order is established
Perennial glacial ice and snow cover reduced or lost	Perennial to ephemeral river water supplies may be lost or reduced, affecting security of regional water supplies, including water needed for irrigation	Managers will need to work with local authorities to assist with the management of the available water from the protected area in a manner that assists local communities and is consistent with the conservation needs of the protected area
Extreme events: storms, winds	Lands and waters inside and outside protected areas may be damaged because of the extreme nature of storms and weather events	Managers need to be an integral part of the community response to incidents and assist with the recovery (Chapter 26)

Mitigating climate change

Given the implications of climate change are so far-reaching, so insidious to life on Earth and so threatening to the prosperity and welfare of humans, there is an optimistic assumption by this book that the interests of the greater good for today's generation and future generations will prevail, and nations of Earth will reduce their greenhouse gas emissions to well below the current dangerous levels. Everyone will need to do their bit. Protected area managers are managers of the environment and they should indeed lead by example. This is especially important for climate change. As a first principle, they should, wherever and whenever possible, minimise the amount of greenhouse gases they generate.

Minimising greenhouse gas emissions

A leadership role in low-emission protected area management operations includes reducing both direct and indirect uses of energy derived from fossil fuels. This approach needs to develop an action plan that includes as many of the following points as possible:

- establishing and implementing organisation-wide emission reduction targets
- using official carbon offset mechanisms such as biodiverse restoration plantings within the protected area system to respond to unavoidable energy consumption such as the use of aircraft during incidents or for official travel
- implementing purchasing policies such as the purchase of green electricity; changing the vehicle fleet (where practical) to electric, hybrid or fuel-efficient vehicles; and undertaking life-cycle (energy consumption) assessments of products prior to purchase

Generating renewable electricity: part of a wind farm in operation, South Gippsland Hills near Toora, Victoria, Australia
Source: Graeme L. Worboys

One of Parks Canada's fleet of hybrid petrol–electric vehicles (with its lower greenhouse gas emissions technology), Banff National Park, Canada
Source: Graeme L. Worboys

- undertaking assessments of energy consumption as part of operational planning as a basis for minimising emissions (Chapter 24) including:
  - implementing design policies that include solar-efficient buildings and buildings that require low energy use for heating and cooling
  - using alternative energy sources such as solar and wind power
  - providing, if appropriate, official low energy use vehicle transport for staff for access to and from work centres
  - undertaking an internal organisation staff energy reduction awareness campaign and encouraging personal energy reduction action plans for employees
  - reducing the generation of waste through purchasing policies, reuse and recycling, and consequently reducing energy consumption for waste removal
  - reducing the use of water, and consequently reducing the energy used to supply water
  - undertaking fire management fuel-reduction burning after estimating the emissions arising and planning and dealing with potential alternative approaches.

Managing for mitigation in protected areas

Climate-responsive management of protected areas can contribute to global greenhouse mitigation efforts by capturing and storing carbon in forests, mires (wetlands), inland and marine waters, grasslands and within agricultural systems. All are important reservoirs of carbon but they can readily lose stored carbon as a result of changes in land and water use. Effective management of protected areas can help ensure that they continue to act as net absorbers of carbon ('carbon sinks') rather than becoming sources of carbon emissions. Such actions may include:

- restoration of damaged peat bogs and wetlands
- developing a clear understanding of the carbon dynamics of vegetation communities, and the responsible management of fire to protect carbon stocks
- undertaking prescribed burning to reduce fuels (such as in northern Australia) to prevent more severe fires later in more adverse fire weather conditions (which lead to greater carbon dioxide emissions)
- managing marine seagrass communities so they are not impacted by disturbance or pollution
- managing old-growth forests to provide additional protection from disturbance.

Heavily disturbed wetland, Pilot Wilderness, Kosciuszko National Park, New South Wales, Australia. Undisturbed, these organically rich peat wetlands retain carbon in their mountain protected area environment and help to conserve water catchments. Despite some control measures, pest horses had grown in numbers in the 2010s and had heavily disturbed this and other wetlands in Kosciuszko's subalpine environments.

Source: Graeme L. Worboys

Greater understanding of carbon processes and cycles in all of these systems is required, and this should be a research and management priority for many protected areas.

Adaptation management

Managing for climate change adaptation means thinking a little differently about how we undertake protected area management given implementation practices are introduced into a dynamic climate change setting. Adaptation practices are defined by the IPCC as 'an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007:720). Well-managed protected areas do have an advantage, however, for 'a good network of protected areas free of other stresses is one of society's and nature's best adaptations to climate change' (Welch 2005:90).

Box 17.4 Ecosystem-based adaptation

Ecosystem-based adaptation integrates the use of biodiversity and ecosystem services into an overall strategy that helps people to adapt to the adverse impacts of climate change. It aims to reduce vulnerability and increase resilience to climate change effects. It is a natural adaptation approach that compares directly to adaptation initiatives that have focused on the use of technologies and climate-resilient infrastructure. As natural buffers, ecosystems are often cheaper to maintain and often more effective than physical engineering structures such as dykes or concrete walls. They are readily available to the rural poor and can be readily integrated into community-based adaptation. This adaptation work may include:

- sustainable-use management
- conservation of ecosystems
- restoration of ecosystems.

Source: Colls et al. (2009)

Box 17.5 Community-based adaptation

Community-based adaptation is about helping people. It takes a local perspective and is focused on those communities which are particularly vulnerable to climate change based on forecasts of how climate change will affect the local environment and a community's assets and capacities. The aim is to enable the community to understand and integrate the concept of climate risk into their livelihood activities in order to increase their resilience to immediate climate variability and long-term climate change. The difference between a community-based adaptation project and a standard development project is not in the intervention but in the way in which the intervention is developed, why it is being developed and with what knowledge. A primary objective is to improve the capacity of local communities to adapt to climate change.

Source: Enser and Berger (2009)

Two important adaptation approaches have been operationalised internationally: ecosystem-based adaptation responses (Box 17.4) and community-based adaptation approaches (Box 17.5). Both are potentially relevant to protected areas. There is overlap in these two approaches, and an integrated approach that includes essential elements of both may be preferred.

Adaptation strategies need to be integrated into local, regional and national (and sometimes international) planning frameworks to ensure their sustainability and to help achieve ownership by local communities. For protected areas, adaptation practice would normally be an integrated part of protected area management—albeit with very clear and well-informed intent. It is important to be clear about what objectives are sought for climate change adaptation practices.

Climate-ready objectives

Dunlop et al. (2013) provide important guidance for establishing 'climate-ready' objectives for adaptation management. Their approach helps protected area practitioners to conceptualise the climate change issues at hand and to frame the types of governance and management adaptation responses needed. Preparing for climate change adaptation is a major task. Changing conditions will mean that the characteristics of a nation's protected areas and management needs will be very different in the future. Assessing strategic climate-ready objectives is critical and, in part, is a matter of identifying what is actually possible and practical in a rapidly changing world. The biodiversity outcomes that can be feasibly achieved—the ends of conservation management—are fundamentally constrained by climate change:

> [A]daptation should include reassessment of the intended outcomes or objectives of biodiversity conservation that are articulated in strategic conservation documents. By objectives we mean statements of outcomes for biodiversity that are desired by society and that management should be focused on trying to achieve. These objectives are embodied in multiple stages of the conservation policy, planning and implementation process. Under a climate-ready approach, the critical question becomes: are the biodiversity objectives of a conservation strategy ecologically feasible given the potential impact of climate change? And, if not, how can climate-ready objectives be developed? (Dunlop et al. 2013:18–19)

Dunlop et al. (2013), in their work on climate-ready conservation objectives, have considered a landscape with a range of tenures. For protected areas, the focus would be more specifically on managing for natural ecological processes; however, importantly, what is being exemplified here is a process of rethinking and refining management objectives so that they are climate-ready. Such a process is most important for protected areas.

We have used this concept of setting climate-ready objectives in this book to help guide the specification of potential protected area climate-ready management actions. Consequently, we have provided more detail on this concept, including some of the terms used (Box 17.6) as well as the 'conservation policy cycle' (Figure 17.5).

Three examples of climate-ready conservation objectives

Dunlop et al. (2013) developed three prototype 'climate-ready' objectives for biodiversity conservation to help illustrate elements of the climate-ready approach for landscapes. Objectives were prepared for 'species' (Box 17.7), 'ecosystem' (Box 17.8) and 'landscape' (Box 17.9). The 'species', 'ecosystem' and 'landscape' examples for climate-ready conservation objectives are valuable for fine-tuning a climate-ready thinking approach to be taken by managers in selecting appropriate protected area adaptive management actions. Each objective for the three examples consists of three key elements):

1. an action (reduce or maintain a biodiversity outcome)
2. a biodiversity outcome that is the focus of the objective (what it is trying to conserve)
3. a biodiversity outcome that is seen as transient—that is, change in it is deemed acceptable, by virtue of the inevitability of that change under climate change (Dunlop et al. 2013).

A key feature of this approach is the consideration of community and social goals. The importance of retaining and managing for natural ecological processes in protected areas would be reinforced as a key social goal.

In managing for species in a climate-ready environment, some tough management decisions may be needed. In Box 17.10, Adrienne Nicotra and Roger Good present a conceptual approach that may assist such decision-making. Clear, climate-ready objectives of management are critical, for their establishment is the precursor to well-considered management actions. Operationalising these objectives as actions would include *planning*; there would be *organisation* to achieve *implementation* and there would be follow-up *evaluation*. We have used these four functions of management (Chapter 8) as a framework to present a range of climate-ready considerations for protected area practitioners. Ideally, any situational responses identified would be prepared as a climate-ready response plan for a protected area.

Box 17.6 Climate-ready conservation objectives for a landscape

[Text provided to stimulate interest in and discussion of the concept of climate-ready objectives and their potential use for protected areas.]

In considering and interpreting climate-ready conservation objectives and the policy cycle (Figure 17.5) for landscapes of multiple tenures, the following abbreviated points from Dunlop et al. (2013) are important. They reinforce that establishing climate-ready objectives is about rethinking the future and adjusting management to deal with these new futures.

- Management actions are the means by which biodiversity outcome ends are met, and conservation objectives are statements of the desired ends.
- Objectives are tools to help diagnose the extent to which policy and planning are climate-ready and to help scope the nature of the task of accommodating the climate change propositions into various decision-making processes with their multiple inputs and constraints.
- The process of revising policy and planning will be far more complex than simply updating objectives: it is potentially a multi-decade process and will depend on the specific context of different institutions. Thinking about the need to recalibrate objectives and the factors that make objectives climate-ready will help develop the capacity of decision-makers, stakeholders and researchers to start addressing the issue.
- Climate-ready objectives might be substantially different from current objectives.
- Policy objectives should reflect social goals, community aspirations and preferences, especially when planning adaptation policy; this framing step in the policy cycle is called 'community biodiversity values' (Figure 17.5).
- Values' in this approach do not mean biodiversity assets (which might be valuable) or dollar values (market or non-market); they refer to preferences and aspirations that are products of the relationship between people and nature.
- Such values can be expected to change as a result of people's understanding of nature changing, including understanding the inevitability of various changes to species, ecosystems and landscapes.
- Community biodiversity values are critical motivators of conservation. Climate-ready conservation objectives are products of recalibrating the current conservation outcomes so they reflect biodiversity outcomes that are both technically feasible and socially desirable under future climate change. For protected areas, this would include society wishing to manage for the retention of natural ecosystem processes and the associated biodiversity.

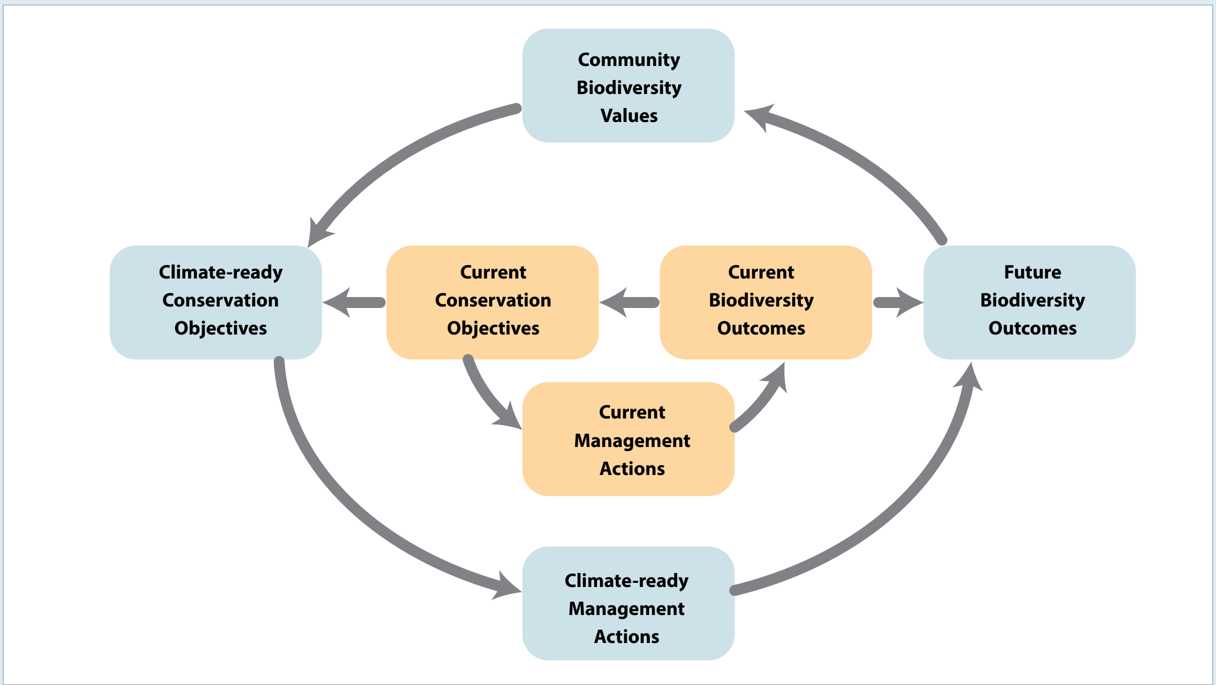


Figure 17.5 The conservation policy cycle

Note: The cycle incorporates recalibrated objectives that describe feasible desired biodiversity outcomes that lead to updated management and revised outcomes.

Source: Dunlop et al. (2013:20)

- Climate-ready management actions are the set of activities needed to implement the new objectives; they are likely to be similar types of actions but possibly implemented in different ways and different places for different ends. Future biodiversity outcomes are the result of new management, evolving threats, climate change impacts and other drivers.

  'Preliminary criteria for assessing the extent to which objectives for biodiversity conservation may be climate-ready have been developed that are applicable to all (forward-looking) objectives that seek to conserve biodiversity in the face of any threats, not just those specifically addressing climate change. In this way, addressing climate change becomes mainstreamed into conservation as a whole. These preliminary criteria for assessing the climate-ready status of conservation objectives are as follows.

  - The objective accommodates large amounts of ecological change and the likelihood of significant climate change-induced loss in biodiversity.
  - The objective remains relevant and feasible under the range of possible future trajectories of ecological change.
  - The objectives (as a set) seek to conserve the multiple different dimensions of biodiversity that are experienced and valued by society.
- Objectives need to be detailed enough to explicitly meet the criteria, not merely being possibly consistent with them.

Source: Adapted from Dunlop et al. (2013:19–20)

Box 17.7 'Species' climate-ready conservation objective for a landscape

[Text provided to stimulate interest in and discussion of the concept of climate-ready objectives and their potential use for protected areas.]

Objective

Reduce species extinctions as abundance and distribution change.

Explanation

The objective explicitly recognises that populations of species may vary considerably over time, and that as these changes occur it may be feasible to reduce the chance of species going extinct, but that it is also infeasible to prevent all extinctions due to climate change (and other threats).

Conceptual issues

- How much reduction in extinction is sought?
- Hybridisation: potentially a mechanism for genes to survive, but it is currently recognised as a threat.
- Distribution shifts into different ecological communities: good for the moving species but potentially threatens the extant community.
- What levels of species richness and turnover between sites are desirable?
- How much does society value other types of diversity (higher taxonomic levels, functional, and so on)?
- Is the presence of any species acceptable in any location, at any abundance?

Residual losses

There will be losses due to the changes in species abundance and distributions and losses associated with those species that do go extinct, given an acceptance that some level of extinction is inevitable.

Climate-ready management for species

- Maintain habitat in a wide variety of environment types (so species can hopefully find suitable habitat somewhere across the landscape as they move in response to climate change).
- Minimise the impact of other threats (pests, weeds, habitat loss and degradation, water extraction) so that species have less competition to establish populations in new areas (as well as potentially persist in their current distributions).
- Maintain and enhance connectivity of vegetation and waterways to facilitate movement of species to areas where they may survive better.
- Protect refuges to help species survive increased climatic and environmental variability and extremes.
- Protect currently outlying populations as potential sources for populations in new areas.

Social considerations

Species and place are strongly linked, and this is potentially a barrier to adopting the climate-ready objective. If some level of extinction is inevitable, how are choices made about which species are preserved? How can the community gauge success if some (uncertain) amount of loss is inevitable?

Institutional considerations

There is a need to develop aspatial or more spatially dynamic ways of characterising species and their future conservation needs. There is extensive work on characterising diversity patterns, but translating this into forms that can be incorporated into objectives or priorities is more complex.

Source: Abbreviated from Dunlop et al. (2013)

Box 17.8 'Ecosystem' climate-ready conservation objective for a landscape

[Text provided to stimulate interest in and discussion of the concept of climate-ready objectives and their potential use for protected areas.]

Objective

Maintain ecosystem health as type, composition, structure and function change.

Explanation

The objective focuses on the quality or health of an ecosystem found at a particular location, with the specific type of ecosystem at that location seen as transient. It explicitly recognises that changes in species abundance and distributions and changes in disturbance regimes will affect the composition, structure and function of ecosystems—their defining features. There is, however, an intuitive concept that any type of ecosystem could be in a healthier or more degraded condition, and as type changes it would be desirable for a location to transition from having a healthy ecosystem of the current type to a healthy ecosystem of a new type rather than a degraded version of the original type (or the future type). Ecosystem health could be seen as the potential of an ecosystem to provide ecosystem services.

Ecosystem, in this objective, means the system of the interacting ecological processes and individual organisms. As such, an ecosystem could be small (a patch of vegetation) or very large. This objective focuses on the biodiversity of a location as it comes and goes and changes, not on the fate elsewhere of the individual species or ecosystem types currently occurring at the location.

Conceptual issues

- The objective is about the properties of ecosystems that people experience and value directly, not about managing ecosystems for the conservation of species *per se*.
- How should ecosystem health be defined? What parameters should be included?
- Some loss of health might be inevitable during (continual) transition, depending on the rate of change.
- If change in type is deemed acceptable, due to being inevitable under climate change, how much is change in type due to human activities also acceptable?
- How should health benchmarks for novel or transitioning ecosystems be determined?
- While ecosystem health applies to all ecosystems, which places might have higher priority? Should we aim for examples of very good ecosystem health or acceptable ecosystem health everywhere?

Residual losses

Residual losses in this objective arise from changes in types of ecosystems occurring at specific locations, and potentially the extent to which some ecosystem types reduce or disappear completely. There may also be some loss of value associated with some reductions in ecosystem health as they enter a phase of continual transition in response to continual climate change, so that they are essentially always out of equilibrium with the climate of the day.

Climate-ready management for ecosystems

- Manage disturbance to avoid any erosion of key parameters (such as soil, trophic structures, primary productivity).
- Limit 'over-dominance' of key species (monocultures, over-predation).
- Manage extractive pressures (such as grazing, harvests).
- Manage for diversity of functional types and manage for ecological redundancy.
- Manage for resilience of key processes.

Ecological considerations

- An agreed definition of ecosystem health; many aspects that might intuitively align with health are well defined ecologically (such as species richness, functional diversity, primary productivity, response to disturbance).
- A variety of measures related to ecosystem health (such as condition) that is decoupled from the type of ecosystem.
- Defining suitable benchmarks as the climate changes. Some changing benchmarks might be predictable from current theory, mechanistic models and statistical analysis of patterns, such as potential primary productivity or species richness. It is unclear, however, if these predictions or extrapolating from similar contemporary climates will be precise enough or actually suitable.

Social considerations

How much of the value held for the ecosystem at a place is associated with the type of ecosystem and with its health? How much does the rate of change in type matter socially? How much does familiarity with the current ecosystem affect perceptions of change in type and health?

Institutional considerations

There are many possible different measures relevant to ecosystem health, but few are well enough characterised to provide simple tools to be built effectively into institutions.

Source: Abbreviated from Dunlop et al. (2013)

Box 17.9 'Landscape' climate-ready conservation objective

[Text provided to stimulate interest in and discussion of the concept of climate-ready objectives and their potential use for protected areas.]

Objective

Maintain a balance between human and natural domination of ecological processes, as ecosystems and land/water uses change.

Explanation

The intent of this objective is to focus on the amount of nature in a landscape, with the particular native ecosystems and human uses in the landscape seen as transient. It recognises landscapes as places with a mixture of natural and human influences, and it focuses on the balance between those influences. Like the ecosystem objective, this one is place-based, but here the place is recognised as having multiple ecosystem types (including natural and human) and the focus is on the 'quantity of nature' across those different ecosystems or the quantity of resources available for nature, not the quality. Whereas the ecosystem objective related to the ability of a place to provide ecosystem services, this objective relates more to the quantity of ecosystem services provided by the landscape. The objective can apply to any scale—for example, a continent or an urban backyard.

Conceptual issues

The objective is about the properties of landscapes that people experience and value directly, not about managing landscapes for the conservation of species *per se*.

- What 'balance' of human and natural domination is right? While this is clearly a significant question in society, this objective focuses on the impact of changes in the balance due to climate change. Where the balance (not just the types) affects how people experience and value a landscape, it may be desirable for any change in the balance to be managed (stopped, slowed, maybe encouraged) rather than just allowed to happen.
- Climate change could drive the balance towards more or less natural domination. Either could be desirable.
- Is the pattern of natural and human activities, and how they are spread across the landscape, important, as well as their relative amounts?
- What aspects of ecosystems, ecological processes and human impacts should be used to judge the extent to which they are naturally dominated? How should human impact on variation be considered (such as flow regimes)? How might impacts on view-scapes and sound-scapes be considered?

Residual losses

Residual losses in this objective arise from changes in the types of ecosystems and land and water uses occurring in the landscape. Clearly, specific ecosystem types and human uses are valued in many landscapes, and change in these will lead to some losses.

Climate-ready management for landscapes

- Understand the institutional and physical drivers of particular balances in landscapes, and their sensitivity to climate change, both directly and via changed land and water use.
- Set aside land and water resources for biodiversity.
- Include the naturalness of semi-natural ecosystems and rivers in quantification of landscape balance (as opposed to simply area of native habitat versus cleared area).
- Maintain natural influences over variability in hydrological systems and disturbance regimes.
- Adjust harvesting (of timber, fishing, grazing) in response to changing productivity.

Social considerations

Sense of place is a powerful concept in culture; how much of it is tied to familiar types of ecosystems, as opposed to a balance? If types change, how much connection might remain? Is the balance worth retaining if the types change?

Institutional considerations

There are few readily available tools for effectively characterising the degree of human and natural influence along the spectrum of balance in a landscape.

Source: Abbreviated from Dunlop et al. (2013)

Box 17.10 The assignment of priority species, assemblages and ecosystems for adaptation research and conservation management

[A potential 'first stage' climate-ready framework for managing for species.]

Considerable protected area-specific ecological and restoration research will be required to successfully manage adaptation challenges. The research requirements for many protected areas will be difficult to determine and clearly articulate and, where identified, will be difficult to address in the short term. In terms of biodiversity, the assignment of priority species, assemblages and ecosystems for research and conservation can be assisted by using an expert systems approach, as described below. It should be noted that this 'first stage' in a thinking approach to dealing with species does not include social and political considerations and these would be a critical input to any final decision about management action.

Assigning species to an adaptation management response space

This conceptual framework (Figure 17.6) provides a useful starting point for prioritising actions, but it must be recognised that assignment of species to these categories is not simple. Resilience or adaptive capacity depends on three interacting factors: innate ecological characteristics (such as life-history traits); genetic variation, which confers the potential for an adaptive evolutionary response; and plasticity, which may buffer the impact of climate change, broaden environmental tolerance and/or provide time for adaptive evolution and range shifts to occur. Assignment of taxa on the framework should therefore be an iterative process, taking into consideration what expert opinion and historical data are available, and then cross-checking with research on the above areas for those species seen to be most important in the system.

The framework

Using a combination of expert opinion, historical data compared with contemporary data, and research on ecological characteristics and adaptive capacity, it is possible to assign species to an 'adaptation' space with axes representing functional importance and resilience (but see caveat below).

X axis

The x axis represents the functional contribution of the taxon to the ecosystem. Taxa would score as having high functional importance if they were keystone species or highly abundant and making large contributions to ecosystem function.

Y axis

The y axis represents the resilience (or adaptive capacity) of a taxon. Taxa that are already showing signs of decline in abundance, slowed growth or reproduction, or increased sensitivity to pests and diseases would score low. In addition, taxa known to have narrow environmental limits or low genetic variation would be likely to fall on the low side of this axis. Taxa that either do not show current impacts of climate change or are increasing in the community would score as highly resilient. From a management perspective, identification of these categories provides a starting point for allocation of conservation and management actions.

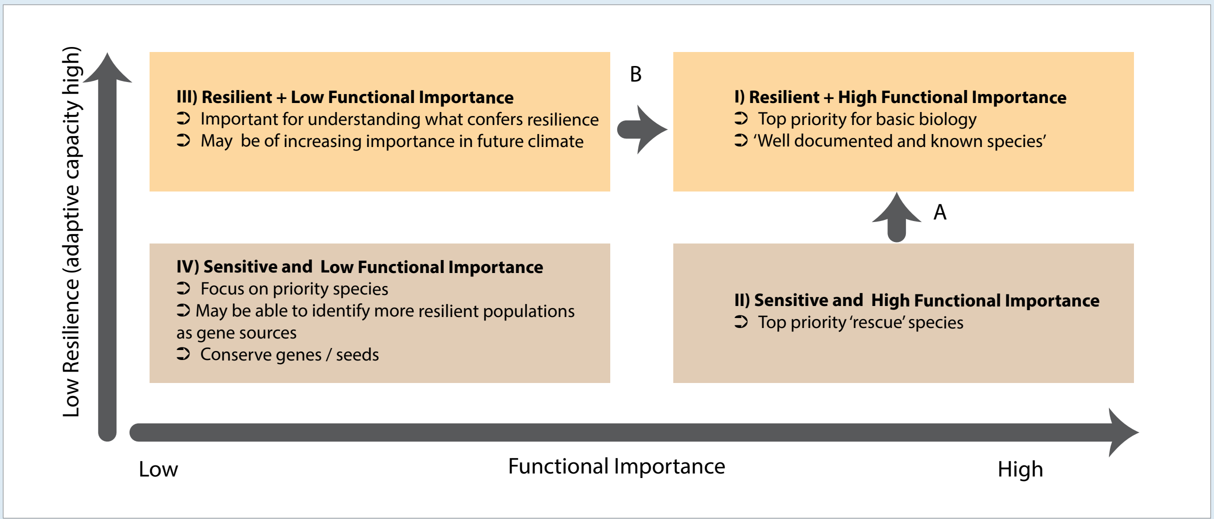


Figure 17.6 Assigning species to an 'adaptation management response space'

Note: This approach uses a combination of expert opinion; historical data compared with contemporary data; and research on ecological characteristics and adaptive capacity.

Source: Nicotra et al. (2014)

Quadrant I

Taxa falling into Quadrant I are both functionally important and resilient. These should be the 'bread and butter' species for restoration efforts. Though conservation and protective actions often overlook the common taxa, they are important species to maintain in *ex situ* conservation and about which to obtain basic biological information as they may play a key role in responding to disturbance as a result of climate change. Basic biological information could include a better understanding of the environmental tolerances of the species and of patterns of genetic variation within the species.

Quadrant II

Taxa falling into Quadrant II are currently of high functional importance but show signs of negative impacts from climate change. These should be considered as species for which 'genetic rescue' might be considered. Alternatively, these are species that are likely to be replaced in the community and preparation for that change should be considered. For some such species, genetic variation may exist within the species that will provide more resilience, and where possible, such variants should be favoured for conservation and restoration (Arrow A).

Quadrant III

Taxa falling into Quadrant III are apparently highly resilient, but currently play a small functional role in the system. Climate change indirectly, or directly through management, may serve to increase the role these taxa play in the community (Arrow B). Taxa in Quadrant III also may be of interest in that they can contribute to our understanding of what makes a resilient taxon.

Quadrant IV

Taxa falling into Quadrant IV both show signs of low resilience and currently play a low functional role in the community. These may include taxa that are rare or at the current edge of their distribution. Quadrant IV taxa should be conserved *ex situ* as potential gene resources and may be of interest from the perspective of future genetic contribution. These taxa are, however, likely to include those least likely to persist in future communities and therefore should be a lower priority for management efforts.

— Adrienne Nicotra and Roger Good

Climate-ready planning

Many protected planning area considerations are described hereunder that could help facilitate climate-ready objectives. For each of the climate-ready topics identified, the planning consideration has been presented as a question in preference to a specific management action. This approach focuses on the further conceptual development and definition of actual climate-ready response actions that will be needed rather than presenting actions as a checklist of tasks. How each adaptation planning action is actually developed will also vary depending on management policy needs (Box 17.11).

The 'planning' considerations that may form response actions to climate-ready objectives include: managing for risks, protected area system considerations, mitigation planning, planning process considerations, asset management and business planning. The considerations have been based on a number of guiding references including Welch (2005), Jarvis (2007), Mackey et al. (2008), Laffoley and Grimsditch (2009), OEH (2011) and IPCC (2014c).

Risk management planning

What are the key climate change impacts that may affect a protected area? Understanding the vulnerability and risks of a protected area or protected area system provides a planning context for management responses. The IPCC (2014d) identifies some criteria that may be used to identify key climate change vulnerabilities:

- magnitude of impacts
- timing of impacts
- persistence and reversibility of impacts
- likelihood (estimates of uncertainty) of impacts and vulnerabilities and confidence in those estimates
- potential for adaptation
- distributional aspects of impacts and vulnerabilities
- importance of the system(s) at risk.

What climate change-associated risks are there to local communities and neighbours and cultural heritage values? Undertaking climate-ready risk assessments allows protected area managers and local communities to assess what risks are likely and to prioritise any planning and preparation relative to the likelihood and consequence of an incident (Chapter 26). Climate change-enhanced risks could include flooding and inundation, more frequent extreme temperatures, droughts, bushfires, changing rainfall intensities, severe snowstorms, extreme weather,

Box 17.11 Approach to planned management actions

Early adaptation response actions are considered a wise investment, and planning is the critical first step. In an environment of planning uncertainty, some of the clearly identified planning considerations may be the following.

- **No-regrets actions:** These are actions that yield benefits even in the absence of climate change and where the costs are low.
- **Win–win actions:** These are actions that have the desired result in terms of minimising climate risks or exploiting potential opportunities but also have other social, environmental or economic benefits.
- **Reversible and flexible:** Which are actions that allow amendments to be made.
- **Expanded:** These are actions for which safety margins have been provided to ensure reliance for a range of climate change effects.
- **Delayed:** Identified actions that provide no benefit when undertaken immediately.

Source: ECAP (2014)

coastal erosion, and many others (Chapter 16). Rising sea-levels and storm surges, for example, may inundate coastal heritage resources of cultural significance (such as an indigenous occupation site), and there may be the need for community consultation and potentially some recovery actions associated with these assets.

From a climate-ready perspective, what risks to natural values exist for individual protected areas and for protected area systems? Such a risk assessment will help to identify the types of changes that may be forecast for a nation's natural values as well as for individual protected areas. It establishes a context for responses such as reviewing the adequacy of the protected area system, anticipating areas that may be inundated and lost, identifying areas that will be different, and providing special management for areas that may be refugia or connectivity conservation areas.

What risks are there to staff, visitor and local community safety? Safety considerations for staff and visitors to protected areas from a climate-ready perspective may include aspects such as changed fire behaviour, dealing with severe heat, unstable slopes in mountains due to the melting of frozen soils, melting glaciers where waters are temporarily dammed and suddenly released, higher sea-levels, wild seas along coastlines in severe weather, and other considerations. These staff safety risks will need to be assessed and managed.

Protected area systems planning

Is the protected area system adequate? Based on regional-level climate change modelling and biome shift forecasting, identify biomes that are at risk and undertake practical response planning. This includes assessing the boundaries of some protected areas and determining if they can be improved to assist biodiversity conservation (Chapter 13).

'Protected area systems will need to be adjusted and often expanded to fulfil their potential climate response roles of mitigation and adaptation, with implications for planning, assessment, policy and training. Individual protected areas will need adaptive management to meet changing conditions' (Dudley et al. 2010:93).

If possible, select and reserve new protected areas that may assist in maintaining a diversity of species and ecosystems based on forecast changes. Specific climate change-forced challenges may include:

- managing for the conservation of specific values, such as the establishment of 'mobile protected areas' in the marine environment to ensure that specific values are protected even though the location of those values changes
- managing for migration routes for terrestrial species, where those routes change with time, and the special protection this may require, irrespective of tenure.

Are protected areas adequately protected in a climate change world? Governance of protected areas will be placed under enormous pressure as the effects of climate change deepen. Special leadership, community support and political support efforts will be needed to keep protected areas 'protected' given 'backsliding' pressures caused by climate change issues are anticipated (Chapter 5). Pressures may, for example, come from:

- proposals for impoundments and the flooding of natural areas
- proposals for hydroelectric energy and the impounding of natural streams
- proposals for use of open space for electricity generation from solar, wind and tides
- drought-relief stock grazing into drought-impacted natural areas
- people seeking natural resources given they are no longer available anywhere else.

Does the protected area system adequately protect refugia sites? Species can persist by range reduction to microhabitats that retain the necessary niche and habitat requirements—the so-called refugia. Locations can function as refugia as a result of species responses to long-term or short-term environmental change. Remnant natural bushland patches in a fragmented landscape can also provide important refugia for species.

Are protected areas an integral part of larger connectivity conservation areas? Where possible and beneficial, protected areas should be embedded in large-scale networks of connectivity conservation areas. Action should be taken to minimise the barriers to the movement of wildlife through these areas (Chapter 27). Protected areas would form core areas for these connectivity conservation areas, which might also be very large and continental in scale. Habitat destruction and fragmentation should be minimised.

Mitigation planning

Have protected areas been adequately considered for the role of restoration in sequestering carbon and mitigating the effects of climate change? For example, restoration of tidal salt marshes and mangrove communities is an excellent way to increase natural carbon sinks. The management of seagrasses and kelp forests may also be considered. In terrestrial environments, the restoration of wetlands and forests, for example, can play an important role in sequestering carbon as well as improving habitat for species.

Planning processes

Have protected areas clearly defined and implemented their climate-ready objectives? Committing quality time and resources to prepare clear climate-ready objectives at strategic, tactical and operational levels of protected area management is a critical investment.

Plans of management for individual reserves

Have protected area plans of management included climate-ready objectives and actions? Climate-ready objectives for individual protected areas will be geographically more specific, but would generally still focus on maintaining ecosystem processes and biodiversity rather than specific species or biomes. The plans could feature enhanced information gathering through monitoring and provide additional support for research into condition and trend in condition. Climate forecasts could provide planned guidance for future restoration investments.

Environmental impact planning

Has an environmental impact assessment of a development proposal or a leasing and licensing proposal adequately included climate-ready considerations? These appraisals are very important and they need to consider the implications of climate change carefully. The commercial success of leasing or licensing proposals, for example, may require access to resources such as snow or to sites in bushfire-prone areas where access is guaranteed for the term of the lease. The decline or absence of snow within the term of a lease, or the closure of tourist destinations due to more frequent fires, could have legal implications for the lessor if this is not managed carefully.

Condition and trend in condition of protected areas

Have managers described the condition and trend in condition of their protected areas? Are they using such information as a basis for keeping track of long-term trends for their protected area? Climate change means that, more than ever before, there is a need to understand the condition of protected areas that are being managed and their trend in condition. This is a long-term program that would need to be institutionalised. It will be critical in helping to define management priorities. The information would be linked to information secured from modelling research that helps to forecast climate-ready futures. This may be a new capability for protected area organisations and it could include:

- legislated (mandated) ecological integrity assessments (Chapter 21)
- new partnerships with research organisations
- routine employment of on-ground and adequately qualified ecosystem management specialists such as postdoctoral qualified staff
- new and improved approaches to communicating effectively to the public about the condition and trend in condition of their local protected area or their protected area system.

Is there adequate investment in forecasting climate futures to assist with planning and management of protected areas? Managers will be faced with rapidly changing environments. The more information they have about potential futures, the better will be their response to these anticipated changes. Planning for and implementing research investments that include modelling and forecasting will provide improved information that can be used for managing individual protected areas and protected area systems.

Asset planning

Are climate-ready planning and forecasting being used in preparing long-term asset management operational plans? Piers, wharves, boat-launching ramps, bridges and other protected area coastal infrastructure will need to be revamped as sea-levels slowly rise. Historic buildings may need special attention as more intense rainstorm events occur, and walking tracks and roads in mountainous or high-latitude terrain may be impacted by melting permafrost. Asset management systems will need to recognise these changes as part of their planning (Chapter 24). The role of the asset management system in helping to minimise greenhouse gas generation is another important consideration.

Business planning

Are climate-ready planning forecasts being taken into account when entering into new legal (leasing or licensing) agreements? This is a basic question, for long-term leases and licences are legal documents and if the natural resource condition changes during the lease or licence period due to climate change influences (such as beaches becoming submerged, water aquifers drying up or an absence of snow), is the lessor liable in any way?

Are climate-ready planning forecasts guiding the management of existing long-term leasing and licensing agreements? Climate change will mean that the condition of protected area destinations may change. It could mean changes in how wild animals behave (such as the great African wildlife migrations), how safety arrangements for visitors differ (such as for more extreme bushfire conditions) and changes in the nature of attractions (such as snowfields and dwindling snow resources). Managers will need to assist lessees with managing for this dynamic. One potential threat, however, is lessees securing, through lobbying, the further adjustment of existing lease opportunities to establish commercial developments inconsistent with the objectives of the protected area (such as urban infrastructure developments). This potential scenario will have to be managed for (Chapter 23).

What climate-ready revenue management forecasts need to be made? Revenue planning for organisations will need to factor in changes in visitor use patterns resulting from climate change.

Climate-ready organisation

Organisational considerations, especially governance, will form a critical part of a climate-ready approach. Legislation and policy frameworks under which protected areas may be established and managed, for example, need to support effective climate-ready management. Three criteria could be used to evaluate existing or proposed biodiversity conservation legislation, policies and strategies for their suitability under a changing climate. They should:

- accommodate change
- be relevant and feasible under a range of possible climate change trajectories
- strengthen support from a broad cross-section of the community (Dunlop et al. 2013).

Most existing biodiversity conservation instruments seek to maintain the status quo of conserving species, communities, habitats, ecosystems and ecosystem processes as and where they have been for millennia. Climate change, however, will alter the distribution of species, the composition of species assemblages (communities) and the nature and functioning of ecosystems. The present focus of legislation and policy on the identification and management of threatened species, communities and ecosystems will need to be reconsidered.

Other 'organisational' considerations that may be implemented in response to climate-ready objectives have been described here and include those under the themes of governance and administration, policy and systems development, capacity development, and working with the community. These considerations have been guided by references prepared by Welch (2005) and Dunlop et al. (2013). For each of the climate-ready topics identified, the organisational consideration has been presented as a question in preference to a specific management action to focus on the further conceptual development and definition of the actual climate-ready response actions needed.

Policy and systems development

Are protected area organisational systems and policies climate-ready? This would include both the removal of maladaptive policies and practices by organisations and the establishment of climate-ready policies and governance arrangements. Increased delegations to on-ground managers may be an important improvement.

Capacity development

Do protected area staff working at strategic, tactical and operational levels possess climate-ready management competencies? Organisations may need to implement a range of climate-ready awareness training programs, and specific competency development training for staff. This may include high-level training for dealing with catastrophic fire events in extreme conditions, specialised training for monitoring, and vocational-based training for restoration management. Special training and skills development in working with the local community will also be needed.

Working with the community

What special governance arrangements are needed to help establish the tough climate-ready policy decisions that will need to be made? Values of special importance to communities will be impacted by climate change. In Australia, for example, many Aboriginal coastal midden deposits made over thousands of years will be impacted by sea-level rise. It will be essential for Aboriginal communities to participate in decisions about how rising sea-level impacts on the middens will be dealt with, and the special governance arrangements established to help with this.

Adaptive environmental governance

What information is made available by protected area managers to facilitate the adaptive capacity of communities to respond to climate change? Local communities are increasingly implementing the sustainable use of ecosystems and landscapes and they need to reconcile a range of individual and collective values. Processes for collaboration, governance arrangements and implementation responses may benefit from information provided, such as condition and trend in condition information for adjacent protected areas. The ways in which institutional arrangements may evolve to satisfy the needs and desires of the community in a changing environment (adaptive governance) may be influenced by this information.

Climate-ready implementation

There is a range of climate-ready implementation considerations that may respond to climate-ready objectives, including: adaptive management, management information, ecosystem integrity, resilience management, preservation management, landscape-scale management, transition management and working with the community. These considerations have been guided by references prepared by Welch (2005), Jarvis (2007), Taylor and Figgis (2007), Dunlop and Brown (2008), Dudley (2008), The Australian National University (2009) and Mantyka-Pringle et al. (2012). As for 'planning' and 'organising', the implementation considerations have been presented as questions.

Adaptive management

Are protected areas sufficiently ready to introduce adaptive management? Adaptive management is especially suited for ecosystem restoration and species management in a dynamic climate change environment. The system does, however, need adequate resourcing, top-level management support and support from the community and politicians for its full implementation (Chapter 8).

Information use

Is the information that is needed to manage for a climate-ready situation readily available for operational managers, and is the available information effectively utilised? Organisations need to carefully consider how the available information is provided for protected area managers. Wherever possible, the information should be pre-analysed and automated so that it forms part of a regular monthly or quarterly review of protected area condition, trend in condition and operational response processes. The information should be highly accessible.

Managing for ecosystem integrity

Have managers effectively communicated to the community the benefits of protected areas for reducing the risks of and impacts from extreme climatic events? Protected areas can help reduce the impacts of all but the worst natural disasters including floods, landslides, storm surges, droughts and desertification. These benefits should be communicated.

Are protected areas sufficiently climate-ready to respond to the very worst incidents that may impact protected areas? Such incidents could include catastrophic fire events, cyclones, tornadoes, severe snowstorms and other extreme phenomena driven by climate change-influenced atmospheric energy levels. Such events will need incident management responses (Chapter 26) and personnel training and competency levels that are at a very high level, including managing sophisticated incident modelling and planning computer software. The response would form part of a larger community response.

Maintaining essential ecosystem services

Have managers effectively communicated the vital role protected areas play in maintaining essential natural resources and services? Protected areas are critical for helping to provide water, fish resources and food, and for health. This important message needs to be constantly reinforced.

Managing for resilience

Is there a capacity to rapidly respond to disturbance events and to undertake restoration work? Climate-ready planning will anticipate the inevitability of severe incidents, and protected areas and their staff will need to be trained, equipped and organised to respond. Restoration implementation for severely burnt areas to minimise the effects of erosion following post-fire heavy rainfall events is one such example.

What threats to natural ecosystem processes exist and are management responses adequate? Minimising threats to natural processes could include controlling introduced (non-native) animals, removing introduced plants where practical, managing the frequency of fire and providing greater protection from threats such as hunting, fishing and poaching (Chapter 16). Weeds, for example, may have increased vigour in a climate change environment and may need enhanced responses.

Have climate change refugia been identified and have they been adequately protected? Refugia are places where favourable habitat persists or develops as the climate changes. Many protected areas will be climate refugia for some species and they may need active management to help retain such special qualities.

Have natural carbon stores been identified and have they been adequately protected? Some features in protected areas have high value for carbon storage, including old-growth forest and peat. These sites need to be protected so this additional carbon is not lost to the atmosphere.

Have climate-ready restoration policies been prepared to guide managers in restoration management? Such policies will need to guide managers on the nature of restoration work and whether the selection of species for use includes climate-ready species or species that are found at the site naturally. Whatever the treatment, protected area practitioners will have a special responsibility to document this work.

For some species, is it appropriate to engineer habitats such as latitudinally (further polewards) or altitudinally (up-mountain)? This question may need to be considered carefully for some species in some locations in the future as original habitats are lost. It is assumed that the community would participate in such decisions and they would be linked to the concept of translocation of species.

Preservation management

Are special interventions necessary to preserve genetic seed stocks for some flora species? As part of being climate-ready, it may be necessary to conserve seed stocks of wild flora (such as the wild varieties of staple foods) in dedicated *ex situ* seed banks. This would be an insurance policy to help protect future food supplies. Seed collection may be undertaken for other distinctive flora that is forecast to be lost in a future climate change world.

Does the community wish to retain captive populations of wild species that will otherwise become extinct due to climate change? Due to community demand, there may be many species that are retained as captive populations locally in zoos or in larger urban zoos long after the natural habitats and ecosystems that supported them have disappeared. Protected area managers may have a special role in looking after these species, or they may have a special partnership arrangement with zoos to help manage for these species.

Is it appropriate to translocate species as a climate-ready response? Translocating species from changed and climate-hostile habitats to climate-friendly habitats may be a management response where the species is otherwise unable to migrate naturally.

Landscape-scale management

What partnerships and collaborative arrangements are being implemented to respond to landscape-scale processes in order to be climate-ready? Contributing as a partner to multi-agency responses to wildfire in a local landscape (Chapter 26) is a good example of this type of work.

How can embedded protected areas within large connectivity conservation areas better facilitate the area being climate-ready? The effective management of protected areas will increasingly be linked to and integrated with the management and sustainability of the wider regions within which they are located and with the wellbeing of the residents and communities of those regions. Climate change planning needs to take into account the mutual dependence between protected areas and their host regions, and to incorporate many cooperative partnerships including connectivity conservation areas (Chapter 27). Protected areas form critical core areas for connectivity conservation. They may be in a position to provide critical condition and trend in condition information that benefits the larger corridor area, and they serve as a centre from which introduced animal or introduced plant control work is initiated. The protected area can play a special hosting and facilitating role as part of the larger connectivity area initiative partnerships.

Transition management

How do long-term coastal inundation forecasts influence how coastal protected areas are managed? The management of coastal protected area facilities and their replacement under asset management systems such as wharves, bridges and other public facilities may be influenced by longer term storm-surge and sea-level forecasts, and transition management approaches may be adopted.

Visitors and old-growth brown barrel eucalypt (*Eucalyptus fastigata*), Brown Mountain, South-East Forests National Park, New South Wales, Australia. Old-growth forests such as this help to retain carbon in the landscape rather than in the atmosphere

Source: Graeme L. Worboys

Working with the community

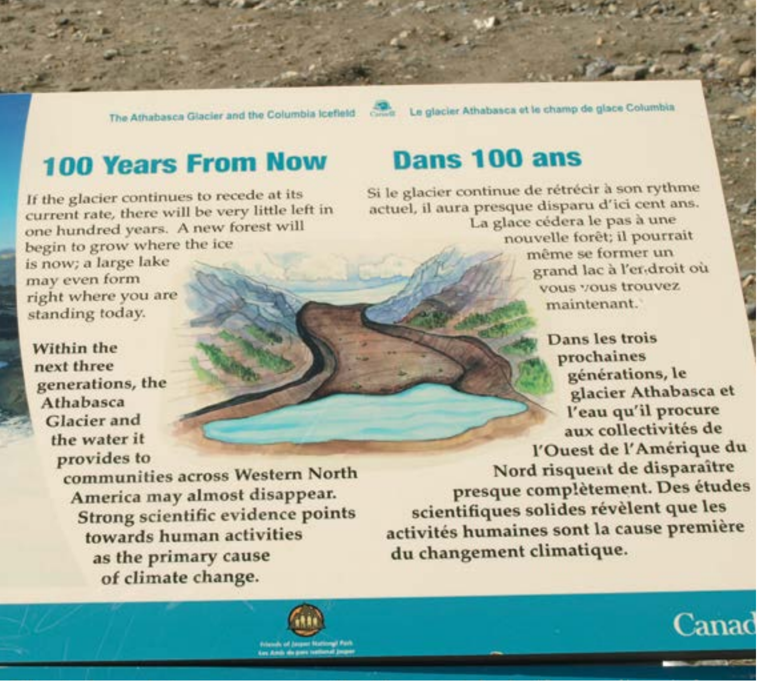
Is the protected area communicating climate-ready messages adequately and effectively? There is an art to effective communication and delivering messages, especially about being climate-ready. The community needs to be well informed, and protected area organisations and communities may need capacity development for staff and may also utilise communication experts to help deliver these messages (Chapter 15).

Are climate-ready messages included within protected area interpretation and education programs? Landscapes and protected area environments are likely to be very different in the future and there is a need to communicate this and to prepare people for change. Decentralised and dispersed protected area systems can play a vital role in communicating the message of climate change and being climate-ready to visitors, neighbours, local communities and concerned people throughout nations.

How climate-ready is the local community, including neighbours and stakeholders? Protected areas are part of a local community, so there is a level of responsibility for organisations to work collaboratively and perhaps through a range of partnerships to help ensure communities are as climate-ready as possible. This may include working and training with emergency services in anticipating incidents, landscape-scale pest animal control work and assisting with wildlife that are moving through areas beyond protected area boundaries.

Is local climate-ready information readily available to the community? Protected areas may commission research into condition and change in condition and into climate change forecasting, and they may collect ambient condition data. This information could potentially be shared with local communities, and some of it could be made available online and in real time. During incidents, real-time incident information could also be posted as a community service.

Are local politicians adequately briefed on 'climate-readiness'? Regularly briefing politicians at local, State or Territory or national level on climate-ready actions and current condition, trend in condition and forecast condition is a critical investment. Ideally, climate change and management responses are a bipartisan political issue and the briefings contribute to implementing improved futures.



Information sign text provided at the location of the Athabasca Glacier's snout in the 2010s, Banff National Park, Canada
Source: Graeme L. Worboys

Climate-ready evaluation

There is a range of climate-ready 'evaluation' considerations that may respond to climate-ready objectives. Evaluation of a protected area's climate-readiness and adaptive responses to climate change is a critical ongoing task. This evaluation work, supported by monitoring, is what provides the opportunity to track how the conditions of protected areas are changing over time. These considerations have been guided by references prepared by Welch (2005), Dunlop and Brown (2008) and Dunlop et al. (2013). As with planning, organisation and implementation, evaluation considerations have been presented as questions.

Monitoring

Has long-term monitoring been established for protected areas and are these investments adequately protected? Some protected areas already have long-term monitoring sites or plots whose value becomes increasingly important as the effects of climate change become more pronounced. These locations need special protection by management, and the monitoring needs to be ongoing.

Condition and trend in condition

Is a protected area climate-ready in terms of tracking its trend in condition from an established baseline? Being able to record the changes in condition of a protected area from a known baseline will be a fundamental contribution to climate-ready management of the future. This is also critical information for local communities and would be part of the information shared locally.

Climate-readiness evaluation and reporting

Is there a system in place whereby climate-readiness, for all aspects of protected area management, is regularly assessed and reported? A regular review of the climate-readiness for a protected area (or areas) of all aspects of management is considered essential.

Conclusion

Anthropogenic climate change is changing the nature of Earth's climate as it has been known for the geological 'recent period', including its weather systems, cryosphere, biomes, oceans and wildlife, and it is influencing more extreme events such as droughts, record high temperatures, catastrophic fires and severe storms. In addition to the essential actions needed from governments of Earth to reduce greenhouse gas generation, protected areas provide an important nature-based solution for mitigating and adapting to climate change threats. In facilitating the effective management of protected areas, opportunities for enhanced biodiversity conservation and healthier environments for people are achieved through the protection of ecosystem processes, a range of species and naturalness in a dynamic environmental setting.

With the deepening of climate change effects, the management of protected areas will need to be different, and carefully developed climate-ready objectives will guide refinements to planning, governance and protected area management implementation. Information—in a readily usable form that includes ambient conditions, trends in condition and climate change research forecasting information—will be increasingly critical for managers, with this same information being made available to the community, thus contributing to the community's understanding of climate change effects. Protected areas will be different in the future, but no less valuable, and more than ever before, managers will be constantly working with local communities to reinforce the importance and intergenerational benefits of protected areas as a critical part of the local landscape and of society.

Spectacular monsoonal storm and freshwater wetlands, Kakadu National Park World Heritage Property, Northern Territory, Australia. Climate change forecasts advise that low-lying areas of the Kakadu Wetlands will be vulnerable to salinity as a result of sea-level rise and saline intrusion into ground water that will convert freshwater wetlands to saline mudflats

Source: Graeme L. Worboys

Dense rainforest canopy, Monteverde Cloud Forest Reserve, Costa Rica. Climate change forecasts suggest that the low-level cloud cover will be reduced, leading to warmer conditions and potentially a drying and changing of the forests and their ecosystems

Source: Graeme L. Worboys

References

Recommended reading

Bergengren, J. C., Waliser, D. E. and Yung, Y. L. (2011) 'Ecological sensitivity: a biospheric view of climate change', *Climatic Change* 107: 433–57.

Colls, A., Ash, N. and Ikkala, N. (2009) *Ecosystem-Based Adaptation: A natural response to climate change*, IUCN, Gland.

Dudley, N. (ed.) (2008) *Guidelines for Applying Protected Area Management Categories*, IUCN, Gland.

Dudley, N., Stolton, S., Belokurov, A., Krueger, L., Lopoukhine, N., MacKinnon, K., Sandwith, T. and Sekhran, N. (eds) (2010) *Natural Solutions: Protected areas helping people cope with climate change*, IUCN WCPA, TNC, UNDP, WCS, The World Bank and WWF, Gland, Washington, DC, and New York.

Dunlop, M. and Brown, P. R. (2008) *Implications of Climate Change for Australia's National Reserve System: A preliminary assessment*, March, Report to the Department of Climate Change, Canberra.

Dunlop, M., Parris, H., Ryan, P. and Kroon, F. (2013) *Climate-Ready Conservation Objectives: A scoping study*, National Climate Change Adaptation Research Facility, Gold Coast, Queensland.

Enser, J. and Berger, R. (2009) 'Community-based adaptation and culture in theory and practice', in W. N. Adger, I. Lorenzoni and K. O'Brien (eds) *Adapting to Climate Change: Thresholds, values, governance*, Cambridge University Press, Cambridge.

European Climate Adaptation Platform (ECAP) (2014) *How to Factor Uncertainty into Adaptation Decision Making*, European Climate Adaptation Platform. <climate-adapt.eea.europa.eu/>

Ferrier, S., Harwood, T. and Williams, K. (2010) *Using generalised dissimilarity modelling to assess potential impacts of climate change on biodiversity composition in Australia, and on the representativeness of the national reserve system*, Report to the Department of Sustainability, the Environment, Water, Population and Communities by CSIRO Ecosystem Sciences for the Impacts of Climate Change for the National Reserve System Project, Canberra.

Folland, C. K., Karl, T. R., Christy, J. R., Clarke, R. A., Gruza, G. V., Jouzel, J., Mann, M. E., Oerlemans, J., Salinger, M. J. and Wang, S.-W. (2001) 'Observed climate variability and change', in T. Houghton, Y. Ding, D. J. Griggs, M. Noquer, P. J. van der Linden, X. Dai, K. Maskell and C. A. Johnson (eds) *Climate Change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 101–81, Cambridge University Press, Cambridge.

Holling, C. S. (1978) *Adaptive Environmental Assessment and Management*, John Wiley & Sons, London.

Intergovernmental Panel on Climate Change (IPCC) (2007) *Climate Change 2007: Working Group II. Impacts, adaptation and vulnerability: Glossary*, Intergovernmental Panel on Climate Change. <www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-a-d.html>

Intergovernmental Panel on Climate Change (IPCC) (2012) 'Glossary of terms', in C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor and P. M. Midgley (eds) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*, pp. 555–64, Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC) (2013a) 'Summary for policymakers', in T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds) *Climate Change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 3–29, Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC) (2013b) 'Introduction', in T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds) *Climate Change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 111–58, Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC) (2014a) 'Final draft: summary for policymakers', in *Report of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC) (2014b) *Criteria for Assessing Key Vulnerabilities*, Intergovernmental Panel on Climate Change. <www.ipcc.ch/publications_and_data/ar4/wg2/en/ch19s19-2.html>

Intergovernmental Panel on Climate Change (IPCC) (2014c) *IPCC WGII AR5 Glossary*, Report of the Intergovernmental Panel on Climate Change, pp. 1–30, Cambridge University Press, Cambridge. <ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Glossary_FGD.pdf>

Intergovernmental Panel on Climate Change (IPCC) (2014d) 'Final draft: Chapter 19 Emergent risks and key vulnerabilities', in *Report of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

International Union for Conservation of Nature (IUCN) and United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) (2014) *World Database on Protected Areas Statistics*, August 2014, World Conservation Monitoring Centre, Cambridge.

Jarvis, J. (2007) 'An inarticulate truth: communicating the science of global climate change', *The George Wright Forum* 24(1): 82–90.

Laffoley, D. and Grimsditch, G. (eds) (2009) *The Management of Natural Coastal Carbon Sinks*, IUCN, Gland.

Mackey, B., Watson, J., Hope, G. and Gilmour, S. (2008) 'Climate change, biodiversity conservation and the role of protected areas: an Australian perspective', *Biodiversity* 9(3–4). <www.uq.edu.au/spatialecology/docs/Publications/2008_Mackey_EtAl_ClimateChangeBiodiversity.pdf>

Mantyka-Pringle, C. S., Martin, T. G. and Rhodes, J. R. (2012) 'Interactions between climate and habitat loss effects on biodiversity: a systematic review and meta-analysis', *Global Change Biology* 18: 1239–52.

McKellar, R., Midgley, G. F., Yates, C. J., Abbott, I., Gioia, P. and Le Maitre, D. (2010) 'The need to develop a coherent research approach for climate change vulnerability impact assessment and adaptation in high biodiversity terrestrial ecosystems', *Austral Ecology* 35(4): 371–3.

Nicotra, A. B., Hoffmann, A. A., Morgan, J. W. and Millar, A. D. (2014) Adaptive restoration and management in the Australian Alps catchment, Presentation at Alpine Ecology Symposium, Australian National Botanic Gardens, Canberra.

Office of Environment and Heritage (OEH) (2011) *Guide to Climate Change Risk Assessment for Local Government*, NSW Office of Environment and Heritage, Sydney. <www.environment.nsw.gov.au/resources/climatechange/20110593riskassesslg.pdf>

Parmesan, C. and Yohe, G. (2003) 'A globally coherent fingerprint of climate change impacts across natural systems', *Nature* 421: 37–42.

Peterson, T. C., Anderson, D. M., Cohen, S. J., Cortez-Vázquez, M., Murnane, R. J., Parmesan, C., Phillips, D., Pulwarty, R. S. and Stone, J. M. R. (2008) 'Why weather and climate extremes matter', in T. R. Karl, G. A. Meehl, C. D. Miller, S. J. Hassol, A. M. Waple and W. L. Murray (eds) *Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands*, pp. 11–33, A report by the US Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

Steffen, W., Burbidge, A. A., Hughes, L., Kitching, R., Lindenmayer, D., Musgrave, W., Stafford Smith, M. and Werner, P. A. (2009) *Australia's Biodiversity and Climate Change: A strategic assessment of the vulnerability of Australia's biodiversity to climate change*, CSIRO Publishing, Melbourne.

Taylor, M. and Figgis, P. (eds) (2007) *Protected Areas: Buffering nature against climate change, Proceedings of a WWF and IUCN World Commission on Protected Areas Symposium*, 18–19 June 2007, Canberra, WWF-Australia, Sydney.

The Australian National University (2009) *Implications of climate change for Australia's World Heritage properties: a preliminary assessment*, A report to the Department of Climate Change and the Department of the Environment, Water, Heritage and the Arts by the Fenner School of Environment and Society, The Australian National University, Canberra.

Welch, D. (2005) 'What should protected areas managers do in the face of climate change?', *The George Wright Forum* 22(1): 75–93.

Yates, C. J., Elith, J., Latimer, A. M., Le Maitre, D., Midgley, G. F., Schurr, F. M. and West, A. G. (2010) 'Projecting climate change impacts on species distributions in megadiverse South African cape and southwest Australian floristic regions: opportunities and challenges', *Austral Ecology* 35: 374–91.

Zhang, X. and Zwiers, F. (2012) 'Statistical indices for diagnosing and detecting changes in extremes', in A. Agha Kouchak, D. Easterling, K. Hsu, S. Schubert and S. Sorooshian (eds) *Extremes in a Changing Climate: Detection, analysis and uncertainty*, pp. 1–14, Springer Science+Business Media, Heidelberg and New York.

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