

A photograph of the Uluru landscape in Australia. The image shows the iconic red sandstone rock formations under a bright blue sky with scattered white clouds. The foreground is a rocky, reddish-brown terrain with sparse green vegetation. The overall scene is a classic representation of the Australian outback.

# Implications for policymakers: **Climate change, biodiversity conservation and the National Reserve System**

Michael Dunlop, David W. Hilbert, Mark Stafford Smith, Ruth Davies, Craig D. James, Simon Ferrier, Alan House, Adam Liedloff, Suzanne M. Prober, Anita Smyth, Tara G. Martin, Tom Harwood, Kristen J. Williams, Cameron Fletcher, and Helen Murphy.

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## Implications for policymakers: **Climate change, biodiversity conservation and the National Reserve System**

A landmark regional analysis of the impacts of climate change on Australia's biodiversity and National Reserve System (NRS) was recently undertaken by CSIRO. It included a series of technical reports and region-based analyses, and a final synthesis report (Dunlop *et al.* 2012).

This document describes the implications for policymakers and was developed with advice from government decision-makers who considered the findings of the synthesis report. It describes the extent of the likely impacts of climate change on biodiversity, and provides guidance for strategic policy directions for protecting biodiversity and managing the NRS into the future.

### **Main report**

Dunlop M., Hilbert D.W., Ferrier S., House A., Liedloff A., Prober S.M., Smyth A., Martin T.G., Harwood T., Williams K.J., Fletcher C., and Murphy H. (2012) *The Implications of Climate Change for Biodiversity Conservation and the National Reserve System: Final Synthesis*.

A report prepared for the Department of Sustainability, Environment, Water, Population and Communities, and the Department of Climate Change and Energy Efficiency. CSIRO Climate Adaptation Flagship, Canberra.

This project was supported by all Australian governments through the Climate Change in Agriculture and NRM (CLAN) Working Group of the Natural Resource Management Ministerial Council, the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), and the Department of Climate Change and Energy Efficiency (DCCEE). The project was co-funded by CSIRO Climate Adaptation Flagship.



# Implications for policymakers: **Climate change, biodiversity conservation and the National Reserve System**

CSIRO recently completed an in-depth analysis of the effects of climate change on Australian biodiversity and the implications for conservation and the National Reserve System (NRS). This project produced a series of technical reports, regionally focused ecological analyses and a final synthesis report (Dunlop *et al.* 2012). It found that climate change impacts on biodiversity will be significant by 2030, within the timeframe of national biodiversity and protected areas' planning. By 2070, the impacts will be widespread and in many cases extreme. The scale of this change creates a pressing and immediate need to consider the implications of climate change for biodiversity conservation policy. This document was developed with policymakers to summarise key evidence, highlight the implications for contemporary policymaking and describe a series of options for adapting biodiversity conservation and the NRS.

## Background

Evidence over the last decade shows that climate change impacts on biodiversity are likely to be substantial. This raises questions about how to conserve biodiversity and, in particular, how to develop and manage the network of protected areas in the future. Preliminary analysis of the implications of climate change for the NRS suggested that protecting habitat in a diversity of environments remains a robust strategy. However, it also found that the ecological impacts of climate change are likely to vary significantly between regions, and management implications and options may need to be assessed at regional scales.

To address this, CSIRO quantitatively assessed, for the first time, the magnitude of the sensitivity of biodiversity to climate change in all of Australia and undertook detailed analyses of potential impacts and adaptation options in four biomes.

The project created an index of the potential for future environmental change to drive ecological change, and used it to translate spatial projections of climate change derived from climate models into information useful for informing biodiversity policy and management. The result is a significant contribution toward broad understanding of the climate change threat to biodiversity, which can be used in formulating adaptation options at multiple scales.

## Modelling the sensitivity of Australia's biodiversity to climate change

The project used two existing well-known descriptors of biodiversity – vegetation classes and species composition – to develop novel models of the sensitivity of biodiversity to environmental variation across the continent. These models were then run with climate change scenarios to

estimate the ecological significance of future climate change across the continent. The resulting indices are measures of 'biotically scaled environmental stress'. They provide an indication of the potential, or force, driving ecological change from the current state; but they do not predict how much ecological change will actually occur, nor which species will be present or absent. Other outputs of the model include maps of new and disappearing environment types and the extent to which local-scale environmental heterogeneity may buffer species from the extremes of environmental change.



# Biodiversity and climate change – key findings

- Policymakers can be very confident that ecological change in response to climate change is unavoidable; it will be widespread and it will be substantial.
- Future biodiversity management plans will need to allow for substantial changes in biodiversity, despite the unpredictable nature of some of these changes.

The scope of the challenge of adapting biodiversity management to climate change is shaped by the nature of the future impact of climate change on biodiversity, including its magnitude and extent; by our ability to predict future ecological changes; and by spatial variation in both climate impacts and Australian landscapes.

## 1. Ecological change will be widespread and potentially very significant

- a. Climate change will lead to most places in Australia having, by 2070, environments that are more ecologically different from current conditions than they are similar.
- b. This is likely to see the emergence of new environments, and the disappearance of many existing environments (Figure 1).
- c. The general pattern of change in vegetation is likely to be a decline in the area of environments that now favour trees, and an increase in more arid environments favouring open woodlands, chenopod shrublands and grasslands.
- d. In time, the ecological systems occurring across the continent are likely to be markedly different from the current systems.

**Within decades, environments across Australia will be substantially different from those currently experienced by biodiversity at most locations. As a result, biodiversity management may need to change significantly to minimise future losses.**

## 2. Biodiversity will be affected by climate change in many different ways

- a. Species populations could respond to climate change in different ways. For example: (A) species persist broadly in or adjacent to their current distributions, with changing climatic conditions and disturbance affecting their abundance and the parts of the landscape they occupy directly; (B) species persist within their current ranges, with changes in occurrence and abundance driven by establishment of new species, including predators and competitors; and, (C) species distributions shift at broad scales across and between regions, as new areas become climatically suitable and existing ones decline in suitability (Figure 2). These processes could occur together, and the relative importance of each will vary between species. Management options will differ in their ability to facilitate each type of change.
- b. In addition to changes to species populations, changes will occur in vegetation structure and composition, which will affect the type, functioning and health of ecosystems.
- c. Similarly, changes in land use as a result of climate change could lead to further losses of biodiversity at the landscape scale.
- d. The responses of species, ecosystems and landscapes to climate change will all be affected by ecological processes and management operating across landscapes, as well as in individual habitat patches.
- e. Other threats such as changing fire regimes and invasive species will increasingly affect the ability of biodiversity to adapt naturally.
- f. Changed interactions between species will have a major effect on ecological outcomes.

**The different processes of ecological change, each driven by climate change, will combine to make prediction about the details of change and likely loss of biodiversity very difficult. As a result, managers will be faced with ongoing uncertainty about some aspects of the future changes to the systems they manage, and this will constrain the choice of options for managing biodiversity.**

**RIGHT: Figure 1. The potential future extent of environments not currently experienced by biodiversity in Australia.**

Green indicates the potential occurrence of future environments that are ecologically similar to current environments. Purple indicates the potential occurrence of future environments, by 2070, that are ecologically dissimilar to environments currently occurring anywhere in Australia.

This analysis was based on Generalised Dissimilarity Modelling of the relationship between spatial variation in plant community composition, climate and other environmental variables. Novelty of future environments was calculated for two climate change scenarios generated with the CSIRO mark 3.5 Global Climate Model based on the A1FI (Figure 1a) and A1B (Figure 1b) greenhouse gas emissions scenarios developed by the Intergovernmental Panel on Climate Change in 2000 (see Dunlop *et al.* 2012 for details). Actual emissions since then have exceeded the trajectory of the A1FI scenario used in the greater impact analysis. The lesser impact analysis, using the A1B scenario, illustrates that a substantially lower trajectory of future emissions could lead to a lower level of future environmental change.

### 3. There will be much spatial variation in ecological change

- a. Ecological patterns and processes and the distribution and sensitivities of species vary considerably across landscapes due to environmental variation along broad climatic gradients and local variation in topography and soils. The effects of climate change on Australia's already spatially diverse environments will not be distributed evenly across the continent.
- b. Spatial variability in the environment at local and landscape scales can reduce the magnitude of environmental change in a process known as ecological or landscape buffering, by increasing opportunities for species to find suitable habitat locally. While buffering may reduce the impacts of future climate change, it will not eliminate it; by 2070 much local-scale buffering may be exceeded by the magnitude of environmental change.

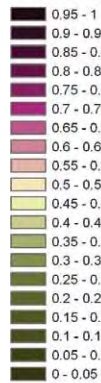
**The spatial variation in biodiversity, in Australia's landscapes and in climate change provides many opportunities for management to facilitate the natural adaptation of biodiversity through ecological and evolutionary processes.**

Novel biotically scaled environments

2070

**Greater impact analysis**

Minimum predicted dissimilarity between the potential future composition of each cell and the current composition of all cells on the continent



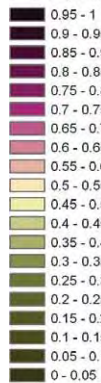
1a

Novel biotically scaled environments

2070

**Lesser impact analysis**

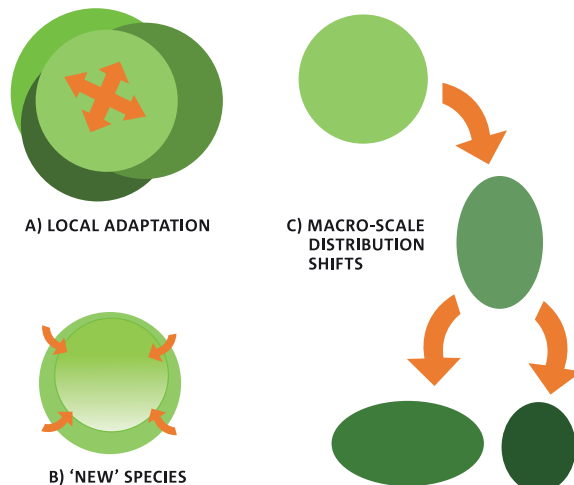
Minimum predicted dissimilarity between the potential future composition of each cell and the current composition of all cells on the continent



1b

**BELOW: Figure 2. An illustration of three different ways species may respond to climate change.**

The arrows show the movement of species between different areas of habitat in response to climate change. Darker greens represent areas of habitat that become more suitable as the climate changes. See text on page 4 for descriptions. B) shows a population contraction due to the arrival of new species. (Figure 5 in Dunlop *et al.* 2012).





# Biodiversity and climate change – implications for policy and management

## 1. Reassess biodiversity objectives

- Engage the community in revising overarching biodiversity objectives in order to meet the challenges of managing biodiversity under climate change.
- Develop concepts of ecosystem health that accommodate climate change, are scientifically defensible, relate to how people experience and value ecosystems, and translate into measurable targets for biodiversity management and planning.

With the extent of the impact on biodiversity of climate change, we will need to move from trying to preserve current biodiversity states towards managing inevitable change in order to minimise the loss of values associated with biodiversity. Significant changes in species, ecosystems and landscapes across the continent are inevitable; future conservation investments may need to focus on protecting community values associated with a more dynamic biodiversity. These could include the *existence* of species, the *health* of ecosystems and the *balance* of natural and human activities across whole landscapes. Public debate in community, scientific and policy circles will be needed to ensure policy changes reflect community biodiversity values and current scientific understanding of the issues.

- ♦ Biodiversity will become increasingly dynamic, including changes in species distribution and abundance; changes in ecosystem composition, structure and function; and changes in the land uses and ecosystems making up our landscapes. The interactions of land use, ecosystems and current threats to biodiversity will change. These changes will be directional and continual and overlaid by variation; in addition the rates of change are likely to vary, and rapid or step changes after disturbance events are possible.
- ♦ Many current conservation mechanisms primarily aim to preserve species and communities in their historical locations. This paradigm of conservation will become increasingly unachievable and less effective for guiding conservation investment and actions.
- ♦ It is possible to develop objectives for conservation that distinguish between inevitable and possibly preventable changes in biodiversity; although it is altogether more challenging to translate these into socially ‘acceptable’ change and ‘undesirable’ loss (columns in Table 1).
- ♦ Various aspects of biodiversity are valued by people and are likely to be affected by climate change in different ways. Therefore, future conservation objectives need to explicitly address different dimensions of biodiversity (rows in Table 1). As well as conserving species as their distributions change, there is a need to consider conserving values associated with ecosystems as their composition and identity change, and values associated with landscapes as their land uses and ecosystems change.
- ♦ Designing new conservation objectives must take into account ecological, social and institutional considerations, and it must also be informed by community engagement as well as developing scientific knowledge.

**Table 1. Potential future objectives for conservation that accommodate the inevitable dynamics of biodiversity**

<b>Dimensions of biodiversity<sup>1</sup></b>	<b>Static attributes</b> <i>Current objectives</i>	<b>Dynamic attributes</b> <i>Future objectives<sup>2</sup></i>
<b>Individual species</b> or genes	Abundance, distribution and co-occurrence	<i>Existence</i> of species
<b>Ecosystem</b> processes; patch+ scale; ability to provide ecosystem services	Ecosystem type (composition, structure and function)	Ecosystem <i>health</i>
<b>Landscapes</b> social-ecological system; quantity of ecosystem services provided	Types of human uses and native biodiversity	The <i>balance</i> of uses

<sup>1</sup> These dimensions reflect different ways people may experience and relate to biodiversity, and the different aspects of biodiversity that contribute to wellbeing and give rise to social values.

<sup>2</sup> Managing for these future objectives would entail focusing more on maintaining ecological processes rather than preserving current ecological states.

## 2. Create management strategies that are robust to uncertainty

- Develop guidelines and mechanisms for planning management and allocating investment that effectively minimise loss under different types and magnitudes of change.
- Reassess definitions and appropriate responses to listing species, communities and ecosystems as threatened that accommodate climate change.

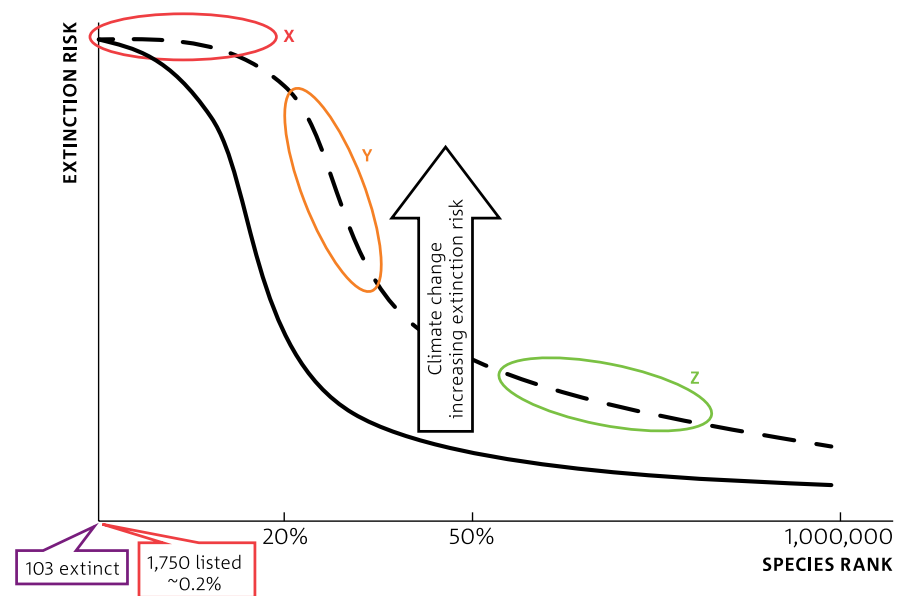
Current biodiversity management strategies largely assume low levels of species loss, relatively high levels of knowledge about threats and the state of biodiversity, and relatively static environments. These strategies will be less effective as high levels of change occur in biodiversity, and as uncertainty increases about the state of species, ecosystems and landscapes. It may be increasingly necessary to adopt robust strategies, which are effective under a wide range of future magnitudes and types of change, for a wide range of species.

- In the absence of climate change, current biodiversity states at any location are a good description of the likely or desirable future states. However, under climate change, future states are uncertain (distribution and abundance of species, composition of communities, types of ecosystems).
- Managers will, in effect, have less knowledge about biodiversity even with substantially increased information from monitoring and modelling. This means that in the majority of situations, it will not be feasible to implement management practices that are based on detailed information about the future state or dynamics of biodiversity. For example, species recovery actions requiring high levels of knowledge will be increasingly challenging, whereas protected area management potentially only requires management of threatening processes.

- Stepwise changes in management will allow adaptation to large ecological changes and uncertainty to begin in the near future, and to progress as more information becomes available. Three key steps are: (1) understanding the possible future ecological changes and their implications; (2) reassessing conservation objectives and overall management approaches; and (3) revising or developing and implementing new management strategies.
- Environmental and biodiversity responses to climate change will vary across the continent and within local regions. In addition, many ecological changes are likely to lag behind the driving environmental changes. Therefore, management that is dependent on responding to observed changes will be challenging, even with increased monitoring effort.
- High levels of loss of species and values associated with ecosystems and landscapes are likely to be

unavoidable. Management approaches must be able to accommodate this degree of change, for example, in the setting of targets and priorities (Figure 3).

- Robust management strategies – those that are effective under a wide range of future ecological changes – are likely to require less detailed information to implement and be more efficient than highly specific and targeted strategies. For a given situation, a targeted strategy may be more effective, but where detailed information about future change is lacking and proactive management required, choosing and designing such strategies will often be impossible.
- Intensive monitoring may be effective for those high value aspects of biodiversity where responsive management is possible and necessary.



**Figure 3. Hypothetical curve of extinction risk for Australian species ordered from most to least vulnerable on the horizontal axis.**

The shape in the curve shown is only illustrative.

Currently a very small proportion of all Australian species are known to be vulnerable to extinction. Under climate change the risk of extinction for most species would be expected to increase, distorting the curve up and to the right.

The total number of species becoming extinct and at risk of extinction in the future is likely to be considerably greater than at present, although the amount is not known. This increase, and uncertainty about it, greatly complicates any species prioritisation processes. For example: if 20% of all species were destined for extinction (dashed curve), then investment targeted at the species in red may prove to be wasted resources, and the orange species may be more suitable targets. However, if 50% were destined for extinction, then targeting the orange species may likewise be wasted resources. (After Figure 13 in Dunlop *et al.* 2012.)



Photo: Adam Liedloff, 17 Mile Falls (17 Mile Creek) on the Jatbula Trail, Nitmiluk National Park, Northern Territory, Australia

### 3. Plan and manage for biodiversity changes at landscape scales

- Incorporate the relative importance of habitat area, environmental diversity, connectivity, isolation and different types of refuges into planning.
- Develop methods for large-scale habitat restoration, especially in heavily cleared landscapes.
- Develop concepts and guidelines to accommodate rapidly spreading native species and help managers decide when these are desirable or undesirable due to their impact on other resident species.

Managing at landscape scales will help reduce future losses in biodiversity because the responses of biodiversity to climate change will be affected by ecological processes, including threats, operating beyond the scale of individual habitat patches or reserves. Explicit attention will need to be given to both linking and isolating protected areas, depending on the biodiversity objective.

- ♦ Larger areas of habitat will help species survive the multiple additional pressures arising from climate change. This can be accomplished by ensuring existing large areas of habitat are protected from clearing and degradation, and by providing functional connectivity between smaller patches by restoring and maintaining links between habitat patches, for example, local corridors,

stepping stones, free-flowing rivers and riparian vegetation.

- ♦ Higher diversity of habitat types and connectivity within landscapes can help species disperse to and establish in areas with suitable habitat. These can be provided by protecting and restoring habitat in a diversity of environment types and on environmental gradients, and ensuring a variety of disturbance regimes such as fire frequencies and intensities.
- ♦ Within landscapes, parts of the environment that provide refuge for species (habitat and resources) during climatic extremes and ecological disturbance (fire, drought, flood, storms) will be increasingly important to help species survive under climate change. In addition, some places are likely to provide long-term refuge

to contracting species as the climate changes.

- ♦ Ecological isolation is a biodiversity management tool that can be used, for example, to reduce the impacts on persisting species of fire, disease and invasions of new species.
- ♦ Management is necessary at landscape scales because some threats operate at this scale, such as habitat loss and degradation, invasive species and altered hydrology.
- ♦ Current trends in managing biodiversity at landscape scales are sound methods for building the resilience of biodiversity, but specific attention may be required to address:
  - how connectivity is enhanced – what landscape elements are being connected (similar or different types of habitats?), why they are being connected (to increase size, diversity, access to resources, or migration?), at what scale and for the benefit of what species?
  - community values associated with the biodiversity of landscapes as a whole – not just managing landscapes for specific species or ecosystems
  - landscape scale of threats – e.g. preventing spread and re-establishment of invasive species and avoiding the cumulative impacts of land use change and altered hydrology
  - restoration of habitat – especially in heavily transformed environments where large areas of native habitat may need to be re-created.



## 4. Expand the network of protected areas to accommodate significant ecological changes

- Maintain the ‘comprehensive, adequate and representative’ reserve (CAR) principles for the NRS under climate change, but continually re-assess the effectiveness of their implementation as new information becomes available.
- Accommodate and manage establishment of new species and changes in ecosystems in protected area management.
- Work with neighbours to minimise the impacts of land-use change in whole landscapes.

The fundamental principle underpinning the development of the NRS – protecting a diversity of habitat types at multiple scales – will remain effective under climate change as a practical mechanism for conserving values associated with Australian species, ecosystems and landscapes. However, with substantial changes in biodiversity and loss of biodiversity highly likely, additional criteria for selecting priority areas of habitat, including connectivity at multiple scales and refuges, will help enable landscape-scale ecological processes that build the resilience of biodiversity to climate change.

- ♦ The NRS will continue to provide a very wide diversity of native ecosystems and habitat with relatively low levels of threat (aside from climate change) for Australian species.
- ♦ The species and ecosystems found in particular protected areas can be expected to change significantly over time. As this happens, individual protected areas will maintain their conservation value of contributing to the patchwork of different types of habitat within the network of protected areas. The comprehensiveness and representativeness criteria of the NRS framework ensure that the system captures a wide diversity of habitat types, and can support a high diversity of species and ecosystems in Australia as the climate changes.
- ♦ Given the increased level of threat and the dynamics of species, areas

of habitat outside the NRS will be increasingly important, in combination with the NRS, to provide habitat for species and to support ecological processes across whole landscapes.

- ♦ In addition to continuing to target ecological diversity in expansion of the NRS, selection criteria that could increase the effectiveness of the NRS under climate change include:
  - large areas of habitat at risk of fragmentation or degradation
  - refuges from disturbance, especially associated with climatic extremes, and areas that may provide long-term refuge from changing climate
  - areas with high connectivity between diverse habitats, including areas with steep environmental gradients

- areas that reduce the largest gaps between existing protected areas
- areas that support landscape-scale ecological processes, including hydrological processes (e.g. watersheds, floodplains, wetlands, free-flowing rivers).
- ♦ There will be an increased need to factor climate change responses of species, ecosystems and landscapes into the management of individual protected areas. This includes accommodating any changes to conservation objectives and to the complement of species and ecosystems in the protected area, anticipating and responding to new threats, and managing habitat across multiple tenures at landscape scales.
- ♦ The concept of ‘adequacy’ of individual reserves may need to be revised as species become more dynamic, and management may need to focus on maintaining ecosystem health and reducing threats, as opposed to the viability of specific populations.





## 5. Carefully manage interactions between biodiversity and changing land and water use

- Anticipate and respond to complex landscape interactions among land uses and the potential negative impacts of adaptation in other sectors.
- Plan more effectively for extreme events to avoid the need for ‘emergency provisions’ with negative ecological impacts in responses to large floods, fires and droughts.

The level of threat and the sensitivity of biodiversity to threats are both likely to increase as a result of climate change. In particular, changes in land and water use, as other sectors adapt to climate change, have the potential to greatly increase the pressures on biodiversity. However, if carefully managed, changes in other sectors could lead to better protection or restoration of habitat for biodiversity.

- ♦ How other sectors – such as grazing, cropping, forestry, fisheries, water resource management, bushfire management, and tourism – respond to climate change could have adverse impacts on biodiversity. The negative impacts on biodiversity may be outside environmental regulation, or the benefits from other land use may be judged greater than the biodiversity costs, as might happen in intensification of agriculture (including conversion of permanent pasture to cropping and small-scale habitat clearing), activation of sleeper water licences, extraction of groundwater and increased fuel reduction.
- ♦ Careful management, possibly with new regulation and positive incentives, could mitigate some of the potential impacts. In particular, in systems where water availability or biological productivity is decreasing, mass ecosystem degradation could be avoided by ensuring industry adjustment occurs *before* the intensity of current land uses exceeds the capacity of the landscape.
- ♦ Changes in land and water use in other sectors could result in benefits for biodiversity. However, it is likely these may require new partnerships and positive incentives to achieve high uptake and to ensure negative impacts are avoided. For example, biodiversity co-payments may be required to make permanent biodiverse carbon plantings on cleared land more competitive than short rotation bioenergy plantations.
- ♦ In addition to climate change increasing various threats to biodiversity, species are likely to become more susceptible to existing pressures (water extraction, habitat degradation, fragmentation and alien species), therefore managing existing and new threats is increasingly important. Key elements of this include anticipating future threats, monitoring and responding to new threats, and significantly increasing the management of all threats.

## 6. Adapt our biodiversity conservation institutions to new challenges and information

- Achieve balance in management strategies between anticipating change and being responsive to new information.
- Build the capacity of agency staff to understand and accommodate high levels of future change with uncertainty in the detail.
- Engage NRM and conservation groups and the general public in the challenges of the likely future trends and choices of strategies that might be needed.

For biodiversity conservation institutions, adapting to climate change brings the immediate challenge of accommodating high levels of change, loss and uncertainty. It also entails developing ways to continue learning and becoming more responsive to information as it becomes available, over decades, about environmental and ecological change, the effectiveness of alternative strategies, and evolving community values and expectations about conservation.

- Biodiversity managers and agencies need to know about the range of possible responses of species and ecosystems to climate change, how to match strategies to the scale of change and availability of information, and how to obtain and respond to new information about changing biodiversity.
- Effective policy responses require good information about how the community values different aspects of biodiversity and how those values may be affected by climate change.
- Early action with strategies designed to be robust to uncertainty can help reduce future losses; however, as ecological changes occur, management options will need continual re-assessment using the best available science.
- With careful planning, policy and management institutions will be able to increase their ability to acquire and respond to new information.

- The elements of such planning could include:
  - Develop methods to help managers anticipate the range of future ecological change scenarios, and use these across agencies to ensure that conservation objectives and approaches accommodate the likelihood of significant change and are robust to uncertainty about the details of ecological responses. This will encourage understanding of the implications of climate change, identification of critical knowledge gaps and a culture of targeted observation about ecological change.
  - Develop adaptation pathways with a long-term outlook so that early actions are effective stepping stones to more transformative adaptation actions that can be implemented if required as new information becomes available. This will also help avoid early actions that may be effective under low levels of change but maladaptive to higher levels of change, for example, intensive management to maintain ecosystem types.
- Carefully design management experiments to test the effectiveness of different adaptation options: for example, explore large-scale habitat restoration with future-adapted species; compare local-scale and regional-scale connectivity management; test incentives to manage the risks from adaptation in other sectors.
- Implement monitoring that is well designed and tightly linked to those uncertainties about ecological responses that are pivotal to decision making.
- Develop institutional structures that anticipate change, encourage testing, are responsive to unfolding information, and engage with the wider community about changing biodiversity values and new management strategies.
- Adopt a system for assessing program effectiveness that can accommodate uncertainty about shifting baselines in targets.

## 7. Address knowledge gaps to respond to the biodiversity impacts of climate change

- Develop new alliances between science and policy to ensure research about climate impacts and management options is targeted and adopted effectively.

The project identified gaps in the knowledge required for well informed public debate and effective management responses to the impacts of climate change on biodiversity. These include:

- a new discipline of climate change biogeography that integrates the disparate approaches and information about the responses of species and ecosystems to climate change
- debate in science, policy and public domains about suitable objectives for conservation under climate change, informed by community values associated with biodiversity
- regionally specific information about impacts and their implications, combining local ecological expertise with modelling and published information
- more information about landscape processes and features that might give rise to persistence and adaptability of biodiversity
- a richer body of science-policy knowledge to enable managers to determine and seek information of use to them, and to help researchers develop analysis tools and monitoring
- knowledge and tools to help managers balance worthy but competing demands, such as the protection of habitat and management of threats
- more understanding and better use of tools to deal with uncertainty.

Establishing new alliances between science and conservation agencies will ensure that research is focused on priority policy and management knowledge gaps, and help facilitate rapid flow of information into conservation agencies' decision making.

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