NSW GOVERNMENT
Environment, Climate Change & Water

Priorities for Biodiversity Adaptation to Climate Change

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Statement of Intent in response to the listing of Anthropogenic Climate Change as a Key Threatening Process under the NSW *Threatened Species Conservation Act 1995*

Cover photos: (Left) Three Mile Creek, Kosciuszko National Park / S Cohen DECCW. (Top to bottom) River red gums in in drought / M Pennay DECCW. Grass tree /M van Ewijk DECCW. Green turtle / Sascha Schulz.

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Published by:

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ISBN 978 1 74232 928 4
DECCW 2010/771
September 2010

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Acronyms and abbreviations

CAR	Comprehensiveness, adequacy and representativeness
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	Department of Environment, Climate Change and Water NSW
NV Act	*Native Vegetation Act 2003*
PAS	Threatened Species Priorities Action Statement
TAP	Threat Abatement Plan
TSC Act	*Threatened Species Conservation Act 1995*

Executive summary

Protecting native flora and fauna and improving the extent and condition of native vegetation and the health of rivers and wetlands are key objectives of NSW State Plan 2010 (NSW Government 2010). Climate change is emerging as a serious threat to native species and ecosystems and is expected to be an ongoing challenge to the effective conservation of these assets.

Rising temperatures and sea levels and climate-induced changes in fire regimes, water quality and ocean chemistry will have a wide-ranging impact on biodiversity in NSW. Climate change is also expected to intensify existing threats to biodiversity, such as habitat loss, weeds and pest animals, and drought.

Species that have survived previous climatic changes by evolving, moving or changing their behaviour may find it more difficult to use these coping strategies when the change is rapid, especially where their habitat is degraded or lost.

The priorities outlined in this document have been identified in response to the listing in 2000 of 'anthropogenic climate change' as a key threatening process to NSW biodiversity under the *Threatened Species Conservation Act 1995* (see the Appendix). It draws on recent national and state assessments that have evaluated the likely impacts of climate change on species and ecosystems in the state.

A broad range of management strategies and mix of actions from the species level up to the landscape level are needed, particularly in light of the uncertainty around both the climate projections and the ecological impacts. While it will be possible to build on many existing conservation programs as a foundation for conserving biodiversity in the face of climate change, some adjustments and new approaches will also be necessary.

This document outlines priority measures that the NSW Department of Environment, Climate Change and Water (DECCW) will undertake to help biodiversity adapt to a changing climate. They focus on four key areas:

1. Enhancing our understanding of the likely responses of biodiversity to climate change and re-adjusting management programs where necessary in light of this information
2. Protecting a diverse range of habitats by building a comprehensive, adequate and representative public reserve system in NSW, with a focus on under-represented bioregions
3. Increasing opportunities for species to move across the landscape by working with partners and the community to protect habitat and create the necessary connections
4. Assessing adaptation options for those ecosystems most at risk from climate change in NSW

DECCW will take the actions identified in this document (and summarised below) over the next five years.

Addressing the impacts of climate change in biodiversity conservation and natural resource management programs will require new ways of thinking and a long-term commitment. Climate change will affect terrestrial, aquatic and marine biodiversity across all land tenures and to be effective any response will need the cooperation of scientists, conservation managers, landholders and the public.

Ultimately, it is everyone's responsibility to respond to climate change. The contribution of both private landholders, who manage 73% of NSW for agriculture or cropping (ABS 2009), and community groups will be essential in meeting the challenge. DECCW and the state's catchment management authorities are committed to informing and supporting landholders in their efforts.

Summary of actions (2010–15)

Science and research

1.1 Develop research priorities for biodiversity adaptation to climate change with advice from the Climate Change Science Research Network

1.2 Review and evaluate current long-term monitoring programs and develop guidance for considering climate change impacts in monitoring design

Building the protected area system

2.1 Revise guidelines for reserve acquisition to prioritise those landscape features important for biodiversity adaptation, such as refugia, functional connectivity, climatic gradients and water security

2.2 Consider the future viability of proposed reserves when prioritising acquisitions in ecosystems likely to face severe impacts from climate change including:

- *coastal reserves* – consider the risk of sea-level rise and associated inundation and coastal recession and the potential for landward migration of coastal and estuarine communities
- *inland wetlands and woodlands of south-western NSW* – consider water security using regional climate projections when assessing new inland wetland reserves and coordinate priority-setting processes for both reserve acquisition and the purchase of environmental water

2.3 Revise the criteria for assessing conservation values when selecting Conservation Agreement properties and Wildlife Refuges to prioritise those landscape features important for biodiversity adaptation

2.4 Work with other agencies, communities and regional partners to promote and implement conservation programs that build functional connectivity across the landscape through such programs as the Great Eastern Ranges Initiative

2.5 Work with other agencies to identify and protect aquatic ecosystems that are important for providing connectivity and potential refugia in the landscape under likely future climate scenarios

2.6 Identify characteristics and locations of climate refugia in NSW bioregions and prioritise these in criteria for protection

Conservation management

3.1 Review land management programs (fire, invasive species and water management) in light of potential climate change impacts, bringing together key researchers and operational program staff

3.2 Incorporate new knowledge on regional climate projections and potential impacts when developing and reviewing park management processes, such as park plans of management, regional pest management strategies and reserve fire management strategies for:

- *coastal reserves* – use the benchmarks for sea-level rise and risks of coastal recession outlined in the NSW Sea Level Rise Policy Statement to assess the exposure of reserves and identify key vulnerable areas and opportunities for the landward migration of coastal and estuarine habitat, removing barriers where feasible
- *alpine ecosystems (and other at-risk fire-sensitive ecosystems)* – explore options for enhancing mitigation, fire detection, early warning systems and capacity for rapid fire suppression
- *inland wetlands and woodlands of south-western NSW* – consider water security using regional climate projections in the management of inland wetland reserves

3.3 Monitor and review the outcomes of water sharing plans, including the Murray–Darling Basin Plan, to ensure they are adequate to protect, enhance and restore aquatic biodiversity, particularly at times of streamflow variability and low flows, and reduced recharge into groundwater systems

3.4 Consider new regional climate projections and potential impacts when developing and reviewing water sharing plans

3.5 Assess the vulnerability of species and ecosystems at high risk from climate change in NSW rangelands

3.6 Continue to increase the representativeness of the NSW Seedbank, targeting species vulnerable to climate change

Biodiversity planning and regional delivery

4.1 Refine and expand existing modelling approaches and decision support tools (for terrestrial and aquatic biodiversity) to incorporate climate change impacts and support actions 3.3, 3.4 and 4.2

4.2 Provide advice to catchment management authorities on climate projections and regional biodiversity impacts

Regulation and land-use planning

5.1 Consider climate change as part of the reviews of relevant legislation

5.2 Provide advice to the Department of Planning and local councils on how planning instruments can protect areas important for biodiversity adaptation to climate change, such as habitat corridors, climate refugia and high conservation value areas

Education and raising awareness

6.1 Develop and make publicly available web-based material profiling species and ecosystems at risk from climate change in NSW

1. Purpose and scope

This document outlines how the NSW Department of Environment, Climate Change and Water (DECCW) will respond to the listing of 'anthropogenic climate change' as a key threatening process for biodiversity under the *Threatened Species Conservation Act 1995* (TSC Act). Reducing the threat of climate change to biodiversity will require a long-term approach and the implementation of a range of effective mitigation and adaptation strategies.

This document focuses on adaptation measures for biodiversity and outlines priorities for DECCW over the next five years to minimise the impacts of climate change on the state's native species and ecosystems. It builds on initial planning for dealing with biodiversity adaptation developed in several previous national and state initiatives. These include the *National Biodiversity and Climate Change Action Plan 2004–2007* (NRMMC 2004) and the NSW Government's response to implementing this plan (DECC 2007a and 2007b).

The aims of this document are to:

- recognise climate change and its potential as a severe and wide-ranging threat to biodiversity in NSW
- integrate knowledge of climate change impacts into existing DECCW biodiversity conservation programs and policies and water management planning for rivers, wetlands and groundwater
- increase our understanding of climate change impacts on biodiversity to inform future adaptation priorities for biodiversity conservation programs
- outline actions to minimise the impacts of climate change and increase the potential for the long-term persistence of species and functional ecosystems.

2. Our changing climate

2.1 Climate variability in NSW

NSW has a highly variable climate. The Great Dividing Range creates four distinct climate zones: the coastal strip, the high country, the western slopes of the range, and the flatter country in western NSW (DEC 2006). The rainfall regime in NSW is unique in Australia as it includes regions where winter or summer rainfall dominates as well as large areas with a uniform rainfall distribution (BOM 2010). The state also experiences climate extremes, such as widespread flooding and prolonged drought. These climate patterns have been attributed to the combined influences of the El-Niño Southern Oscillation, Southern Annular Mode and the Indian Ocean Dipole (DECCW 2010). However these phenomena are still active areas for research and much uncertainty remains about their future patterns and influence.

Long-term changes in climate have driven processes such as evolution and extinction, with the species and ecosystems that survive today successfully adapting to the changes. In particular, most ecosystems in Australia have had to cope with an extremely variable rainfall regime (DECCW 2010). In general, arid and semi-arid species are better adapted to this variability than many species in coastal and tropical areas where the rainfall is more regular and reliable.

Understanding past climatic patterns and their ecological impacts will help assess the likely impacts of future climatic variability and change on ecosystems.

2.2 How has the climate changed?

The Intergovernmental Panel on Climate Change (IPCC) has assessed that the Earth's climate has warmed and that the rise in average global temperatures since the mid 20th century is very likely the result of increasing levels of greenhouse gas concentrations (IPCC 2007). Evidence of this warming includes increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels (IPCC 2007).

In NSW, recent climate records which exclude historic variability show an accelerating increase in average annual temperatures. Between the 1950s and 1980s, average annual temperature rise was around 0.1°C per decade, but since 1990 it has been about 0.5°C per decade (DECCW 2010). Additionally, from 1997 to 2007, all years were warmer than average, an unprecedented sequence in the historical records.

2.3 How is the climate in NSW likely to change?

Developing refined regional climate projections for NSW

In the past it has been difficult to predict the regional impacts and risks from climate change because the scale of climate projections has been too coarse. The Climate Change Research Centre at the University of NSW, in partnership with DECCW, has refined regional projections to 2050 for the following climate variables that directly affect biophysical systems in NSW: rainfall, evaporation, and maximum and minimum temperatures (see DECCW 2010 for a detailed summary).

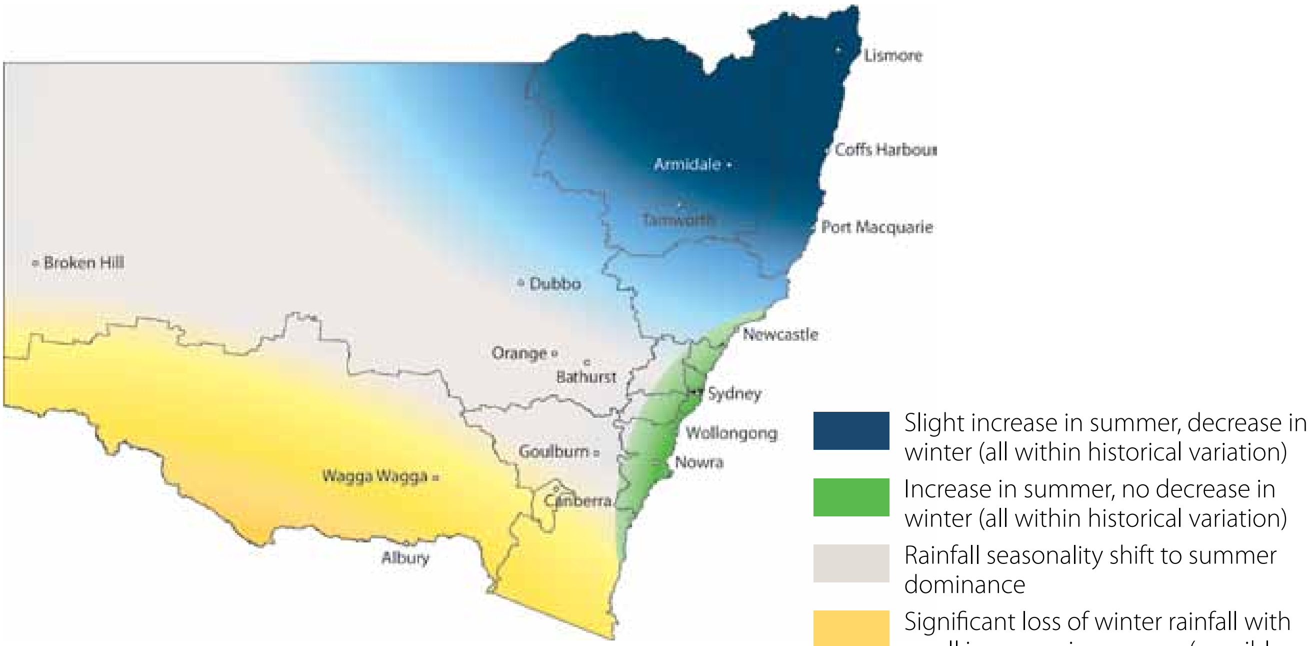
These projections were based on the selective use of outputs from four global climate models that best fit south-eastern Australian conditions, applied to a single, realistic emissions scenario, known as the 'A2 scenario'. Based on current growth trends in global emissions and the latest climate observations, this scenario assumes rapid economic growth and a low uptake of alternatives to carbon fuels. No new model development was involved, with the projections using the model outputs employed by the IPCC in its most recent assessment report (IPCC 2007). The projections, however, do not account for natural variability and are less certain in coastal regions than inland areas.

Projections of sea-level rise in NSW to 2050 and 2100 are based on projections from the IPCC and CSIRO (DECCW 2009a).

Summary of likely changes in NSW climate

The regional climate projections are presented in full in *NSW Climate Impact Profile* (DECCW 2010). The main projected changes for NSW to 2050 can be summarised as follows:

- **Increasing temperatures**, with higher maximum and minimum temperatures very likely across NSW in all seasons
- **Regionally variable changes in rainfall seasonality** – A slight increase in summer rainfall in north-eas NSW and a significant decrease in winter rainfall in south-western regions is likely (Map 1). Many parts of the state will experience a shift from winter-dominated to summer-dominated rainfall, which may have implications for the duration and severity of drought in these areas. Significantly, the drying of the autumn, winter and spring seasons in the south, and particularly the south-west, is expected to be outside the range of historical variability.
- **Significant reduction in winter snowfalls** on the Alps and Southern Tablelands, with warmer conditions producing rainfall instead of snow at higher elevations
- **Significantly increased potential evaporation** across much of NSW by 2050 because of higher temperatures, which may counteract expected increases in summer rainfall and result in drier soils
- **Sea-level rise of 0.4 m by 2050 and 0.9 m by 2100**, both relative to 1990 mean sea level – In lower areas of coastal flood plains, sea-level rise is very likely to exacerbate catchment-driven flooding, resulting in increased flood frequency, height and extent. Sea-level rise will also directly increase low, mid and high tide levels. This is very likely to expose larger areas of low-lying land around coastal waterways to more frequent tidal inundation.



Map 1: Projected average changes in rainfall in 2050 (DECCW 2010)

Future changes in climate will include changes in both average conditions (such as mean temperatures and seasonal rainfall patterns) and extreme events (CSIRO and BOM 2007). Projected changes in Australian weather extremes include increased wind speed in most coastal areas and substantial increases in fire weather risk in south-eastern Australia (Lynch et al. 2008). For example, in Sydney and the Blue Mountains, bushfires are likely to occur more frequently and extensively as a result of climate change by 2050 (Pitman et al. 2007; Bradstock et al. 2008).

A crucial point is that *accelerated* rates of change in some climate variables will increase the selective pressure on many organisms (Steffen et al. 2009). Rapid change may overwhelm the adaptive capacity of many species and lead to widespread reorganisation of ecosystems and an increasing number of extinctions. Another concern is that actual measurements of several climate variables are currently at the high end of, or exceeding, the range of scientific projections of climate change (Rahmstorf et al. 2007; Raupach et al. 2007). Mitigation activities are thus vital to reduce the overall magnitude and rates of change that species will face in coming decades.

3. Climate change: a broad-scale threat to biodiversity

3.1 Threatening processes for biodiversity

NSW has a great diversity of native species and ecosystems. Their natural value is internationally recognised through the listing of a number of World Heritage areas, wetlands identified as internationally significant, and the protection of species by international agreements. Biodiversity is intrinsically valuable and critical to ecological and economic sustainability and the delivery of ecosystem services (MacNally et al. 2008; Steffen 2008; Steffen et al. 2009).

For conservation measures to be effective they must ameliorate threats that either directly or indirectly increase the risk to species, populations and ecosystem functions (Auld and Keith 2009). As threatening processes affect multiple species and ecosystem processes, taking action to reduce one threat is likely to produce broad benefits by reducing risks to many species. Climate change is considered by Auld and Keith (2009) to be one of the five major threats to biodiversity, the others being destruction and fragmentation of habitat, changes in disturbance regimes, threats reducing functionality of biological interactions or life cycle processes, and over-exploitation of native species. Climate change may also exacerbate several existing threats to biodiversity. For example, changes in rainfall and temperature could alter the distribution of pests and weeds and create new opportunities for the establishment of some species.

*Changes in the frequency and intensity of fires are likely to have a major impact on many ecosystems/*M Lauder DECCW

3.2 Effects of climate change on biodiversity in NSW

Learning from the past

Knowledge of species' responses to past climate variability can shed light on how they may respond to the changes in climate ahead (Harle et al. 2005). Australian palaeo-ecological records suggest that species responded to past climate change through changes in relative abundance (including extinctions) and persisting *in situ* (possibly including evolution into new species and surviving in microrefugia) rather than continental-scale changes in their distribution (Markgraf et al. 1995; Markgraf and McGlone 2005; McGlone and Clark 2005). For example, research indicates that over the last 700,000 years many of the biota of southern Australia persisted through climatic changes in patchy localised refugia rather than moving long distances (Byrne 2007).

Past global environmental change has caused species loss and changes in range. Many species, however, have been able to persist through multiple cycles of warming and cooling because of a range of attributes and responses. These are outlined by Mackey et al. (2008) and include:

- local adaptation through microevolution
- the ability of an organism to change within its own lifetime but not genetically, such as changing growth form from tree to shrub in response to reduced water availability ('phenotypic plasticity'), thus allowing it to survive in changing ecosystems
- dispersal to, and establishment at, more suitable locations
- reductions in range to micro-habitats (e.g. refugia) that retain necessary niche and habitat requirements
- persistence because of a wide fundamental niche requiring a generalised habitat.

Although many native species have managed to persist through significant climate variability, the future changes in climate and the context for biodiversity persistence and adaptation may differ from the past. This is because in many regions the future rates of change may exceed past rates (Overpeck et al. 2005) and other concurrent threats to biodiversity will limit potential responses. For example, habitat loss and fragmentation may constrain options for the movement of species or reduce suitable refuge habitats. In addition, many of these (such as land clearing, invasive species and pollution) are historically new threats and the compound effects with climate change are relatively unknown. Thus Mackey et al. (2008) argue that while in the past a full complement of adaptive response mechanisms was potentially available to a species, this is no longer necessarily the case.

Mechanisms of future impact

Climate change will affect biodiversity both directly (through impacts from changes such as rising temperatures and sea levels, changes in water availability and ocean chemistry) and indirectly (via interactions with other threats to ecosystem function and changes to the interactions between species). Relatively modest changes in climate over the past few decades have already affected species distributions, life cycle events, abundances, genetic make-up, species interactions and ecosystem-level processes.

Sea level rise is likely to threaten estuarine communities such as those at Wagonga Inlet near Narooma/J Lugg DECCW

Responses to climate change already observed in Australia

Observed shifts in range (particularly expansions at cool boundaries rather than contractions at warm margins), along with changes in the timing of life-history events, are the best documented of recent impacts that have been linked to a climate signal (reviewed in Hughes 2000; Walther et al. 2002; Parmesan and Yohe 2003; Parmesan 2006; Hennessy et al. 2007; Steffen et al. 2009).

Some observed changes in species in Australia consistent with a climate-change signal include:

- native and introduced animals from lower elevations colonising alpine ecosystems (Green 2003; Pickering et al. 2004)
- widespread reductions in the occurrence of freshwater invertebrates in rivers and streams that prefer cooler and fast-flowing water bodies (Chessman 2009)
- kookaburras hunting at higher altitudes in the Australian Alps, which were once too cold for them, and preying on alpine skinks that have not yet learned to identify them as predators (Low 2007)
- sleepy lizards (*Tiliqua rugosa*) changing their mating behaviour with warmer and drier winters leading to earlier pairings (Bull and Burzacott 2002)
- landwards transgression of mangroves into saltmarsh environments over the past five decades in estuaries in Queensland, NSW, Victoria and South Australia with multiple causes, including sea-level rise (Saintilan and Williams 1999)
- declines of giant kelp forest communities in the coastal waters of eastern Tasmania associated with changing oceanographic conditions including warming temperatures (Edgar et al. 1997; Edyvane 2003).

The types of likely climate change impacts on biodiversity and the species and ecosystems most vulnerable to these changes can be catalogued (see 'Species at risk from future changes in climate in NSW' below). However, there remains great uncertainty about how these impacts will unfold. Climate change is the most pervasive and least understood and predictable of the threatening processes affecting biodiversity (Auld and Keith 2009).

Some biological responses will be rapid, others will take decades or centuries to materialise and species are expected to respond in their own individual ways to climate change (Lovejoy and Hannah 2005). Novel climates may emerge, with combinations of temperatures, rainfall and seasonality that have no current analogues (Steffen et al. 2009). Increasing frequencies and intensities of extreme events increases the potential for tipping points and thresholds in ecological systems to be breached (Steffen et al. 2009).

In response to a changing climate, some species may be able to adapt, evolve and move if local conditions become unsuitable. Short-lived species have some potential for evolutionary adaptation in response to climate change (Skelly et al. 2007), but many of them will not have the capacity to move at the rates likely to be required and these species face an increased risk of extinction (Midgley et al. 2006; Morin et al. 2008).

Changes in climate will also have significant impacts on freshwater and marine biodiversity. Increases in the variability of river flows, wetland inundation and groundwater recharge will influence aquatic biodiversity, particularly those species that respond to seasonal flow or inundation cues (such as fish, frogs and aquatic plants). Sea-surface temperatures around Australia are predicted to increase by 1-2°C by 2070, with the greatest warming in south-eastern Australia and the Tasman Sea due to the strengthening of the East Australian Current (Hobday et al. 2006). Increased concentrations of carbon dioxide in seawater is already acidifying the oceans. Predicted consequences for marine biodiversity include changes in the abundance, distribution and reproductive patterns of marine organisms and consequently food-web dynamics, regular bleaching of coral, and erosion of carbonate shells (such as those formed by molluscs and corals) (Hobday et al. 2006).

Climate change, however, will not cause declines in all species. The risk of extinction for many widespread, generalist species found across a range of habitats may be low and some species may be able to disperse sufficiently to maintain large populations and ranges (such as highly dispersive insects or birds) (Hoegh-Guldberg et al. 2008). Changes in climate may also result in new opportunities for invasive species, both exotic and native (Lovejoy 2005).

Species at risk from future changes in climate in NSW

Species with the following traits or particular habitats may be vulnerable to the impacts of climate change. Note this list is not in any particular order and there may be other factors or traits that increase vulnerability to climate change.

Dependence on habitat that is likely to disappear or become unsuitable

This includes species confined to alpine regions and mountain tops (such as the mountain pygmy-possum, alpine frogs and cloud forest species) and low-lying coastal areas (such as seagrass, mangrove and saltmarsh communities). However, some species may reduce their exposure to risk through their use of microhabitats. For example, regions of high topographic relief, dissected plateaus with cool, moist gorges or boulder fields and logs may provide refugia for some species in the short term as the regional climate warms (Steffen et al. 2009).

Narrow ranges of physiological tolerances

Species and ecosystems that are dependent on historical climatic regimes (including particular thresholds, seasonal characteristics and patterns within and between decades) may be more at risk. For example, plants with seedbanks activated by fire may be disadvantaged (compared with those that resprout from dormant buds) in areas where fires become more frequent (Hammill 2007). Species with narrow thermal tolerances (such as low upper lethal temperatures or strict temperature requirements for seed production) are more at risk (DECCW 2010). Physiological changes may also alter competitive interactions. For example, in the terrestrial environment increased levels of carbon dioxide may shift vegetation from herbaceous to increasingly woody growth forms (Berry and Roderick 2006). In the marine environment, increased CO_2 may raise ocean acidity, reducing the ability of calcifying organisms (such as corals) to build and maintain skeletons (Hoegh-Guldberg et al. 2007).

Specialised dependent relationships with other species

Species that depend on inter-specific relationships (such as pollinators, parasites, competitors and predators) may be at risk (Steffen et al. 2009). For example, individuals may respond to changes in climate by altering their behaviour or the timing of life cycle events such as flowering, dispersal, migration and reproduction. As species respond at different rates to changes in climate, progressive decoupling of present-day interactions between species may also occur (Steffen et al. 2009).

Restricted habitat and/or existing decline caused by other threatening processes

Species that have a restricted habitat (such as a particular soil type) or are naturally localised (or have become so after habitat clearing) may be at risk. These species have no back-up refugia and will be under increasing threat from climate change. Examples include highly localised plants such as the Nielsen Park she-oak, Bolivia Hill boronia, a number of *Zieria* species, and such animals as the eastern bristlebird and Lord Howe Island woodhen. However, the narrow ranges of some species may be due to species-species interactions rather than their fundamental environmental niche. These species may thus have a greater capacity for response to climate variability than their current geographic range might suggest (Steffen et al. 2009).

Limited capacity to move at the rate dictated by climate change

An ability to disperse across landscapes will be crucial in determining the capacity of a species to adapt to shifting climatic zones. Species that might be at risk due to poor dispersal capacity include those in highly diverse heathlands on nutrient-poor sandstone on the coast and tablelands and plants primarily dispersed by ants (Tony Auld, DECCW, pers. comm.). Conversely, animals capable of flight, plants with small, numerous seeds dispersed by wind and water, and those with seed dispersal vectors capable of long-distance movement (such as birds and bats) will be better able to disperse to new sites (Steffen et al. 2009). However the capacity for mobile species to disperse to more suitable areas will depend on the 'permeability' of the landscape between suitable habitats (Steffen et al. 2009): for example, physical barriers, such as extensively cleared land, may prevent some species from shifting their range.

Limited ability to adapt *in situ*

Some species may be able to adapt genetically or have sufficient phenotypic plasticity to tolerate new conditions *in situ* (Skelly et al. 2007; Agosta and Klemens 2008; Steffen et al. 2009). However, knowledge about this group is limited (Auld and Keith 2009). In assessing the potential limits on evolutionary response to climate change, both the species of interest and the environmental context will affect evolutionary responses, and there is likely to be a range of outcomes (Skelly et al. 2007).

4. Regional impacts of climate change on NSW ecosystems

4.1 NSW Climate Impact Profile

DECCW has recently assessed the likely biophysical impacts of climate change throughout NSW to 2050 in the NSW Climate Impact Profile (DECCW 2010). The profile includes regional impact 'snapshots' and will inform DECCW's planning and response strategies.

Projections of climate in 2050 (Section 2) and the physical responses to these changes (including sea-level rise and changes in runoff and fire regimes) were used to assess likely regional impacts on biodiversity, soils, stream flow, the coastal zone and the risk of flooding. The results were combined into an integrated assessment of the main impacts of climate change on land, settlements and natural ecosystems that can be expected across NSW by 2050.

Technical working groups assessed each biophysical component with approaches that varied according to our current understanding of it. For example, biodiversity was assessed through a series of expert regional panels of ecologists, whereas computer modelling was used to estimate changes in runoff and stream flow.

4.2 Summary of climate change impacts on ecosystems in NSW

The NSW Climate Impact Profile has identified some of the likely impacts of climate change on natural ecosystems across the state at a regional level. Natural ecosystems include biological communities, individual species and ecological processes. The profile found the following impacts are expected:

- The structure, composition and function of ecosystems are likely to change through the loss of some sensitive species and the persistence and spread of some hardy generalists and invasive species.
- Distributions of individual species are likely to change with northerly species extending further south and many ecosystems contracting to higher altitudes, leading to changes in primary and secondary production and other ecological processes.
- Sea-level rise resulting in saline intrusion and receding coastlines may eliminate some coastal ecosystems and threaten some estuarine communities. These include rainforests, wetlands, heaths and dry forests of the coastal sands, rock platforms, beaches, sand spits and mudflats, seagrass beds, mangroves and saltmarshes. A loss or decline of these ecosystems would affect species such as resident and migratory shorebirds, waders and fish populations.
- Changes in the frequency and intensity of fire may have widespread impacts through the loss of fire-sensitive species and changes in forest structure and composition.
- Many high-altitude treeless communities (including montane and tableland bogs) are likely to contract. Other ecosystems most likely to be affected include temperate rainforest, cool-climate wet sclerophyll forest and grassy woodlands.
- Snow-dependent species are likely to be lost because they will be unable to migrate to suitable habitat elsewhere.
- Reduced rainfall, loss of spring snow-melt and altered rainfall seasonality are likely to cause major ecological changes in the Riverina–Murray region.
- Species and ecosystems stressed by other factors are more likely to be affected by climate change.

Current science (as presented in the Climate Impact Profile and other published research) suggests that the ecosystems in NSW that may face the most severe impacts from climate change are those along the coast and in alpine areas, the inland wetlands and woodlands of south-western NSW, marine systems and some fire-sensitive ecosystems. Adaptation options must be assessed for these ecosystems to make the best investments in conservation.

5. Reducing the impacts of climate change on biodiversity

5.1 Importance of mitigation and adaptation

The impacts of climate change on biodiversity can be reduced through two complementary measures: mitigation and adaptation (Steffen et al. 2009). *Mitigation* attempts to limit future changes in global climate by both reducing emissions of greenhouse gases (through emission control measures) and removing gases already in the atmosphere (via carbon sinks). Greenhouse gases come from many sources and effective mitigation will require a concerted effort from all parts of the community, including government, industry and individuals. Reducing emissions lessens the magnitude and rate of change experienced by species and ecosystems.

Some greenhouse gases persist in the atmosphere for decades, centuries or longer. The greenhouse gases already emitted will cause the climate to continue to change over future decades or longer, even without further emissions (IPCC 2007). Mitigation on its own is therefore not enough and adaptation measures are vital to reduce the vulnerability of biodiversity to unavoidable changes in climate.

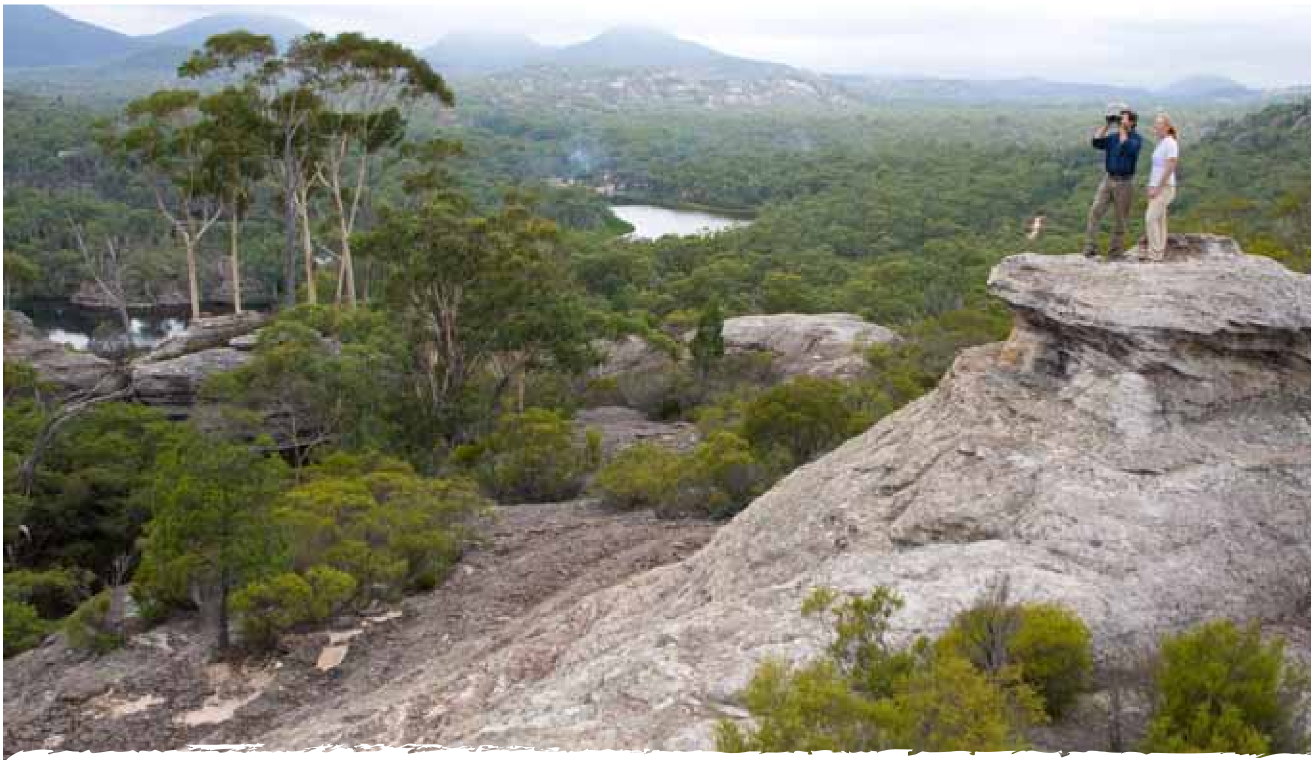
Adaptation aims to increase the resilience of ecosystems and decrease the risk of ecosystem degradation or collapse (NRMMC 2004). In the context of climate change, Steffen et al. (2009) defines 'resilience' as the extent to which ecosystems can cope with a changing climate and continue to exist in their current state. The related term 'transformation' refers to substantive changes (transition to a new state) in response to changes in climate. However, the use of terms such as resilience and transformation depends on the scale to which they are applied: for example, transformation at one scale may be necessary to deliver resilience at higher scales.

5.2 Building on existing biodiversity conservation management programs

Many existing biodiversity conservation and natural resource management programs in NSW already help build the resilience of native species to climate change by reducing threats to their survival and promoting landscape functionality through improved connectivity. Some current programs include:

- **Building and managing the terrestrial and marine protected area system in NSW:** This includes expanding the terrestrial public reserve system by over 2 million hectares over the last decade and undertaking programs to manage invasive species and fire. The area of land managed for biodiversity includes public reserves complemented by protected private lands. Protecting more habitat will help species cope with climate change and should be continued as a priority.
- **Working with catchment management authorities (CMAs) and local government and supporting private land conservation initiatives** (such as the Great Eastern Ranges Initiative) to identify priority areas across the landscape for restoration and conservation management
- **Developing water sharing plans** to provide environmental water and buying water for environmental benefits through the NSW RiverBank fund
- **Regulating the clearance of native vegetation through the *Native Vegetation Act 2003*:** Protecting remnant native vegetation will be vital in increasing the capacity of biodiversity to persist in a changing climate.
- **Developing statewide natural resource management targets and regional investment programs** to protect and restore vegetation and assist landholders to adopt conservation management actions
- **Developing regional biodiversity management plans** to identify priority areas for conservation across the landscape and coordinate recovery efforts for threatened species and communities
- **Managing threatened species and areas of high conservation value** through regulation, environmental planning instruments and assessment, recovery programs and the Priorities Action Statement under the *Threatened Species Conservation Act 1995*, and protected areas declared under the *National Parks and Wildlife Act 1974* and other similar legislation

These activities are a foundation for conserving biodiversity in the face of climate change but will need to expand and develop as our understanding of the likely impacts on biodiversity grows.



*Wildlife corridors, such as this near Dunns Swamp in Wollemi National Park, will allow some species to move across the landscape in response to threats like climate change/*You shoot.tv

5.3 Biodiversity conservation in a changing climate

Biodiversity adaptation principles

The vulnerability of Australia's biodiversity and national reserve system (NRS) to the impacts of climate change has recently been assessed (Dunlop and Brown 2008; Steffen et al. 2009). These national assessments acknowledge the potential for large and rapid transformations of biodiversity due to the impacts of climate change in concert with other threats. They suggest changes are inevitable and that some species will be lost while others will not persist in their current locations. The structure and composition of individual locations may change over time, but the aim for management is for the function and values of the system as a whole to persist. Key messages from these national assessments that can be used to guide future conservation management include:

- **Build resilience to give species, ecological communities and ecosystems the best chance to adapt:** Approaches include expanding existing threat management programs at the landscape scale, increasing the extent and representativeness of the NRS, enhancing understanding and management of disturbance regimes, increasing opportunities for dispersal across the landscape, protecting key refugia, and managing keystone species.
- **Many existing conservation approaches are likely to continue to be important under climate change:** However, some adjustments and new approaches may be needed. These may include more pro-active interventions, such as assisted migration (translocation), reintroductions, managing invasive native species and *ex situ* conservation for taxa at high risk of decline or extinction.
- **Spread risk by implementing a range of conservation strategies, coupled with adaptive management approaches:** This is an effective way to deal with scientific uncertainties.

Managing for uncertainty

A diversity of management responses is needed as there is much uncertainty in forecasting future climates and predicting their likely environmental and ecological consequences. Implementing a broad range of strategies that includes reducing existing threats, increasing the rate of protection of remnant vegetation and functional connectivity, and protecting climate refugia spreads the risk associated with different management actions.

Where a good understanding on the likely impacts of climate change is available, resources need to be committed in the absence of perfect information. For example, sea levels are rising and ecosystems vulnerable to this have been identified so actions to minimise the impacts of rises need to be taken now. This is consistent with the accepted general principle of environmental management, the Precautionary Principle, where action is taken to avoid serious environmental harm in the absence of scientific certainty. The application of this principle is critical to managing the impacts of climate change that have the potential to be severe and in some cases irreversible.

Prioritising conservation actions

As the impacts of climate change unfold and biodiversity comes under further pressure, there will be an increasing need for discussion and debate about what change is acceptable and what we as a society want to maintain. As ecological components shift with the climate we may need to reconsider our conservation priorities. Priority setting requires an assessment of ecological, cultural and economic values, as well as consideration of the importance that society places on particular species, ecosystems and natural areas. Societal value of biodiversity is difficult to gauge and even harder to quantify. However, community involvement in the debate about priority setting in a changing climate, and better information about what impact climate change may have on biodiversity values will be important (Dunlop and Brown 2008).

6. Responding to anthropogenic climate change: key challenges and actions

This section describes six key challenges and the actions DECCW will take to respond to them over the next five years. Existing DECCW resources or external grants will be required to implement these actions. The actions listed under each challenge may not be exclusive to that challenge. There is a high degree of interaction and value-adding associated with many of the actions, so one particular action may address a number of challenges. The indicative time frames allocated to each action are:

- *short term*, i.e. 1–3 years
- *medium term*, i.e. 3–5 years
- *long term*, i.e. 5 years or more.

Reducing the impacts of climate change will be a long-term challenge. Due to the uncertainty around the climate projections and their potential impacts, there needs to be a broad range of management strategies and a mix of actions at each of the species, community and landscape levels. Short-term actions are focused on reducing existing threats, protecting a diversity of habitats (both on- and off-reserve), increasing opportunities for dispersal across the landscape, and assessing adaptation options for the ecosystems identified as likely to face the most severe impacts from climate change in NSW.

At the same time, it is fundamentally important to:

- increase our understanding of potential climate change impacts and their interaction with other threats to biodiversity
- communicate this to the general public
- integrate climate change considerations into regional biodiversity conservation and land-use planning and regulation.

Future and longer term directions include exploring or trialling more pro-active measures, such as translocation.

Incorporating climate change impacts into current biodiversity conservation programs and policies is a goal of this document. Key climate change issues can be addressed within adaptive management frameworks that currently guide conservation planning across DECCW (Section 5.3). Some current DECCW programs and policies may need to be reviewed and supporting systems updated as new knowledge on impacts becomes available to deal with added risks from climate change. Outcomes from research and the monitoring and evaluation of management programs should inform future management.

Challenge 1: Improving scientific understanding of climate change impacts on biodiversity conservation

Improving our scientific understanding of the impacts of climate change on biodiversity is an overarching challenge. Good science underpins adaptive management decisions and informs decision-making, planning and policy development. Effective adaptation strategies and actions to meet the other five challenges in this document must be informed by up-to-date scientific knowledge.

The NSW Climate Impact Profile is a first step towards improving our understanding of the regional implications of climate change for biodiversity in NSW (Section 4). Several research projects funded under the Climate Change Impacts and Adaptation Research Program (NSW Government 2005; DECC 2007a; DECC 2007b) have also contributed to our understanding of climate change impacts. These include projects on invasive species (DECCW 2009d); biodiversity (Auld and Keith 2009); bushfire risk in the Sydney region (Bradstock et al. 2008); inland aquatic ecosystems (Rogers et al. 2009); and the extension of regional conservation planning tools to address potential climate change impacts (DECC 2008a).

Key knowledge gaps

Gaps in ecological knowledge will hinder effective management of biodiversity under climate change. While the types of ecological impacts as a result of climate change might be known, it is almost impossible to predict the impacts that will occur (and at what rate) for specific species or locations (Dunlop 2008). These significant knowledge gaps limit predictions of the likely responses of species to future climates.

The development of risk assessment models that integrate habitat and bioclimatic data with demographic, physiological and genetic processes would improve our capacity to predict likely climate-change impacts and identify species or ecological communities at risk (Auld and Keith 2009). A number of approaches is currently emerging (Keith et al. 2008; Anderson et al. 2009) and DECCW is actively collaborating with university partners to further the development of such models.

Given the scale of the ecological complexities, uncertainties and knowledge gaps, it is important to seek opportunities to collaborate with research institutions on identified research priorities. A Climate Change Science Research Network has been established to enhance links, knowledge transfer and collaboration between the NSW Government and leading scientists from other institutions.

Over the next five years, DECCW will work in partnership with the network, NSW-based universities and other government agencies to carry out research in line with identified climate change impact and adaptation research priorities. This collaboration recognises the considerable effort already invested in research and model development in NSW and intends to both enhance existing research programs and develop new projects to address critical knowledge gaps. This may include research projects to improve our understanding of climate systems (including past and present climate and natural variability) and to identify and assess impacts for native vegetation and terrestrial biodiversity, the coastal zone and sea-level rise, rivers and other freshwater ecosystems, and soil and land systems. Processes will also be set up to aid the communication of research results and ensure the appropriate transfer of knowledge into conservation management programs.

At a national level, there may be opportunities for collaboration or research relevant to meeting the priorities identified in this document via the National Climate Change Adaptation Research Facility (NCCARF). One of the key roles of the NCCARF is to coordinate the development of national adaptation research plans in a number of priority theme areas that identify critical gaps in the information available to decision-makers and set national research priorities (NCCARF 2010). Research plans being developed for several priority theme areas that are relevant for this document including terrestrial biodiversity, marine biodiversity and resources, water resources, and freshwater biodiversity.

Monitoring

Monitoring is vital to filling key knowledge gaps about the response of biodiversity to climate change and evaluating the success of management actions. However, incorporating climate change impacts into existing monitoring programs or designing and implementing monitoring programs specifically to detect the impacts of climate change is difficult for a number of reasons:

- There is still a large amount of uncertainty about which species and ecosystems are most sensitive to climate changes.
- Changes in biodiversity caused by changes in climate may be difficult to distinguish from those caused by other threats that have developed at the same time.
- The period of time necessary to detect changes may be longer than the time for which we have records.

Some long-term monitoring programs are already under way in areas vulnerable to climate change. For example, ongoing monitoring programs over the last 40 years by DECCW scientists in the Snowy Mountains (Green 2003) have recorded changes in snow depth and dates of the break-up of ice on alpine lakes, together with the responses of vertebrate fauna. Over the last decade a network of monitoring sites in NSW estuaries has examined the response of mangroves and saltmarshes to sea-level rise. Many existing monitoring programs may not have been initiated specifically to detect responses to changes in climate, but can help to establish ongoing trends. This includes monitoring the impacts of drought and fire on ground-dwelling small mammals over the last 36 years in the Nadgee Nature Reserve in south-eastern NSW (Recher et al. 2009); monitoring perennial plant populations in arid NSW (Denham and Auld 2004); and monitoring associated with the implementation of biodiversity management plans and threatened species recovery plans.

Current (often long-term) monitoring programs need to be reviewed and evaluated for both their cost-effectiveness as information providers and whether they have detected a climate signal. Ideally, any new monitoring programs established specifically for detecting the impacts of climate change on biodiversity would be linked to a national program and designed to provide information on the following:

- rates of ecological change, including early warnings of key changes in ecological processes
- types of ecological change, such as *in situ* changes in species abundance, changes in interactions between species and distributional shifts
- patterns of geographic range shifts over elevational and latitudinal gradients
- changes in other threats to biodiversity and their interactions with climate change
- detection of new invasive species at sites and changes in abundance and dynamics of species that may become problematic in the future
- effectiveness of management actions.

Alpine complex*/S Cohen DECCW*

Coastal saltmarsh*/S Ruming DECCW*

Challenge 1:
Improving scientific understanding of climate change impacts on biodiversity conservation

Actions

1.1 Develop research priorities for biodiversity adaptation to climate change with advice from the Climate Change Science Research Network ... *short-medium term*

1.2 Review and evaluate current long-term monitoring programs and develop guidance for considering climate change impacts in monitoring design ... *medium term*

Challenge 2: Building the protected area system to protect a diversity of habitats and increase opportunities for dispersal across the landscape

Protecting more habitat is one of the most effective ways to maintain viable populations of a wide range of species. Building a diverse protected area system of terrestrial habitats (including freshwater) and marine habitats is critical in the face of climate change. Reserves protect natural habitat and source populations of native species, function as carbon sinks, provide refugia for species from many environmental and human threats, and allow for species to migrate along altitudinal and latitudinal corridors. However, in many instances, ecological processes operate at larger scales than reserves so conservation actions in the lands beyond the reserve system are important for maintaining ecosystem function (Soulé et al. 2006). In NSW, the reserve system is only one element of a larger network of private and public lands that supports biodiversity conservation across the landscape.

Building a diverse 'CAR' reserve system in NSW

Almost 6.7 million hectares of NSW is protected in conservation reserves, established under the *National Parks and Wildlife Act 1974*. This includes national parks, nature reserves, state conservation areas, karst conservation reserves, historic sites and Aboriginal areas. Reserves are places where non-climatic stresses can be more effectively limited through management and enforcement and contain areas that may act as seed populations for use outside of reserves. In addition to conserving biodiversity, reserves also protect water catchment quality; Aboriginal cultural heritage sites and artefacts; historic and geologic heritage; and resources for scientific study and education (DECC 2008b).

A specific NSW Government objective is to build a 'CAR' public reserve system, one that is 'comprehensive, adequate and representative' (DECC 2008b). A reserve system built using CAR principles will protect a diverse array of habitats and ecological processes, which is critical to minimise the impacts of climate change for biodiversity. These principles will continue to be important and applicable when making additions to the reserve system in times of climate change (Hughes 2008; Dunlop and Brown 2008). However, there needs to be greater emphasis on landscape diversity, including both well-connected and isolated areas of habitat, and the degree of physical heterogeneity rather than current biotic composition (Hughes 2008; Steffen et al. 2009).

The NSW National Parks Establishment Plan 2008 (DECC 2008b) identifies priorities for building the state's parks and reserve system in biogeographic region clusters across the state. The plan focuses on the inclusion of under-represented bioregions and ecosystems in the reserve system and augmenting existing reserves to improve their size and configuration. This will involve establishing new reserves in western and central western NSW, building up existing reserves in the western slopes and tablelands, and consolidating existing reserve boundaries along the coast and coastal ranges.

Protecting freshwater systems will become increasingly important as climate change places further stress on the water available for a variety of uses. The establishment plan identifies, as a priority, the protection and representation of aquatic ecosystems, habitat and biodiversity in the reserve system. DECCW currently targets the protection of inland and coastal wetlands and riverine-dependent ecosystems of high conservation value, as well as 'wild rivers' within national parks and reserves.

The distribution of species and ecosystems across the landscape will change over time as the climate changes and designing the protected area system for conservation needs to consider these potential shifts in range (Hannah et al. 2002; Hughes 2008). For example, as sea-level rises, coastal species may need room to move landwards. Future distributions of species have been predicted through the use of bioclimatic models (Williams et al. 2003; Thomas et al. 2004). Although these types of models have inherent assumptions and limitations, they can provide a good first guide to 'realised' niches in both current and future climates and a 'first cut' in understanding future changes (Steffen et al. 2009).

Some of the key issues that climate change raises for setting priorities for future reserve establishment are discussed below. As a first step, DECCW will review the current guidelines used for reserve acquisition to ensure they prioritise landscape features identified as important for biodiversity adaptation, including refugia, functional connectivity, climatic gradients and water security.

Climate change and reserve establishment

Changes in biodiversity values across the landscape due to climate change will have implications for identifying and prioritising areas for reserve acquisition. To make the best investment choices there is a need to protect areas and ecosystems that build the resilience of biodiversity to climate change. In the short term, increasing protection of the full range of native ecosystems will help minimise losses as ecosystems respond to climate change.

As the impacts of climate change are very hard to predict, it is likely that the best approach to minimise species loss will be to protect a diversity of habitats at a range of scales (Dunlop and Brown 2008). This allows a wide range of environmental conditions to be available to help native species survive as ecosystems and habitats change over time. For this reason, the current framework for reserve acquisition – comprehensive, adequate and representative ('CAR') – is well suited for developing a system of protected areas that remains effective during climate change. However, many ecosystems remain unprotected and need to be targeted for inclusion. Further, the levels of reservation required to prevent the loss of biodiversity are likely to increase under climate change (that is, the 'adequacy' component of CAR). More species are likely to have a greater chance of surviving if larger areas of habitat and larger effective population sizes are protected.

When making decisions on priorities for future reserve establishment, some of the key issues raised by climate change that need to be considered at various scales include:

- changes to the viability of ecosystems as a result, for example, of sea-level rise or reduced water availability
- changes in other threats to biodiversity
- climate refugia, that is, landscape features that can help species persist *in situ*
- functional connectivity to help species disperse or migrate in response to changing conditions.

For example, viability is a key consideration in the selection of new areas for reserves. The NSW Climate Impact Profile identifies the ecosystems that are likely to face some of the most significant impacts from climate change, including coastal freshwater wetlands and dune communities, and the forested wetlands of the inland rivers. Prioritisation processes for reserve establishment in coastal ecosystems must incorporate an assessment of the risk of inundation and coastal recession and potential for landward migration of coastal wetlands, mangroves and saltmarshes. This may include any future reserve acquisition in these regions, targeted to provide buffer zones to allow landward retreat. For the inland wetlands and woodlands of south-western NSW, considering viability might include assessing water security using the latest regional climate projections, and aligning priorities for reserve acquisition and the purchase of environmental water. For example, the more secure sites in river red gum forests may be nearer the permanent river channels, as opposed to the outer flood plain that is predicted to be rarely flooded.

Voluntary conservation on private land

Conservation action on private land buffers and improves the representativeness of the reserve system and can facilitate connectivity across the landscape. In addition, improving the biodiversity value of agricultural land can offset some of the negative impacts of fragmentation on biodiversity (Dunlop and Brown 2008).

The reserve system in NSW is complemented by a spectrum of off-reserve conservation mechanisms. Several voluntary schemes encourage landholders to manage for positive biodiversity outcomes. These include the Conservation Partnerships Program that provides an opportunity for private and non-reserved public lands to be permanently protected through Conservation Agreements and as Wildlife Refuges; programs run by the Nature Conservation Trust; and landholder incentive programs through catchment management authorities (CMAs).

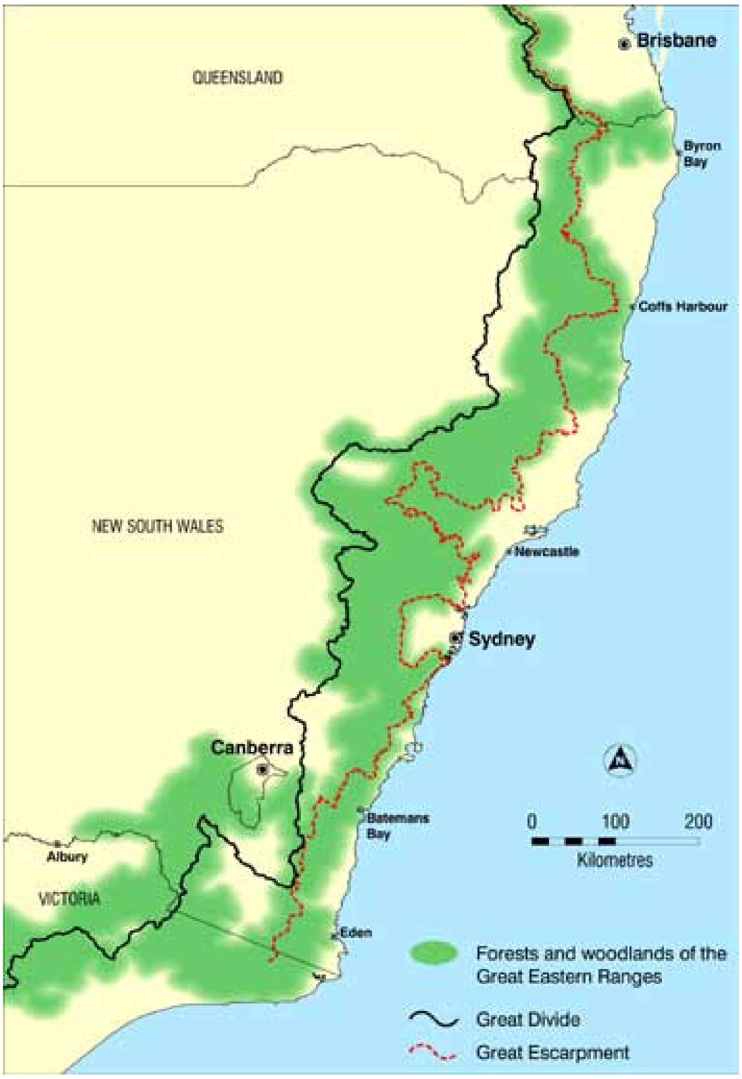
In addition, the Biodiversity Banking and Offsets Scheme ('BioBanking') has been established under the *Threatened Species Conservation Act 1995* (TSC Act). This market-based scheme provides a mechanism to fund conservation through development actions by landowners who establish biobanking sites under biobanking agreements. Clearing is only allowed where biodiversity values are 'improved or maintained' and the impacts of clearing are offset through the buying and selling of 'biodiversity credits'.

As our knowledge grows about the landscape features important for biodiversity adaptation (such as refugia, functional connectivity and buffer zones), their protection should be actively promoted in regulatory and incentive programs, voluntary conservation programs and community and landholder education and extension programs. DECCW will review the assessment criteria of conservation values for the selection and establishment of sites for inclusion in the Conservation Partnerships Program to prioritise landscape features identified as important for biodiversity adaptation.

Building functional connectivity across the landscape

Increasing the functional connectivity of the landscape will increase the viability of populations (Hughes 2008). Functional connectivity has four aspects: landscape connectivity, habitat connectivity, ecological connectivity and evolutionary connectivity (Mackey et al. 2009). Maintaining and improving the links (or connectivity) between landscapes and habitats at different scales (such as corridors and habitat stepping stones) allows species to progressively adjust their ranges in response to shifting climatic zones.

Continental-scale programs, such as the Great Eastern Ranges Initiative led by a consortium of non-government conservation bodies and DECCW, are putting 'connectivity conservation' into practice. The Great Eastern Ranges Initiative (www.greateasternranges.org.au) aims to link intact natural ecosystems along the Great Divide and Eastern Escarpment from the Australian Alps in Victoria to the Atherton Tablelands in far north Queensland. Work on the initiative began in mid-2007 and is achieving the widespread voluntary involvement of landholders and regional bodies through a range of mechanisms, including awareness-raising, engagement of youth and Indigenous communities, industry partnerships and private land management mechanisms. Inclusion of a range of habitats across altitudinal and climatic gradients will facilitate the movement of species across the landscape and between habitats. This will broaden the representativeness and adequacy of the conservation estate and provide context to help landowners and stewards understand and value the contribution of their land to biodiversity conservation. Note, however, that improved linkages may also raise other management issues by promoting the spread of fire and invasive species (Dunlop and Brown 2008).



The NSW section of the Great Eastern Ranges Initiative, designed to provide connectivity of the forests, woodlands and grasslands from the Victorian to Queensland borders.

In fragmented landscapes in NSW, remnant vegetation of high conservation value, such as that on travelling stock reserves (TSRs), roadsides and rail easements, can provide important habitat for biodiversity. For example, the landscape networks of TSRs running north-south and east-west across the tablelands, slopes and plains of western NSW retain relict habitats in highly cleared landscapes and provide connectivity across the landscape and climatic gradients. DECCW is working with the Land and Property Management Authority (formerly the Department of Lands) and the Livestock Health and Pest Authority (formerly the Rural Lands Protection Boards) to assess future uses of TSRs and provide input into the development of management plans to maintain conservation values within the context of multi-tenures and multiple uses.

Functioning river systems and their associated riparian vegetation are also important connective features across landscapes. These need to be protected and restored to reinstate connections along rivers and across flood plains.

Refugia and keystone species

It is important to identify and protect any known fire and climate refugia, and relict habitats, which may provide important habitat allowing species to persist in the face of climatic stress. However, the characteristics of refugia differ between regions, depending on their scale and the species that target them. For example, refuge areas might include sites that provide microhabitats that are moister and cooler than the surrounding environment (such as deep south-facing gullies in hilly terrain), drought refugia (for example areas with reliable surface or groundwater and wetlands that persist during severe droughts), and areas sheltered from fire (such as rocky or granitic outcrops) (Mackey et al. 2002; Byrne 2007; Dunlop and Brown 2008). Marine refugia may include sites that have strong currents, upwelling or other oceanographic features that make them less prone to thermal fluxes (Hansen 2003). The initial challenge is to identify climate refugia for a broad range of taxa on a bioregional scale across NSW.

As individual species become increasingly at risk from climate change, there is a greater need to prioritise species that play an important role in maintaining ecological processes, such as dispersal. 'Keystone' species have a disproportionately large influence on community and ecosystem function relative to their numbers or biomass. Some keystone dispersal agents in NSW have been identified and include emus (Calviño-Cancela et al. 2006, 2008) and flying foxes (Shilton et al. 1999; McConkey and Drake 2006). However, our overall knowledge of keystone species is poor. Information on keystone species (their identification, ecology and biology, and how they interact with climate change) needs to be addressed when developing future adaptation priorities.

Booroolong frog and climate refugia

Climate refugia: *Parts of the landscape (such as places with permanent water or a variety of landforms) that are likely to be particularly important for helping species persist during extreme events like drought and bushfire and times of ongoing environmental change.*

The endangered Booroolong frog lives and breeds along permanent rivers on the western slopes of the Great Dividing Range in NSW. This species is particularly reliant on rock crevices within streams, as this is where eggs are laid and tadpoles forage and seek refuge from predators. Over the past 30 years, this species has disappeared from more than half of its former known range, primarily due to disease and habitat degradation. More recently, there have been further declines and local extinctions in streams that have dried out for the first time since European settlement.

The Booroolong frog is a seasonal breeder and relies on successful recruitment to metamorphose each year. It is therefore particularly sensitive to stream drying and subsequent tadpole mortality. Lower flow rates during drought can increase sedimentation in rock crevices, which reduces the amount and quality of breeding habitat. Given the predicted increase in severity and frequency of droughts in the near future, it is very likely that the species will decline further as a result of climate change.

Understanding the distribution, life history and habitat requirements of the Booroolong frog has allowed conservation managers to identify the mechanisms by which climate change will affect this endangered species and how best to protect it from extinction. Targeting larger streams for riparian restoration to protect breeding habitat is particularly important as these streams are less susceptible to complete drying and will serve as refuge areas in the future. It will also be important to limit agricultural and silvicultural practices that may reduce surface water flow in streams where the frog lives, such as direct pumping and establishment of softwood plantations.

D Hunter DECCW

Challenge 2:
Building the protected area system to protect a diversity of habitats and increase opportunities for dispersal across the landscape

Actions

2.1 Revise guidelines for reserve acquisition to prioritise those landscape features important for biodiversity adaptation, such as refugia, functional connectivity, climatic gradients and water security ... *short term*

2.2 Consider the future viability of proposed reserves when prioritising acquisitions in ecosystems likely to face severe impacts from climate change including:

- *coastal reserves* – consider the risk of sea-level rise and associated inundation and coastal recession and the potential for landward migration of coastal and estuarine communities
- *inland wetlands and woodlands of south-western NSW* – consider water security using regional climate projections when assessing new inland wetland reserves and coordinate priority-setting processes for both reserve acquisition and the purchase of environmental water.

... *ongoing short-medium-long term*

2.3 Revise the criteria for assessing conservation values when selecting Conservation Agreement properties and Wildlife Refuges to prioritise those landscape features important for biodiversity adaptation ... *short term*

2.4 Work with other agencies, communities and regional partners to promote and implement conservation programs that build functional connectivity across the landscape through such programs as the Great Eastern Ranges Initiative ... *short-medium term*

2.5 Work with other agencies to identify and protect aquatic ecosystems that are important for providing connectivity and potential refugia in the landscape under likely future climate scenarios ... *short-medium-long term*

2.6 Identify characteristics and locations of climate refugia in NSW bioregions and prioritise these in criteria for protection ... *long term*

Challenge 3: Conservation management – reducing other threats to biodiversity

Climate change may exacerbate other threats to biodiversity. Minimising the impact and intensity of other threats to biodiversity will be the most effective option for enabling species to withstand or adapt to climate change (Dunlop and Brown 2008). Managing the threats of habitat loss, invasive species, pathogens and pollution, disturbance regimes and water stress (from drought and river regulation) will enhance the capacity of species to persist in their current habitat and improve their ability to migrate (Auld and Keith 2009). However, changes in the frequency, intensity and seasonality of extreme events will make conservation management especially difficult.

Park management policies and programs in NSW aim to protect natural and cultural values associated with the reserve system. As new information becomes available, practices can be modified. This may include incorporating new knowledge on regional climate projections and potential impacts when developing and reviewing park management processes, such as park plans of management, regional pest management strategies and reserve fire management strategies.

Climate change and extreme events

Changes in the frequency, intensity and seasonality of extreme weather events (floods, droughts, storms and fire) may have larger impacts on many species than directional shifts in average temperatures and changes in rainfall patterns (Steffen et al. 2009). For example, heatwaves can decimate populations of fauna vulnerable to heat stress like flying foxes, and projected sea-level rise and potential increases in storm surges will threaten coastal ecosystems.

A diversity of responses spreads the risk associated with different management options and builds the resilience of some species to extreme events. Adaptation strategies may include the following:

- protecting large areas of habitat to maintain population viability and genetic diversity
- identifying and protecting climate refugia that will help species persist during extreme conditions

- revegetation, which can moderate climatic extremes through the formation and retention of soil, promotion of soil permeability, reduction of runoff, and creation of lower surface temperatures and evaporation rates.

Current management programs that address the impacts of extreme events on biodiversity will become even more critical during climate change. For example, to reduce the impact of fire on natural assets and property, DECCW has a coordinated fire detection system that involves monitoring from detection towers and patrols of vulnerable areas during periods of extreme fire weather. If fires become more intense as a result of climate change, a greater emphasis on early detection and suppression may be warranted. In the coastal zone, a constraint on developing effective long-term strategies is the lack of sufficient knowledge about how physical systems currently operate and will respond into the future (such as potential changes caused by the frequency and intensity of storm events in NSW). Existing programs will need to be informed by up-to-date regional projections of climate scenarios and associated impacts. The *NSW Sea Level Rise Policy Statement* (DECCW 2009a) sets state benchmarks for sea-level rise to assist in future coastal zone planning.

Habitat loss and fragmentation

Habitat loss, through the clearing of native vegetation for settlement, industry and agriculture, has been identified as the process representing the greatest single threat to biodiversity in NSW (Glanznig 1995; Coutts-Smith and Downey 2006). Changes in climate may bring about land-use change, as agriculture and other industries are forced to adapt to altered conditions, leading to further habitat loss. Sea-level rise is also likely to result in habitat loss in low-lying, coastal areas through inundation and submergence.

Protecting remnant native vegetation across the landscape will play a key role in the capacity of biodiversity to persist in the face of a changing climate. For example, remnant habitats in fragmented areas may provide refugia or stepping stones for dispersal to sites that may become suitable habitat in the future (Auld and Keith 2009). Maintaining or improving the condition of existing vegetation is likely to be more productive than trying to restore land that has been substantially altered. In NSW, the clearing of native vegetation is primarily regulated through the *Native Vegetation Act 2003*. The objects of the Act include ending broad-scale clearing unless it improves or maintains environmental outcomes, protecting native vegetation of high conservation value, improving the condition of existing vegetation, and encouraging revegetation of land. To ensure these objects are met, DECCW has developed and uses the *Native Vegetation Compliance and Enforcement Strategy* (DECCW 2009b). The protection of native vegetation in NSW through regulation and land-use planning is discussed in more detail under Challenge 5.

Invasive species

Invasive species are already a major threat to biodiversity in NSW: pest animals and weeds have been identified as a threat to 70% of the state's threatened species, second only to native vegetation clearing in terms of the number of species affected (Coutts-Smith and Downey 2006; Coutts-Smith et al. 2007). Disturbance facilitates invasion, and climate change has the potential to promote invasion by introduced and native species through more extreme weather events, changed fire regimes, higher temperatures, increased levels of carbon dioxide and changes in ocean circulation patterns (Hilbert et al. 2007). The majority of invasive species are yet to reach their full range in NSW. Therefore, the most problematic species will often be those that are already present and able to further exploit the changing conditions, not just those that are expanding their range in response to climate change (Low 2007). Changes in climate may lead to a contraction in the distribution of some pest animals and weeds in some areas and an expansion in other places. For example, recent research by Macquarie University and DECCW indicates that the area of climatically suitable habitat for hawkweed will decline under climate change (Beaumont et al. 2009) while weeds like gamba grass will be favoured by climate change (Wilson et al. in press; DECCW 2009d).

The *NSW Invasive Species Plan* (NSW DPI 2008) aims to prevent new incursions of invasive species, contain existing populations, and adaptively manage widespread species at sites where the benefits will be greatest. In NSW, invasive-species priorities for the conservation of biodiversity are identified in the Priorities Action Statement prepared under the TSC Act, as well as individual threat abatement plans (TAPs). These documents set the main priorities for the management of invasive species for biodiversity conservation across all land tenures. DECCW's Regional Pest Management Strategies detail priorities for each region, including the actions listed in the PAS and TAPs and other initiatives such as site-based weed control (the primary approach used to manage weeds) and controls on wild dogs and feral pigs. Future priorities for these programs will need to reflect changes in the distribution, abundance and impacts of invasive species that may occur in response to changing climates. See below for how climate change may be incorporated into weed management for biodiversity conservation in NSW.

Incorporating climate change when prioritising weed control for biodiversity conservation

Bitou bush invading dunes on Sydney's northern beaches/H Cherry DECCW

A 'triage' approach has been developed to help ensure that weed management delivers biodiversity conservation outcomes (Downey et al. 2010). This forms the basis of the NSW Bitou Bush Threat Abatement Plan, and managing widespread weeds more broadly for biodiversity conservation in NSW (Downey et al. 2009). The approach is based on a site-scale assessment of the native plant species and ecological communities at risk from weeds and our ability to protect the biodiversity at risk at a particular site. The site model assesses:

- the degree of weed threat present
- the condition of the native plant species or ecological community
- the value of individuals present to the survival of the species or community
- the feasibility of control (in terms of site access and control options)
- the level of other threats present.

Information becoming available on the impact of climate change on both native and introduced species can be incorporated into this process. When the Bitou TAP is reviewed in 2011, this approach will be developed and trialled to ensure climate change is considered when sites for biodiversity conservation are being prioritised during bitou bush control. The outcome of this approach will then be incorporated into other similar NSW weed strategies.

Changing fire regimes

Extreme fires kill many plants and animals and may spread to areas that seldom burn. The severity of fire weather and the total area burned are both predicted to increase under climate change (Hennessy et al. 2005; Cary et al. 2006; Bradstock et al. 2008). Fires may become too frequent or intense for some fire-sensitive species to tolerate, threatening their persistence. However, translating projected climate trends into changes in fire regimes is complex because fires are influenced by many factors, including fuel loads and patterns of ignitions (Williams et al. 2008). Therefore, predictions for changed fire regimes must be interpreted cautiously.

Future fire planning will need to respond to the predicted influence of climate change to help reduce the impacts of bushfires on biodiversity and other important assets. DECCW plays a key role in developing fire risk management plans in partnership with the NSW Rural Fire Service, Forests NSW, the NSW Fire Brigades and local government. These risk management plans identify community and environmental assets at risk on a local level and provide appropriate strategies to reduce the risk of damage from fire, including hazard reduction. They are reviewed every five years and it is critical that these reviews are informed by up-to-date information on the impacts of climate change on fire regimes in NSW.

Fire management within DECCW reserves is guided by Reserve Fire Management Strategies, which are used to plan fire suppression, hazard reduction burning and other fire-related operations. These strategies need to incorporate new knowledge of likely shifts in fire regimes under climate change. For example, if fires become more intense under climate change, a greater emphasis on prevention and rapid suppression of fires may be needed (Bradstock et al. 2008). Any shift in fire management must consider the high levels of uncertainty and complexity involved in predicting changes to fire regimes.

Environmental water

The drier conditions expected under climate change in some regions will exacerbate existing pressures on aquatic ecosystems. Drought, regulation of rivers by dams and weirs, and extraction of water from rivers have reduced the number and size of floods that once supported and replenished wetland ecosystems in NSW. Alteration of the natural flow regimes of rivers and streams and their floodplains and wetlands has been identified as a Key Threatening Process for a number of threatened species and communities. Contractions of wetlands will reduce breeding opportunities for wetland-dependent fauna such as colonial waterbirds and their habitat. The south-west of the state is particularly vulnerable to the impacts of climate change as rainfall is predicted to decrease in this region (DECCW 2010).

DECCW manages rivers and wetlands suffering from reduced water availability by increasing the environment's share of water through the purchase of water licences and the development of water sharing plans. The *Water Management Act 2000* requires water to be allocated, as a first priority, for the fundamental health of a water source and its dependent ecosystems, such as wetlands and flood plains. 'Cease to pump' rules have been developed that provide water to maintain aquatic biodiversity during periods of low flow, while 'first flush' rules have been included in some plans, allowing for higher flows to move through sections of rivers to enable species dispersal. In regulated rivers, plans may prescribe dam releases or set aside allocations for environmental purposes. The endangered Booroolong frog is an example of a species that may be protected by specific water sharing rules. Groundwater water sharing plans have also been developed that have implications for environmental water by establishing exclusion zones and limits on the access to water at depth to protect groundwater-dependent ecosystems.

The Murray–Darling Basin Authority will develop a plan by 2011 that sets sustainable diversion limits on the amount of water that can be extracted from basin water resources. Future water sharing plans made within NSW will need to be consistent with this plan. An environmental watering plan will also be developed as part of the exercise and this will inform the use of environmental water to protect the basin's water-dependent ecosystems. As information becomes available, DECCW will provide the Murray–Darling Basin Authority with details of key ecosystem functions and priority refugia for consideration in basin planning.

Conserving vulnerable species and populations

DECCW undertakes a range of species recovery and threat abatement programs that aim to protect threatened species and populations. To guide recovery and threat abatement actions, the TSC Act provides for the Threatened Species Priorities Action Statement (PAS) which outlines broad strategies and priority actions for managing key threatening processes and promotes the recovery of threatened species, populations and ecological communities in NSW. The PAS is currently being reviewed and this provides an opportunity to re-target priorities for actions in light of new information on the threat of climate change provided by the NSW Climate Impact Profile and other published research.

A newly developed PAS will establish a cost-effective approach to species prioritisation by considering species value, likelihood of extinction and recovery, and the cost of management actions. Recognising that achieving the protection of all species is unlikely, this approach will establish relative priorities between species so that the limited resources available for biodiversity protection are allocated in a way that maximises recovery of threatened species. Climate change will exacerbate existing threats and may have a strong influence over some prioritisation criteria, particularly the cost of management actions and the likelihood of recovery in response to these. It is critical that the impacts of climate change are considered as part of the prioritisation process.

The species most at threat from climate change need to be identified and adaptation options assessed, particularly for those such as the mountain pygmy-possum that occur within highly vulnerable ecosystems (see below). Options may include protecting key climate refugia, targeted threat management, establishment of appropriate connectivity, and more active measures such as captive breeding and 'translocation', the intentional movement of species from one location and their release in another. These options for highly vulnerable species need to be carefully considered as part of the revised PAS. For example, translocations are highly uncertain and often very costly and therefore need to be preceded by a rigorous analysis of need, viability and cost-effectiveness. Any translocations undertaken need to follow the DECCW Translocation Policy (NPWS 2001), which aims to maximise conservation benefit and minimise the risks associated with translocations.

As a first step, DECCW will assess the vulnerability of selected species and ecosystems in a region identified as highly vulnerable to the impacts of climate change: NSW rangelands including south-western NSW. The information from this project will be used in future integrated vulnerability assessments for this region. DECCW is leading the development of similar assessments in all NSW State Plan regions. This will involve assessing vulnerability, climate change risks and opportunities for each region. Biodiversity impacts will be considered in these assessments. The outputs of the assessments will provide an information base on which to prepare regional adaptation strategies.

Assessing management options for a highly vulnerable species: mountain pygmy-possum

The mountain pygmy-possum (*Burramys parvus*) occurs only above the winter snowline and appears to require snow for its survival. It is a highly vulnerable species already suffering from a range of threats, including predation and fragmentation of habitat. Loss of the insulating effects of snow through decreased depth and duration of cover and high summer temperatures will expose the species to temperature extremes in which they have limited capacity to cope.

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Early spring thaws may increasingly lead to arousal from hibernation before the arrival of migratory bogong moths, a major food source for the species, although increased production of seeds, nectar and fruit from a longer, warmer growing season may partly compensate. However, exposure to feral cats and foxes is likely to intensify as the possums search outside the shelter of their boulderfield habitats for alternative food sources. In addition, these predators are likely to increase their activity and survival with decreased snow coverage. The effects of competition from bush rats and *Antechinus* spp. are also likely to increase as snow recedes.

Disentangling the effects of climate change from existing threats to this species is difficult and complicates the application of effective management strategies. Despite these complexities, action focusing on reducing existing threats will increase the species' short-term resilience to climate change. These include careful management of fire regimes, control of feral predators, close monitoring of populations and food resources, and new approaches, such as supplemental feeding in early spring and removal of common, native competitors. Importantly, management actions to reduce one threat must account for potential flow-on effects. A good understanding of the ecology of these systems must underpin management to avoid unwanted outcomes.

Conserving genetic diversity

Genetic diversity within species is best conserved by managing all populations across their range. For species at high risk from climate change and unlikely to survive in the wild, maintaining populations in artificial situations, such as living collections (zoos and botanical gardens) and seedbanks, is a last-resort option. Under severe climate change scenarios, conserving genetic diversity will become even more important for preserving species (such as holding taxa that are extinct in the wild) and assisting recovery after loss in the wild (for example by reintroducing species) (CHABG 2008). Conserving genetic diversity requires an understanding of the factors that influence the distribution of genetic variation and relationships to proxies, such as spatial, environmental and morphological variation.

Genetic studies exploring historical responses to climate change can support predictive management strategies by recognising differences in vulnerability across plant functional groups (Rossetto et al. 2009). Research programs at the Botanic Gardens Trust that include new DNA-based biomonitoring techniques have the potential to account for landscape-level sources of adaptive variation and will guide *in situ* management and *ex situ* storage strategies.

Actions to conserve genetic diversity of populations *in situ* remain critical for maintaining evolutionary potential. *Ex situ* conservation of species and the assessment of genetic diversity is resource-intensive, particularly for fauna, and so the objectives, risks and benefits need to be carefully considered and reviewed before programs start. Application of *ex situ* conservation techniques needs to be coordinated against agreed standards, including the revised guidelines for managing *ex situ* collections for plants (Offord and Meagher 2009) and targeted to priority species at risk from climate change (CHABG 2008).

The Botanic Gardens Trust participates in international *ex situ* conservation efforts, such as the Millennium Seed Bank and contributes to actions identified in the *National Strategy and Action Plan for the Role of Australia's Botanic Gardens in Adapting to Climate Change* (CHABG 2008). One of the major goals of this is to coordinate a national safety net for Australia's plant species through *ex situ* conservation, by representing plant species in danger of extinction from climate change in a seedbank, living collection or gene bank and making them available for use in species recovery programs.

NSW Seedbank

Well-sampled and documented seed collections provide a very cost-effective means of conserving genetic diversity for future conservation work. Under good storage conditions, some species may retain viability for hundreds of years.

The NSW Seedbank, located at Mount Annan Botanic Garden, is the repository for seeds in the state. The seedbank is a reference resource now holding representatives of 40% of all species in NSW, including almost 30% of threatened plants. Seed is held as an insurance policy against extinction for threatened species and, where appropriate, is used for re-establishment in the wild. Seed can also be used for community revegetation projects and contract-growing of local species. Future plans for the seedbank include the acquisition of representatives of all NSW seed-bearing flora, broadening the diversity by collecting species from multiple provenances, and expanding the research collaborations to understand species responses to climate change.

For more on the NSW Seedbank, visit www.rbgsyd.nsw.gov.au/seedbank

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Challenge 3: Conservation management – reducing other threats to biodiversity

Actions

3.1 Review land management programs (fire, invasive species and water management) in light of potential climate change impacts, bringing together key researchers and operational program staff ... *short term*

3.2 Incorporate new knowledge on regional climate projections and potential impacts when developing and reviewing park management processes, such as park plans of management, regional pest management strategies and reserve fire management strategies for:

- *coastal reserves* – use the benchmarks for sea-level rise and risks of coastal recession outlined in the NSW Sea Level Rise Policy Statement to assess the exposure of reserves and identify key vulnerable areas and opportunities for the landward migration of coastal and estuarine habitat, removing barriers where feasible
- *alpine ecosystems (and other at-risk fire-sensitive ecosystems)* – explore options for enhancing mitigation, fire detection, early warning systems and capacity for rapid fire suppression
- *inland wetlands and woodlands of south-western NSW* – consider water security using regional climate projections in the management of inland wetland reserves

... short-medium-long term

3.3 Monitor and review the outcomes of water sharing plans, including the Murray–Darling Basin Plan, to ensure they are adequate to protect, enhance and restore aquatic biodiversity, particularly at times of streamflow variability and low flows, and reduced recharge into groundwater systems ... *short-medium-long term*

3.4 Consider new regional climate projections and potential impacts when developing and reviewing water sharing plans ... *short-medium term*

3.5 Assess the vulnerability of species and ecosystems at high risk from climate change in NSW rangelands ... *short term*

3.6 Continue to increase the representativeness of the NSW Seedbank, targeting species vulnerable to climate change ... *ongoing short-medium-long term*

Challenge 4: Integrating biodiversity adaptation into regional biodiversity planning and investment programs

Extending decision support systems

DECCW has developed a suite of modelling tools to predict the outcomes for terrestrial biodiversity of regional land use and management. These tools are currently being applied to a wide range of assessment and management activities across NSW via regional conservation plans and multi-species recovery planning (e.g. biodiversity management plans), as well as supporting the work of CMAs. They model other threats, such as vegetation clearing, urban expansion, grazing and invasive species, but do not yet incorporate potential impacts of climate change due to its complexity and uncertainty.

DECCW is currently investigating ways to incorporate climate change into decision support systems. This includes the Biodiversity Forecasting Tool (BFT), which considers the contributions, both positive and negative, that various land uses, management actions and areas make to maintaining biodiversity across a landscape. The BFT is able to consider the main regional threats to biodiversity (such as weeds, pests and degradation) where they can be represented spatially across a planning region. In recent times attempts have been made to consider the distributional implications of climate change on some communities (as in the Lord Howe Island Biodiversity Management Plans) and to plan for land corridors to aid the migration of wildlife under climate change (the Northern Rivers Biodiversity Management Plan).

Decision support systems designed to manage freshwater and marine biodiversity also need to be updated to include the impacts of climate change. These include tools used to inform water sharing plans, water quality improvement plans, and coastal and estuary management plans. The BFT has recently been adapted for use in aquatic environments to describe the distribution of biodiversity in rivers and streams and model the links between stream condition and catchment land use and management. It needs to be extended to wetland ecosystems and to include climate change in projections of streamflow, runoff and aquatic ecosystems.

Regional delivery

Information on the likely impacts of climate change on biodiversity at a regional scale is needed to develop effective adaptation strategies. The NSW Climate Impact Profile is a first-pass statewide biophysical assessment that provides insight into the likely threats to biodiversity values in NSW. This information needs to be distilled into practical advice for use in adaptation planning targeted at key local and regional stakeholders, including CMAs, local councils and landholders.

CMAs are separate statutory bodies with a specific focus on engaging regional communities in natural resource management. CMAs develop and implement catchment action plans (CAPs), which set priorities for investment over 10 years. Over the next two years, the current CAPs are to be revised. DECCW will support CMAs to incorporate information on the potential impacts of climate change on biodiversity and design programs to minimise these impacts. Transferring relevant information on climate projections and regional biodiversity impacts will be the first step in this process. CMAs also have an important role in disseminating this information to the community.

Challenge 4:
Integrating biodiversity adaptation into regional biodiversity planning and investment programs

Actions

4.1 Refine and expand existing modelling approaches and decision support tools (for terrestrial and aquatic biodiversity) to incorporate climate change impacts and support actions 3.3, 3.4 and 4.2 ... *short-medium term*

4.2 Provide advice to catchment management authorities on climate projections and regional biodiversity impacts ... *short term*

Challenge 5: Regulation and land-use planning – integrating biodiversity adaptation considerations

Protecting remnant native vegetation across the landscape plays a key role in biodiversity adaptation under climate change and maintaining or improving the condition of existing vegetation is likely to be more productive than trying to restore land that has been substantially altered. The *Native Vegetation Act 2003* (NV Act) is the primary legislation regulating the clearing of native vegetation in NSW. The objects of the Act include ending broad-scale clearing unless it improves or maintains environmental outcomes, protecting native vegetation of high conservation value, improving the condition of existing vegetation and encouraging the revegetation of land. DECCW implements a compliance and enforcement framework for native vegetation (DECCW 2009b) to protect both the environmental values of native vegetation and ensure that landholders who comply with the NV Act are not disadvantaged.

The periodic statutory reviews by the NSW Government of legislation such as the NV Act and TSC Act need to consider climate change within the terms of those reviews. The NV Act has recently been reviewed after consultation with the community and industry (DECCW 2009c). The review found that in light of gains in native vegetation management and a decline in the rate of clearing, the policy objects of the Act remain valid and there is no immediate cause for amendment. The review considered that climate change adaptation programs can be brought forward under the existing objects, although acknowledged that it may be useful to consider explicitly recognising climate change among any future legislative amendments to the Act. Other issues, including the need to adequately protect species that move in response to climate change, may need to be considered under a review of the TSC Act.

Private and public lands with high conservation value can be protected through the planning system and development assessment processes, including environmental planning instruments such as local environmental plans (LEPs) and state environmental planning policies. For example, LEPs can exclude certain development types in areas of high conservation value through appropriate zoning. In addition, the use of overlay maps and development controls can assist in limiting and mitigating impacts from development in areas with high biodiversity values. This approach could be used to protect areas identified as critical for biodiversity adaptation, such as those important for maintaining and enhancing connectivity.

DECCW provides advice to the Department of Planning on the development of regional strategies which provide direction for the development of LEPs in higher growth areas of the state. DECCW develops regional conservation plans that identify conservation values in areas covered by regional strategies and also provides advice to local councils for the development of their LEPs. Advice provided by DECCW needs to be backed by up-to-date information on the impacts of climate change and include policy options for facilitating adaptation, such as allowing for the landward retreat of vulnerable coastal ecological communities. For example, the *NSW Sea Level Rise Policy Statement* (DECCW 2009a) sets benchmarks of sea-level rise to help councils plan for the likely impacts. A greater emphasis on protecting a diverse range of habitat types at the local scale will also complement conservation efforts at larger scales to enhance habitat diversity and minimise climate change impacts.

BioBanking and biocertification of planning instruments provide an opportunity to protect landscape features identified as important for biodiversity adaptation, such as habitat corridors, climate refugia and areas of high conservation value. As information becomes available on the characteristics and location of landscape features that may aid biodiversity adaptation, they need to be included in assessment processes for these schemes. For example, offsets could be encouraged in areas likely to be important for biodiversity under climate change, such as habitat corridors.

Challenge 5:
Regulation and land-use planning – integrating biodiversity adaptation considerations

Actions

5.1 Consider climate change as part of the reviews of relevant legislation ... *short-medium term*

5.2 Provide advice to the Department of Planning and local councils on how planning instruments can protect areas important for biodiversity adaptation to climate change, such as habitat corridors, climate refugia and high conservation value areas ... *medium-long term*

Challenge 6: Increasing awareness of biodiversity and climate change impacts

Community awareness of the potential impacts of climate change on biodiversity is currently low. Informing the public about the likely risks and impacts of climate change will help build community-wide support for appropriate policy responses and lead to earlier adoption of adaptation measures. Scientific information is complex and technical. Concepts including risk, uncertainty and the potential for severe impacts on biodiversity need to be conveyed using plain English in order to reach a broad audience.

Key actions by DECCW to increase broader community awareness about climate change impacts include:

- developing both printed and online profiles for native species and ecosystems at risk from climate change which outline potential impacts and options for reducing them
- development of a pilot Discovery for Schools program in the North Coast region, which will provide an opportunity to interact with school-age students and explore ways to deliver a presentation and interactive discussion on climate change issues
- directly engaging with Aboriginal knowledge-holders and communities to produce a discussion paper on the potential impacts of climate change on Aboriginal culture and heritage, including cultural resources and biodiversity, with feedback from the affected communities helping to direct future work.

Engaging landholders is essential to increase the uptake of conservation actions and long-term protection mechanisms on private land and facilitate biodiversity conservation across landscapes. DECCW already communicates with landholders through its Conservation Partnerships Program about the importance of protecting landscape features that help biodiversity adapt to climate change (DECC 2009). The Great Eastern Ranges Initiative is also building strong partnerships with landholders, land managers and community groups to achieve long-lasting conservation results: see Challenge 2 and www.greateasternranges.org.au for further information.

Involving the community in biodiversity monitoring can increase community awareness of the ecological impacts of climate change. Studying the influence of climate on annual phenomena such as blossoming and bird migrations ('phenological' monitoring) is a good opportunity for community engagement (Steffen et al. 2009). The recently established *ClimateWatch* program (Earthwatch Institute 2010) is a key initiative which involves schools, community groups and individuals watching and recording events like flowering times. ClimateWatch has been developed by Earthwatch Australia and other partners, with DECCW officers currently participating on the program's Scientific Advisory and Community Engagement Panels. The program has the potential to simultaneously monitor biodiversity responses to climate change, inform decision-making and engage the community. Other existing large-scale community monitoring programs, such as those for the swift parrot and regent honeyeater, will complement ClimateWatch and these types of programs need continued support.

CMAs are responsible for facilitating the delivery of better outcomes for natural resources at a regional scale and could assist in providing advice on climate change to regional communities. In addition, other state agencies, such as Industry & Investment NSW (which includes the former Department of Primary Industries) and other natural resource bodies (including non-government organisations), will also be an important avenue for disseminating information to the community, particularly on regionally specific impacts.

Challenge 6:
Increasing awareness of biodiversity and climate change impacts

Action

6.1 Develop and make publicly available web-based material profiling species and ecosystems at risk from climate change in NSW ... *short term*

7. Implementation and working in partnership

DECCW is coordinating delivery of the actions presented in this document through an internal Biodiversity and Climate Change Working Group. Implementation of the actions will involve updating existing programs and taking on new activities. DECCW will regularly track progress on actions and review priorities for biodiversity adaptation in 2015.

While DECCW will implement these actions, anthropogenic climate change affects biodiversity across all land tenures and the effectiveness of implementation will also depend on participation from a range of stakeholders and partners including:

- other state agencies, such as Industry & Investment NSW (which includes the former Department of Primary Industries), the Department of Planning, and the Land and Property Management Authority – opportunities for shared information, extension and common solutions
- catchment management authorities (CMAs) – willing to apply best-available information, tools and resources, and funds to implement priority actions and an important extension role through existing community networks
- state and national research institutions – opportunities for sharing knowledge and collaboration
- non-government organisations, community groups and private landholders – opportunities for funding, outreach, awareness-raising, community actions, promoting private land conservation measures and maintaining native vegetation
- local councils – responsibility for land-use planning at the local level.

Further information

For further information, contact DECCW's Conservation Policy and Strategy Section, Landscapes and Ecosystems Conservation Branch:

Phone: (02) 9995 5000
Email: info@environment.nsw.gov.au

Useful web sites

DECCW's NSW threatened species information:
www.threatenedspecies.environment.nsw.gov.au/tsprofile/index.aspx

Information on climate change and its impacts in NSW:
www.environment.nsw.gov.au/climatechange/

NSW Biodiversity Strategy:
www.environment.nsw.gov.au/biodiversity/nswbiostrategy.htm

DECCW Biodiversity Management Planning:
www.environment.nsw.gov.au/biodiversity/biomangmntplanning.htm

A strategic assessment of the vulnerability of Australia's biodiversity to climate change:
www.climatechange.gov.au/publications/biodiversity/biodiversity-climatechange.aspx

Appendix: NSW Scientific Committee – final determination

The NSW Scientific Committee, established by the Threatened Species Conservation Act, has made a Final Determination to list Anthropogenic Climate Change as a Key Threatening Process on Schedule 3 of the Act. Listing of Key Threatening Processes is provided for by Part 2 of the Act.

The Scientific Committee has found that:

1. The distribution of most species, populations and communities is determined, at least at some spatial scale, by climate.
2. Climate change has occurred throughout geological history and has been a major driving force for evolution.
3. There is evidence that modification of the environment by humans may result in future climate change. Such anthropogenic change to climate may occur at a faster rate than has previously occurred naturally. Climate change may involve both changes in average conditions and changes to the frequency of occurrence of extreme events.
4. Response of organisms to future climate change (however caused) is likely to differ from that in the past because it will occur in a highly modified landscape in which the distribution of natural communities is highly modified. This may limit the ability of organisms to survive climate change through dispersal (Brasher & Pittock 1998; Australian Greenhouse Office 1998). Species at risk include those with long generations, poor mobility, narrow ranges, specific host relationships, isolated and specialised species and those with large home ranges (Hughes & Westoby 1994). Pest species may also be advantaged by climate change.
5. Modelling of the distribution of species under realistic climate change scenarios suggests that many species would be adversely affected unless populations were able to move across the landscape (for example, Brereton et al. 1995). Examples of species which would be at risk in New South Wales include:

Mammals

Burramys parvus – Mountain pygmy-possum
Potorous longipes – Long-footed potoroo
Mastacomys fuscus – Broad-toothed rat
Pseudomys fumeus – Smoky mouse

Amphibians

Litoria spenceri – Spotted frog
Litoria raniformis – Southern bell frog
Pseudophryne pengilleyi – Northern corroboree frog
Pseudophryne corroboree – Southern corroboree frog

Reptiles

Delma impar – Striped legless lizard

Birds

Leipoa ocellata – Malleefowl
Pedionomus torquatus – Plains-wanderer
Tyto tenebricosa – Sooty owl
Calyptorhynchus banksii graptogyne – Red-tailed black-cockatoo
Polytelis anthopeplus – Regent parrot
Petroica rodinogaster – Pink robin
Pachycephala rufogularis – Red-lored whistler

Flora

Communities likely to become threatened include alpine vegetation communities (Busby 1988; Hughes & Westoby 1994)

6. The present protected area network was not designed specifically to accommodate climate change, and the present biodiversity values of the protected area system may not all survive under different climatic conditions (see Pouliquen-Young 1999). Conservation planning at the landscape scale could provide opportunities for species to respond to future climate change and the Threat Abatement Plan could address modifications to the present protected area network to account for climate change.
7. Fire is an integral part of the dynamics of many Australian ecosystems. Studies suggest that the risk of fire may increase in some areas as the climate changes and decrease in others with consequent changes to the species composition and structure of ecological communities (Brasher & Pittock 1998; NSW Scientific Committee 2000).
8. In view of the above, the Scientific Committee is of the opinion that Anthropogenic Climate Change adversely affects two or more threatened species or could cause species, populations or ecological communities that are not threatened to become threatened.

Gazettal date: 17/11/00; Exhibition period: 3/11/00–8/12/00

Glossary

Term	Meaning in this document
Adaptation	Responses, whether natural or assisted by humans, which enable species and ecological processes to adjust to and evolve in a changed environment
Anthropogenic	Resulting from, or produced by, human activities, such as industry, agriculture, mining, transport and settlement
Biodiversity	The diversity of living organisms of all types, including genetic, species and ecosystem diversity
Climate	The weather conditions of a region, such as temperature, pressure, humidity, precipitation, sunshine, cloudiness and winds, averaged over some period of time, such as the 30-year time span used by the World Meteorological Organization
Climate change	The statistically significant variation in the average state of the global or regional climate persisting for an extended period. The UN Framework Convention on Climate Change definition relates to changes in climate due to anthropogenic factors in addition to changes caused by natural processes.
Connectivity	Describes the functional capacity of a landscape to enable the movement of species between different areas of habitat which are not necessarily physically connected and can be thought of as 'stepping stones' in the landscape. It has a wider meaning than wildlife corridors, which are continuous land links and include stepping stones and proximities of related habitats.
Refugia	Areas where organisms can survive periods of unfavourable conditions, e.g. during extreme weather events.
Resilience	The extent to which ecosystems can cope with a changing climate and continue to exist in their current state (in terms of composition, structure and functioning). The related term 'transformation' refers to substantive changes (that is, transition to a new state) in response to changes in climate (Steffen et al. 2009). The application of these terms is scale-dependent, that is, transformation at one scale may be necessary to deliver resilience at higher scales.
Transformation	See 'resilience'
Translocation	The intentional movement of species from one location and their release in another including, for example, reintroduction of species into the wild, movement of individuals between populations, or movement of populations out of the path of a development

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