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Department of Environment and Climate Change NSW Adaptation Strategy for Climate Change Impacts on Biodiversity

Actions to implement the National Biodiversity and Climate Change Action Plan and the NSW Biodiversity and Climate Change and Adaptation Framework

Department of **Environment & Climate Change** NSW

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J. Little, S. Garland – DECC, A. Jelinek – DECC, G. Woods – DECC, G. Robertson – DECC,
S. Schulz and J. Little (centre)

Published by:
Department of Environment and Climate Change NSW
59–61 Goulburn Street
PO Box A290
Sydney South 1232
Ph: (02) 9995 5000 (switchboard)
Ph: 131 555 (environment information and publications requests)
Ph: 1300 361 967 (national parks information and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

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Director General's foreword

Climate change is the most pressing environmental issue we face in the 21st century. Likely consequences include more extreme weather events, hotter and drier conditions, more frequent and intense bushfires, more prolonged droughts, coastal storms and floods, and disappearing snowfields. These changes in climate will have inevitable ramifications for the broader society, and far-reaching consequences for our unique biodiversity. In addition many Aboriginal communities in NSW live in areas identified as particularly vulnerable to changes in climate. As a result, projected climatic changes may have a detrimental impact on Indigenous Australians' cultural practices and values.

The Department of Environment and Climate Change NSW (DECC) has primary responsibility within the NSW Government for developing policies and programs and implementing government regulations and reforms to conserve our natural and cultural heritage. Working with the community, DECC is responsible for protecting our environment, and for maintaining and improving the biodiversity of the State. Climate change has the potential to affect all of DECC's conservation objectives, activities and responsibilities.

NSW is tackling climate change through the NSW Greenhouse Plan, which is designed to reduce the greenhouse gas emissions that are driving climate change. At the same time, we need to put in place programs that will help us adapt to climate change. Adaptation, as a complementary measure to lowering greenhouse gas emissions, will lessen the severity of the impact of climate change, by reducing pressures on native species and ecosystems helping them to maintain their viability and resilience.

In response to this challenge, DECC has developed Department of Environment and Climate Change NSW: Adaptation Strategy for Climate Change Impacts on Biodiversity. This document outlines priority areas for action to be taken by DECC over the next two years to help buffer NSW's natural and cultural heritage against climate change impacts. This practical approach to climate change adaptation planning in DECC includes a range of measures, such as maintaining and expanding the reserve system, establishing connectivity between habitats to allow species to move to more favourable environments, scientific research, monitoring and modelling on which to base natural resource management and planning, and improved communication between and awareness raising within the community, scientists and policy makers.

This plan outlines actions, taking into account the uncertainty in climate change projections and gaps in our knowledge. These actions are the starting point for biodiversity adaptation, conservation and management, and will help us reduce the vulnerability of biodiversity in NSW to climate change.

Lisa Corbyn
Director General

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There is increasing evidence that the Earth's climate is changing and will continue to change, and that the process is being accelerated by human activities. Projected changes in future climate include changes in temperature, rainfall patterns, mean sea level, ocean currents and increases in extreme weather events. Anthropogenically induced climate change has been listed as a key threatening process under the NSW Threatened Species Conservation Act 1995.

The Department of Environment and Climate Change NSW (DECC) is committed to a significant effort to prepare for the impacts of climate change under the National Biodiversity and Climate Change Action Plan and the NSW Greenhouse Plan in order to protect and conserve this State's natural and cultural heritage. This document represents the first significant adaptation planning initiative to reduce the vulnerability of biodiversity to climate change, and outlines actions for this agency to undertake in the next two years.

Much uncertainty remains over the specific impacts on biodiversity from climate change. We need to understand the likely impacts from climate change on ecosystems before we can fully understand the potential impacts on human societies and their cultural values. This plan focuses on a technical and scientific approach to improve our understanding of and management responses to impacts, and at this point does not address social impacts.

The climate is a dynamic system, encompassing a variety of natural processes and cycles that operate over many spatial and temporal scales. However, it is very likely that humans are having a direct impact on the global climate system and are magnifying natural processes, in particular through burning fossil fuels, agriculture and land-use change. Eleven of the last 12 years (1995–2006) rank among the warmest years globally on record and 2005 was Australia's warmest year in recorded history. Atmospheric greenhouse gas concentrations are higher now than they have been at any time in the last 650,000 years.

Projections of future changes in climate for NSW include increasing temperatures, increasing sea level, the possibility of decreasing rainfall, increased temperature extremes and severity of droughts, regional flooding, and reduced water availability including in the Murray–Darling Basin.

Maintaining biodiversity is crucial for human survival and wellbeing. We gain fresh air, food, shelter, medicinal substances, clean water, soil nutrients, plant pollination and climate regulation from healthy ecosystems.

Australia has experienced cycles of climatic change in the past that had significant effects on species and ecosystems. However, the current changes in climate pose a more serious threat due to the unprecedented rates of increase in atmospheric greenhouse gas levels and temperatures, and because ecosystems are already stressed by other human impacts.

Scientific evidence is rapidly mounting to indicate that we are already seeing the impacts of changes in climate on biodiversity in the form of changes in species ranges and life cycle events, with winners and losers emerging as conditions change. The most vulnerable ecosystems include coastal ecosystems, alpine areas, rainforests, fragmented terrestrial ecosystems and areas vulnerable to fire or low freshwater availability. Additionally, places of high biodiversity value are often places of high Aboriginal cultural value.

The impacts of climate change on biodiversity can be reduced through mitigation and adaptation measures. Mitigation limits further changes in global climate through reducing emissions of greenhouse gases. NSW has already committed to significant reductions in greenhouse gas emissions in the NSW Greenhouse Plan and The State Plan, A New Direction for NSW. However, further climate change is inevitable because both past and future emissions will contribute to warming for centuries to come, due to the timescales required for removal of these emissions from the atmosphere.

Adaptation is therefore essential to reduce the severity of the effects of climate change and is complementary to climate change mitigation strategies. It involves adjusting our management of the environment through programs to reduce the pressures arising from other threats such as habitat fragmentation, invasive species, bushfires, pollution and urban expansion.

Due to the complexity of climate change, scientific uncertainty is inevitable. There is uncertainty over the timing and extent of projected changes in climate, and over how species and habitats will respond. However, it is certain that climate change poses a risk to biodiversity and the effects are likely to be pervasive. Strategies to support adaptation to climate change must account for uncertainty in projections, risks and benefits. Initial focus needs to be on reducing existing threats to biodiversity, and increasing our knowledge of the most vulnerable species and ecosystems, the likely impacts from climate change, and options to protect biodiversity.

This document outlines a number of priority focus areas along with a detailed list of priority actions that will form the basis of a practical approach to climate change adaptation planning for DECC. These priorities link with the objectives of the National Biodiversity and Climate Change Action Plan, the NSW Greenhouse Plan and The State Plan, A New Direction for NSW.

The priority focus areas identified in this document are:

- building the reserve system
- managing the reserve system
- cross-tenure connectivity conservation planning
- wildlife management
- climate change adaptation science, research and modelling
- natural resource management and environmental planning
- communication, awareness raising and capacity building.

Within these broad priority focus areas, a number of actions have been identified that are critical first steps for adaptation planning. These focus on identifying key needs and information gaps, undertaking critical research, monitoring and modelling, and developing tools to identify areas of vulnerability and adaptation options.

DECC scientists have commenced five climate change adaptation research projects that focus on the impacts of climate change on other major threats to biodiversity: bushfires; invasive species; threatened terrestrial species and ecosystems; threats to inland aquatic ecosystems; and the development of conservation planning tools.

The reserve establishment program will incorporate strategies to improve the ecological resilience of the reserve system in the face of climate change. This will involve assessing likely options for species movement, developing wildlife corridors, increasing 'habitat connectivity' and factoring in scenarios on future water availability where available. Increasing our understanding of likely climate change impacts on key threats to our reserve system will also enable effective reserve management and build ecosystem resilience.

Continuing and enhancing existing fire, pest and weed management programs will increase the probability that our reserve system will be better able to cope with future disturbances, including a rapidly changing climate. New information on climate change impacts needs to be incorporated into park plans of management, a process that has begun with the new plan for Kosciuszko National Park.

We must examine options to connect our reserves and key habitats on other lands, both altitudinally and latitudinally, to allow species to move and find refuges in response to climate change. Using a combination of protected areas and practical conservation management measures on other public and private land, we can establish cross-tenure habitat connectivity through strategic wildlife habitats and corridors, including links between reserves and with their surrounding landscapes, and fostering cooperative management with other landholders.

Adaptation to climate change needs to be incorporated into routine planning and decision making. As the information becomes available, DECC will incorporate projected reductions in rainfall and river flows into existing plans for environmental water use, such as the NSW Wetlands Recovery Plan and NSW RiverBank. Undertaking risk assessments of projected climate change impacts, in order to quantify levels of risk and uncertainty, are also important tools to inform planning and management decisions.

The dynamic nature of both human and natural systems demands that climate change policy and management be adaptable and flexible. A long-term and strategic approach to adaptation will be required to reduce the risks posed to the biodiversity of NSW associated with a changing climate. The actions in this document are intended to be the starting point to build our understanding and overall capacity for adaptation planning and are necessary first steps for informing future, more detailed management actions.

Finally, climate change provides several challenges to some fundamental concepts in biodiversity conservation. For example, the extent to which we should be trying to preserve existing biodiversity in the face of future climatic change, and the extent to which we should permit or assist the adjustment of biodiversity to these changes are being raised in the scientific literature. The answer to these questions is not easy and far from agreed. However, the programs identified in this DECC adaptation strategy will help us respond to these questions in the future.

1 Introduction

Climate change is now predicted to be the greatest threat to biodiversity in many regions (Thomas et al. 2004) and is listed as a key threatening process under the Threatened Species Conservation Act 1995 and the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth). The global climate has changed significantly during the last 100 years, with the average surface temperature of the Earth increasing by 0.74±0.18°C. There is a very high confidence level that the globally averaged net effect of human activities since 1750 has been one of warming, with palaeoclimatic information supporting the interpretation that the warmth of the last half century is unusual in at least the previous 1300 years and that it is 'very likely' (>90% certain) that greenhouse gas increases caused most of this recent warming (IPCC 2007). Regardless of any future reductions in greenhouse gas emissions, some climatic changes will occur due to the level of gases already in the atmosphere and the slow response of the climate system to any reductions in emissions. Adaptation is thus essential to reduce the vulnerability of the environment to the impacts of climate change.

The greenhouse gases in the atmosphere absorb and re-emit infrared radiation from the Sun, trapping heat. This is known as the greenhouse effect. Because of the increasing concentrations of greenhouse gases in the atmosphere, the greenhouse effect is being 'enhanced'. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the primary greenhouse gases, with a number of anthropogenic (made by humans) gases, such as the halocarbons and other gases containing chlorine and bromine, dealt with under the Montreal Protocol. Besides carbon dioxide, nitrous oxide and methane, the Kyoto Protocol includes sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons (IPCC 2001b).

The palaeoecological (fossil) record indicates that Australia has experienced cycles of climate change in the past that had significant effects on the distribution, composition and abundance of flora, fauna and ecological systems (Harle et al. 2005). However, the current changes in climate pose a more serious threat to biodiversity due to the unprecedented rates of change of carbon dioxide levels and temperature, and because Earth's ecosystems are already stressed by other human activities.

Although there is uncertainty about specific responses to future climate change, there is already evidence of effects of climate change on biodiversity. There is a vital need for biodiversity conservation policy and management to incorporate projected climatic change and adaptation strategies to enhance the ability of species to survive. This growing recognition of the potential magnitude of climate change impacts on biodiversity led to the development of the National Biodiversity and Climate Change Action Plan by the Natural Resource Management Ministerial Council, which has been endorsed by all jurisdictions (NRMMC 2004).

This adaptation strategy outlines how the Department of Environment and Climate Change NSW (DECC) will implement the National Biodiversity and Climate Change Action Plan during the next two years. It sets out a number of priority actions, which are primarily focused around expansion, preservation and management of the NSW reserve system, including managing threats to biodiversity, examining options for increasing ecological connectivity and participating in key science projects. The aim is thus to enhance the capacity of biodiversity to adapt to projected changes in climate in order to conserve the natural and cultural values of NSW.

2 Background

2.1 DECC and climate change

DECC has primary responsibility within the NSW Government to protect and conserve the State's environment, including its natural and cultural heritage, by developing policies and programs and implementing government regulations and reforms. It also manages a significant area of NSW.

DECC is responsible for conserving protected Australian animals and plants across the State and for managing NSW national parks and reserves, with a strong commitment to maintain and improve biodiversity. In addition, DECC promotes sustainable consumption, resource use and waste management, and has responsibilities for air and water quality, and for noise control, chemical and radiation regulation. For example, DECC is closely involved in developing national ambient air quality standards for key air pollutants, sets policy directions for managing air quality in NSW (such as those outlined in Action for Air), regulates industrial emission sources through licensing, and encourages industry and the community to reduce their impact on air quality through education, economic tools and cleaner production. NSW RiverBank has been set up to purchase and manage water to achieve a wide range of environmental benefits, particularly for the most stressed rivers and iconic wetlands. Climate change has the potential to affect all of DECC's conservation objectives, activities and responsibilities.

Part of DECC's responsibility is the protection of Aboriginal heritage in NSW. DECC recognises that Aboriginal heritage is much more than rock engravings and stone artefacts and that it encompasses all aspects of the environment. In the Aboriginal view, people and Country (including both land and water) are integrated. For example, particular plant and animal species can be highly significant to Aboriginal cultures, placing responsibilities on Aboriginal people to maintain and improve their habitats and environment through songs, dance, rituals and environmental management. Protecting Country through the maintenance of Aboriginal culture is therefore crucial to the wellbeing of Aboriginal communities, many of which are in areas identified as particularly vulnerable to changes in climate. Thus, projected climate changes may have a detrimental impact on cultural practices and values through impacts on culturally significant plant and animal species and traditional uses of land and water.

Climate change is the most pressing environmental issue facing us. It is one of the major threats to biodiversity on a global scale, and is now listed as a key threatening process under the Threatened Species Conservation Act 1995. Anthropogenic climate change is driven predominantly by the release of greenhouse gases into the atmosphere by the combustion of fossil fuels, and also from agriculture and industry. Projected consequences include changes in temperature, precipitation patterns, mean sea level, ocean circulation patterns, and increases in extreme events.

The climate is a dynamic system and includes many natural cycles and processes that have influenced and changed the landscape in the past. It is therefore not the process of change itself that is the issue. Changes in climate threaten biological resources when the magnitude and, in particular, the rate of change lie outside the range to which living organisms have been exposed over the last several hundred thousand years (Pearman 1988; Hughes et al. 1996). There is already evidence of the impact of climate change on biodiversity, including effects on the physiology and distribution of species, and the timing of life-cycle events (Hughes 2000, 2003a, 2003c; Howden et al. 2003; Root et al. 2003; Thomas et al. 2004).

Despite global efforts to mitigate greenhouse gas emissions by reducing the sources or enhancing the sinks of greenhouse gases (IPCC 2001b), some level of climate change is inevitable, due to the time lag effect of greenhouse gases in the atmosphere. Only half the atmospheric carbon dioxide is currently absorbed by the oceans and biosphere, and the remainder has a lifetime of 50–200 years, so we will be subject to many decades of climate change that we cannot prevent (Whetton 2003; Hennessy et al. 2004a).

Therefore, in order to maintain environmental values, we need to undertake adaptation measures which minimise costs and maximise any benefits of unavoidable climate change. Adaptation is defined here as:

> … responses that decrease the negative effects of climate change and capitalise on positive opportunities associated with impacts. Adaptation actions can be split into 'autonomous' (internal, automatic system adjustments such as evolutionary responses in natural systems) and 'planned' (where a deliberate intervention is made in an attempt to achieve a specific goal, recognising the change in environment) (Howden et al. 2003).

DECC is committed to a significant effort to prepare for the impact of climate change under the National Biodiversity and Climate Change Action Plan, the NSW Greenhouse Plan and The State Plan, A New Direction for NSW.

2.2 The importance of biodiversity

Biodiversity (biological diversity) means the diversity of life and is made up of the following three components, as defined in the Threatened Species Conservation Act 1995:

- genetic diversity – the variety of genes (or units of heredity) in any population
- species diversity – the variety of species
- ecosystem diversity – the variety of communities or ecosystems.

Biodiversity encompasses a multitude of life-forms ranging from the most obvious, such as birds, mammals and plants, to the least obvious, such as soil micro-organisms, with an indeterminate number yet to be discovered. The species of animals and plants on Earth today have evolved over hundreds of millions of years. Australia is one of fewer than twenty countries in the world recognised as 'megadiverse'. These countries together contain two-thirds of the world's biodiversity.

Australia has a high number of endemic species – species found nowhere else – because of its long-term isolation. Our biodiversity is internationally significant. There are four areas in NSW on the World Heritage List – Willandra Lakes, Greater Blue Mountains, Gondwana Rainforests of Australia and Lord Howe Island – for their outstanding natural values, as well as eleven wetlands of international significance listed under the Ramsar Convention. A number of our species are protected by international agreements.

NSW has a great variety of native ecosystems: the alpine areas of Kosciuszko National Park; woodlands, grasslands and rainforests; coastal lakes, estuaries and marine ecosystems; inland freshwater wetlands, floodplains, riverine systems and extensive coastal wetlands; and the arid and semi-arid environments of the far west of the State.

Biodiversity underlies the goods and services provided by ecosystems that are crucial for human survival and wellbeing (Gitay 2003). 'Ecosystem services' is a term used to describe the goods and services that we gain from ecosystems, such as fresh air, food, shelter, medicinal substances, clean water, soil nutrients, plant pollination and climate regulation. Many of these are taken for granted. The complex ecological systems that sustain them may be poorly understood or undervalued until they decline. Human activities that modify or destroy natural ecosystems may cause deterioration of ecosystem services whose value, in the long term, exceeds the short-term economic benefits of some activities. Very large numbers of species and populations, and retention of large natural areas, are required to sustain some ecosystem services (Daily et al. 1997). Protecting biodiversity will contribute significantly to the protection of ecosystem services.

2.3 Timescales and climate change

Past changes in climate and human impact

The climate is a dynamic system, encompassing a variety of natural processes and cycles that operate over many spatial and temporal scales. When considering the impacts of climate change long timescales need to be taken into account. The Quaternary period (approximately the last two million years) has been marked by regular cycles of climatic change, with oscillations between cold (glacial) and warm (interglacial) conditions, known as glacial–interglacial cycles, which are 100,000–120,000 years long. These cycles have been dominated by slow and uneven cooling ('ice ages'), followed by rapid warming (Williams et al. 1998). We have been in an interglacial period, known as the Holocene, for approximately the last 10,000 years. It is widely accepted that the main cause of glacial–interglacial cycles is small variations in the Earth's orbit around the Sun, known as Milankovitch cycles (Imbrie et al. 1993). Since major climatic and landscape cycles operate at these long timescales they are the appropriate scales at which to consider significant evolutionary processes (McGlone 2000) and to distinguish between natural climatic variability and long-term trends.

The leading authority on climate change is the Intergovernmental Panel on Climate Change (IPCC), a group of hundreds of internationally recognised scientists, who periodically review and synthesise climate change science published in peer-reviewed scientific papers. The IPCC has released the Summary for Policymakers section of the first volume of their Fourth Assessment Report. This summary provides an assessment of the current scientific knowledge of the natural and human drivers of climate change, observed changes in climate, the ability of science to attribute changes to different causes, and projections for future climate change. There is now a very high confidence level that the globally averaged net effect of human activities since 1750 has been one of warming and it is very likely (>90% certain) that greenhouse gas increases caused most of the warming since the mid 20th century (IPCC 2007).

Evidence from the analysis of ice core records taken from Antarctica indicates that the current atmospheric concentration of carbon dioxide, which makes up the bulk of the greenhouse gases, is higher now than at any time in the last 650,000 years (Siegenthaler et al. 2005). This period of time spans several glacial–interglacial cycles and lends support to human causes to explain the increasing carbon dioxide concentration in the last few hundred years. Increases in greenhouse gases are primarily due to fossil-fuel combustion, agriculture and land-use change (IPCC 2007). On a per capita basis Australia releases greater volumes of greenhouse gases into the atmosphere than any other country (Turton 2004). An unusual feature of the profile of emissions from Australia is the relatively large contribution made by agriculture and other land based sources (CIE 2004).

In support of these conclusions, since temperature recording began in 1861, nine of the ten warmest years were in the last decade (Steffen 2006). In addition, in Australia 2005 was the warmest year on record (BoM 2006). This is particularly significant as many of Australia's warmest years (such as 1988, 1998 and 2002) had temperatures boosted by major El Niño events, but no such event occurred in 2005. The 2005 record continued the trend in which all but four years since 1979 have been warmer than average (Steffen 2006).

The NSW Greenhouse Office commissioned CSIRO to assess climate variability over the past 50–100 years and projected changes in average climate over the next 70 years in NSW (Hennessy et al. 2004a, 2004b). These are the main findings for the past 50–100 years.

- Between 1950 and 2003 there have been increases in annual mean maximum and minimum temperatures, with increases in the number of days 35°C or more and nights 20°C or more.
- Annual total rainfall has decreased 14.3 mm each decade since 1950, with high yearly variability.
- Recent dry periods have been accompanied by warmer temperatures than in the past.
- Mean sea level has risen about 1.2 mm each year from 1920 to 2000.
- In Sydney, the frequency of extreme sea-level events reaching 2.1 m or 2.2 m has doubled and trebled, respectively, since 1950.

Future projections of changes in climate in NSW

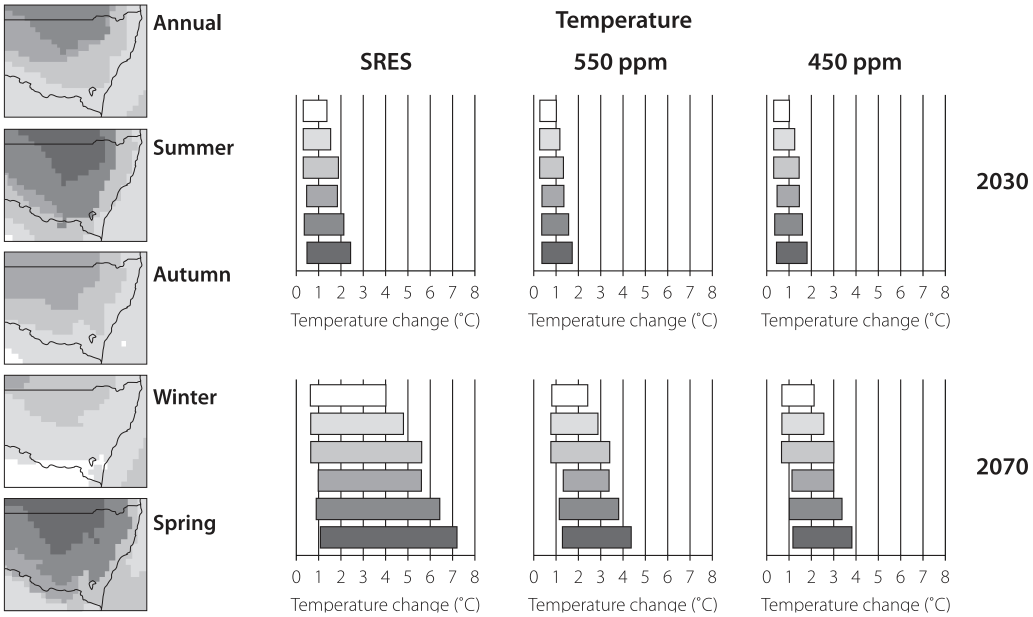
To estimate how climate is projected to change, scientists have developed climate change scenarios (Hennessy et al. 2004b). These are projections based on assumptions about demographic change, economic growth, technological development and future greenhouse gas emission levels. Although there is uncertainty associated with climate change projections, almost all suggest substantial global temperature increases and an associated rise in global mean sea levels. By 2100, relative to 1990 and using the Special Report on Emissions Scenarios (SRES), the IPCC (2007) estimates that global average temperature may rise between 1.1°C and 6.4°C. Using the best estimates and likely ranges for a number of different emissions scenarios, the best estimate for the low scenario is 1.8°C (1.1–2.9°C) and the best estimate for the high scenario is 4.0°C (2.4–6.4°C) (IPCC 2007).

By the end of this century there will be a further 18–59 cm rise in sea level, although there will be regional differences, and outstanding uncertainties with respect to the additional contribution of ice flows to the sea level rise remain. It is important to note that this upper limit of sea level rise does not take account of ice dynamics uncertainty. The IPCC (2007) acknowledges that larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise. The last time the polar regions were significantly warmer than today for an extended period (about 125,000 years ago) sea level was 4–6 m higher (IPCC 2007).

CSIRO has made projections of climate changes in NSW, for a range of future greenhouse gas emission scenarios (Hennessy et al. 2004b). Temperature and rainfall changes are presented in Figures 1 and 2. The main projections include:

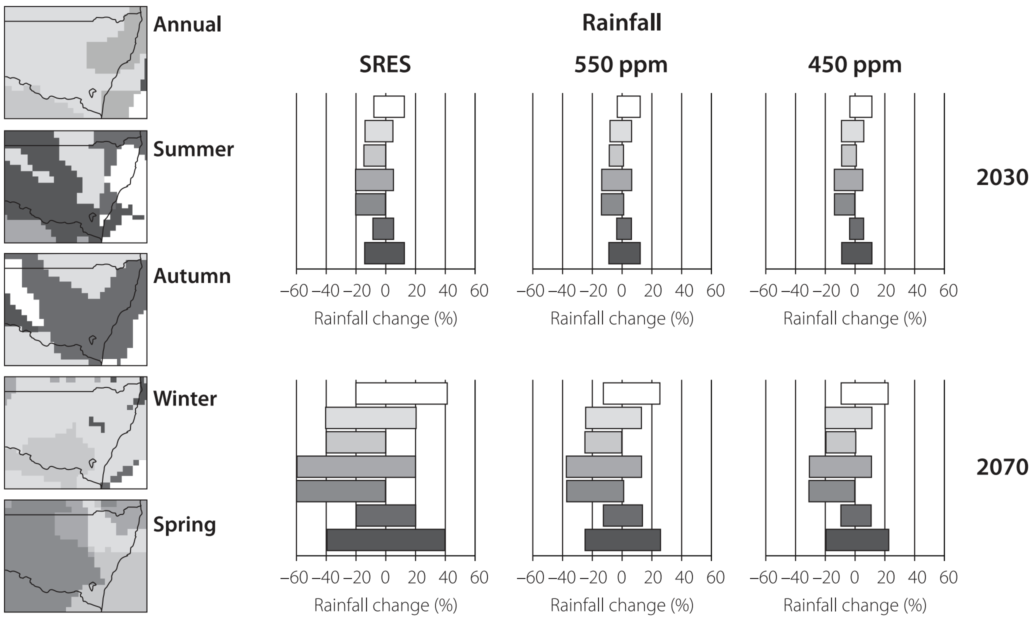
- increasing temperatures (greatest warming west and north of the Great Dividing Range, and most in spring and summer)
- possible decreases in annual average rainfall (mainly in winter and spring)
- decreasing atmospheric moisture balance (resulting in increased heat stress)
- increased temperature extremes (greater number of days 35°C and above)
- possible increases in the severity of droughts (especially in winter and spring)

Figure 1: Projected change in average temperature for 2030 and 2070 relative to 1990



Source: Hennessy et al. (2004a)
The shaded bars show temperature changes for areas with corresponding shading in the maps. The IPCC SRES scenarios exclude explicit attempts to reduce greenhouse gas emissions. Temperature changes are also shown for the IPCC's 550 ppm and 450 ppm CO_2 stabilisation scenarios.

Figure 2: Projected change in average rainfall for 2030 and 2070 relative to 1990



Source: Hennessy et al. (2004a)
The shaded bars show rainfall changes for areas with corresponding shading in the maps. The IPCC SRES scenarios exclude explicit attempts to reduce greenhouse gas emissions. Rainfall changes are also shown for the IPCC's 550 ppm and 450 ppm CO_2 stabilisation scenarios.

- regional increases in extreme daily rainfall intensity (mainly central and south-east NSW)
- increases in mean wind speed
- changes in wave behaviour with waves from the south-east becoming more prevalent.

Note that the projection of decreasing annual average rainfall is relative to 1990, which occurred during a 'flood-dominated' period – the second half of the 20th century was relatively wet compared with the first half (Warner 1987).

It is also very likely that river flow throughout the Murray–Darling Basin will be reduced. CSIRO modelling indicates variations of 0 to −20% by 2030 and 5% to −45% by 2070 (AGO 2002). Reductions in flow in the Macquarie River may be smaller than those in southern catchments (Jones et al. 2002).

Projected changes in climate all have the potential to affect natural and managed systems (Whetton 2003). Changes in temperature, rainfall, atmospheric moisture balance, and climatic extremes have implications for altitudinal, latitudinal and longitudinal shifts of species and for habitat viability across the State (Hennessy et al. 2004a, 2004b).

2.4 Climate change and impacts on biodiversity

The northward progression of Australia since the Tertiary period (approximately the last 65 million years) has led to progressive aridity and the emergence of animal and plant life adapted to complex cycles of climate change (Haberle 2003). More recently, the Quaternary period (approximately the last two million years) has been dominated by glacial climates in which mean land temperatures in the interior of Australia were as much as 9°C cooler than at present (Barrows et al. 2000). The Australian continent is large enough to cover a wide range of climates, so a wide range of habitat types has been retained, albeit in changing locations for species capable of migration. Rare species are often those with limited capacity to disperse, or with habitats that have contracted during this present interglacial period, such as the Wollemi pine (Wollemia nobilis) (Haberle 2003).

The main threat from anthropogenic climate change is a magnitude and rate of change which exceeds the capacity of species and ecosystems to survive. Individual species have two possible survival mechanisms in response to changes in climate – adaptation or migration (Hinckley and Tierney 1992). However, evolutionary responses to environmental change are rare, as the speed at which environmental change is projected to occur, which is estimated to be 10–60 times faster than in the past, means that adequate response through adaptive evolution is unlikely for most species in the short term (Hughes 2003b); behavioural changes, shifts in distribution and extinction are more likely (Lister 1997). The result may be a reduction in ecosystem diversity, which would in turn lead to a reduction in resilience to further change (or other threats) and reduced ecosystem services (McGlone 2001).

The current distribution of species, ecological communities and native ecosystems is determined by many factors as well as climate, such as hydrology, soil condition, competition, localised events, land use and habitat availability. Therefore, modelling the response of species to changes in climate is complex and needs to include a range of factors (Davis et al. 1998). Specific examples where climate change is likely to contribute to or cause effects on biodiversity include:

- animal and plant range changes (for example the southerly expansion of the range of some migratory species, and the increasing establishment of snow gums in subalpine meadows)

- changes to flowering and fruiting times
- vegetation thickening in eucalypt woodlands from carbon dioxide enrichment
- increased coral bleaching as a result of increasing sea surface temperatures
- behavioural changes.

The increasing concentration of carbon dioxide in the atmosphere and consequent increase in ocean uptake of carbon dioxide are affecting marine ecosystems through a direct chemical effect (SCOR/IOC Symposium Planning Committee 2004). The increasing amount of dissolved carbon dioxide in the upper waters of the oceans has led to a rise in acidity, which is already significant as the current level is beyond the normal variation to which marine biota have adapted during at least the last million years between glacial and interglacial states (Steffen 2006).

The rate and extent of predicted warming is likely to exceed ecological tolerances for many species. An increase in global average temperature of 3°C may lead to a shift in habitat, and a consequent shift in species, of 300–400 km in the temperate zone towards cooler latitudes, or an increase of approximately 500 m in altitude (Hughes 2000, 2003b). For species confined to areas of winter snow, such as the mountain pygmy possum, suitable climatic conditions may be totally eliminated (Brereton et al. 1995; Broome and Mansergh 1995) (see Box 1).

However, the likelihood that species will be able to shift their range may be compromised by extensive changes to the natural environment from the loss, fragmentation and isolation of habitat and reduced genetic diversity of species. These changes reduce the natural adaptive capacity of ecosystems and native species. Small increases in average temperature would threaten the survival of species currently living near the upper limit of their temperature range (for example in alpine regions). Other species that have restricted climatic niches and are unable to migrate because of habitat fragmentation and other physical factors (such as topography) could also become endangered or extinct (Pittock 2003).

Of 819 eucalypt species, 53% have current ranges of tolerance less than 3°C of mean annual temperature, 41% have ranges less than 2°C, and 25% have ranges less than 1°C. Thus, if even a modest proportion of ecological boundaries reflect current climatic conditions, substantial changes in Australian trees may be expected in the future (Hughes et al. 1996).

Ecosystems that have been identified as particularly vulnerable to the impacts of climate change are coastal ecosystems, alpine areas, rainforests, fragmented terrestrial ecosystems, and areas vulnerable to high fire intensity and frequency, or low freshwater availability. In NSW, areas such as the Snowy Mountains (Box 1), the Macquarie Marshes (Box 2) and the coastal zone (Box 3) have been identified as under great threat from climate change. The projected effects of climate change will have direct implications for the effectiveness of a number of DECC programs and activities. Additionally, it is no coincidence that places of high biodiversity are often places of important Aboriginal cultural heritage, and climate change has impacts on Aboriginal cultural heritage associated with biodiversity (Box 4).

Climate change is also likely to have a range of indirect effects on biodiversity, particularly through increased frequency of extreme weather events leading to more frequent and severe droughts, heatwaves, floods and storms. Many plants and animals respond very rapidly to changes in climate, and ecological responses are largely driven by extreme weather events rather than by changes in mean climate (Steffen 2006). Extreme weather is partly responsible for the unexpectedly rapid ecological changes. Increased periods of prolonged drought are likely to increase the frequency and magnitude of severe fires. This, in turn, is likely to result in landscapes which are more fire tolerant. Increased disturbance to natural environments will provide greater opportunities for invasive species, both native and introduced, to extend their distribution or colonise new ecological niches.

Thus, the direct impacts of climate change on species and ecosystems may include (Hughes 2000, 2003b; McGlone 2001):

- range shifts and species movement towards cooler latitudes or higher elevations
- extinctions of local populations along range boundaries
- changes in productivity and nutrient cycling within ecosystems, due to a combination of climate change and increasing carbon dioxide levels
- increasing threat to species and ecosystems already under stress if extreme events become more frequent or severe
- increasing threat to freshwater ecosystems through decreasing water flows, and changes in water temperature and chemistry
- increasing invasion by opportunistic, weedy or highly mobile species, especially into sites where local populations of existing species are declining
- progressive decoupling of species interactions (for example plants and pollinators).

The consequences of a rise in sea level could be substantial, resulting in impacts to seagrass beds, mangroves, saltmarsh and other productive coastal and shallow water ecosystems, and include saline incursions into freshwater lakes and lagoons. Mangroves in NSW are likely to become taller and more productive, and support species that are currently limited to latitudes further north (Ellison 2003). The landward transgression of mangroves into saltmarsh environments in Australian estuaries has been observed over the last five decades, with saltmarsh losses already up to 80%. While a number of causal mechanisms can be invoked, changes in climate have been implicated as contributing to this trend (Saintilan and Williams 1999).

Recently, ecologists have made the first estimates of the extent to which natural ecosystems can adapt to a changing climate with regard to the conservation of biodiversity (Steffen 2006). It has been estimated that the maximum temperature rise that can be tolerated without significant loss of biodiversity is 1.5°C above pre-industrial levels, and no greater than 0.5°C per century (van Vliet and Leemans 2006).

Finally, depending on the magnitude and rate of warming, an increasing number of species will be at risk of extinction in the wild during this century. The extinction rate, currently 100–1000 times the rate shown in the fossil record, is projected to increase by more than 10 times this already high rate. Due to a combination of direct human modification of habitat and climate change, 10–30% of all mammal, bird and amphibian species are currently threatened with extinction (Reid et al. 2005). In addition to the social and environmental costs, there are significant economic costs associated with increasing numbers of extinct and threatened species, because of an increased need for threat management (bushfire and invasive species control) and investment in developing and implementing threatened species recovery plans, as well as losses of tourism income and ecosystem services and products.

Anthropogenic climate change is a global threat which is superimposed on all other threats and is expected to exacerbate their effects. Climate change will directly affect biodiversity through temperature change, changes in water supply and quality, and increases in extreme events such as fires, floods and droughts.

Box 1: Climate change impacts in the Snowy Mountains

Kosciuszko National Park contains the largest continuous area of alpine and subalpine ecosystems in Australia and is a UNESCO biosphere reserve (Costin 1989; Green 2003; NSW NPWS 2004). Climate change has been identified as one of the greatest threats to the ecosystems of Kosciuszko National Park (Green 1998; ISC 2004; Pickering et al. 2004).

There is evidence that mammals and birds have already responded to the significant decline in snow cover (30%) in the last 40 years (Green 2003). For example, there is an increased penetration of feral mammals into alpine and subalpine areas, and a prolonged winter presence of browsing macropods. While birds are less constrained by altitude, among migratory species there has been an observable change in time of arrival.

The worst case scenario projections modelled by CSIRO could see a contraction of the snow country to a small area centred on Mount Kosciuszko by the year 2050 and the loss of alpine ecosystems and extinction of species whose climatic ranges are already limited to the mountain tops (DEC 2005). These include such species as the southern corroboree frog (Pseudophryne corroboree) and the mountain pygmy possum (Burramys parvus). The breeding success of the mountain pygmy possum is directly related to the depth of snow cover, and if snow cover continues to contract the survival of the species may be seriously threatened (Brereton et al. 1995). Changes will not only be confined to changes in snow cover and alpine habitat, but will also include increased temperature, reduced rainfall and higher levels of ultraviolet radiation (ISC 2004).

DECC has conducted several programs in the alpine region. These include monitoring:

- the break-up of ice on alpine lakes
- the duration of ephemeral ice ecosystems, snow depth and temperature beneath snow cover
- the vertebrate fauna responses to a 30% reduction in snow cover over the last 40 years
- the snowpatch communities and conducting transects to sample invertebrate responses.

In most climate change scenarios, large protected areas such as Kosciuszko National Park will become increasingly important as biodiversity refuges (ISC 2004). Actions to combat the threat of climate change in this region are detailed in the Kosciuszko National Park Plan of Management (NSW NPWS 2004) (see Box 7).

DECC

Box 2: Climate change impacts in the Macquarie Marshes

The Macquarie Marshes are a large and diverse system of wetlands on the lower reaches of the Macquarie River in central northern NSW. The marshes are a haven for thousands of native plants and animals during floods and are among the most important wetlands in Australia for waterbirds. The importance of the Macquarie Marshes has been recognised for many years. Crown land areas of the wetlands were protected as a nature reserve in 1900 and the reserve and some freehold lands have been listed as wetlands of international importance under the Ramsar Convention.

Climate change scenarios for this region indicate that by 2030 average temperatures in the Macquarie Valley may be 0.5–1.6^{o}C higher than at present, rainfall 3–10% lower, and evaporation 3–10% higher (AGO 1998). An integrated study into the impacts of climate change scenarios on the Macquarie River system found that mean annual flows into the marshes reduced by 11–32% (AGO 2002). If water availability is not changed, less water flowing into the Macquarie Marshes will reduce semi-permanent and ephemeral wetland vegetation by 20–40% by 2030, and lead to less frequent breeding of nesting bird species and local population extinctions.

Climate change presents an additional challenge for managers of scarce water resources, and affects water allocation, water use efficiency, crop breeding and selection of plants (AGO 1998). The uncertainty in climate change requires adaptive approaches to the management of biodiversity, using the best existing knowledge, testing and reviewing strategies.

Box 3: Climate change impacts in NSW coastal regions

Although the NSW marine jurisdiction extends only three nautical miles from the coastline and islands, coastal waters have high biodiversity due to the wide range of oceanic, shoreline and estuarine habitats they contain. In Sydney Harbour alone there are at least 1200 different species of shellfish (Ponder 2003). These environments also provide important ecosystem services including pollutant absorption, prevention of coastal and seabed erosion, maintenance of coastal water quality and fisheries.

Climate change, with associated sea level rise, has the potential to disrupt or destroy many intertidal marine ecosystems. This will be exacerbated in areas where there is foreshore development which hinders natural migrations of ecosystems. Changes to oceanic currents, such as the East Australia Current, could affect the 'passive' dispersal of marine species, and shift the habitats of some species.

Projected increases in sea surface temperatures and changes in runoff rates may affect algal growth and lead to increased sediment flow to the coastal regions, as well as increased nutrients and pollution. An increase in ocean temperatures could also lead to changes in marine pest distribution (Walsh 2002).

Anticipating the potential effects of climate change and implementing adaptation strategies will become increasingly important. In acknowledgement of the vulnerability of the coastal zone to climate change, DECC has commissioned a trial of a risk assessment model to examine the projected impact of climate change (see Box 14).

A. Simpson

A. Simpson

Box 4: Climate change impacts on Aboriginal cultural heritage

Aboriginal cultural heritage refers to objects, places and landscapes that Aboriginal people and communities have cultural associations with and attachments to. The items may be physical (tangible) or non-physical (intangible); they include items of traditional occupation of Country such as campsites, middens, and scarred trees; historical places such as mission and massacre sites; sacred places such as burial sites and ceremonial places; stories, songs and knowledge; and natural features such as waterways, plants, animals and seasons. Some plants and animals have food or medicinal uses and others are of totemic value to an individual, family or group.

Places of high biodiversity value are often places of high Aboriginal cultural heritage value, so adaptation actions undertaken for climate change impacts on biodiversity will also be relevant for conserving Aboriginal heritage. However, the complex associations and attachments of Aboriginal people and communities with Country will require specific consideration.

For example, a recent audit of Aboriginal heritage in coastal NSW found that this heritage was in generally poor condition. The rise in sea levels and more extreme climatic events will lead to greater erosion of midden sites and exposure of highly significant burial sites.

Inland areas will also be severely affected by climate change, as increased temperatures and reductions in water flow may exacerbate existing environmental threats. Plants used for food and medicine, and animals of cultural significance such as goannas, echidnas and kangaroos may also decline locally and regionally.

Other likely impacts of climate change will be on seasonal and natural cycles of life that are integral to Aboriginal culture and wellbeing. For example, the germination and pollination of plants and the complex interrelationships between plants and animals will be altered by climate change. Furthermore, changes in bushfires, an increase in algal growth in river systems, and increased competition from invasive species will have dramatic effects on the viability of natural ecosystems and their associated cultural connection to Aboriginal people.

Where significant sites are at risk from climate change, works to reduce vulnerability and improve site stability may be necessary. On occasions, important material may need to be moved to safer locations with cultural permission.

Aboriginal people have lived in Australia for at least 40,000 years and thus have a long history of adaptation to climatic fluctuations. They have adjusted to around 130 m of sea level rise from the last glacial maximum 18,000 years ago until the present level was reached around 6,000 years ago (Pittock 2003). It has also been argued that Aboriginal people modified and managed the landscape through the controlled use of low-intensity fire (Kohen 1995), and these approaches may be helpful in managing changing vegetation patterns and increased fire danger in a changing climate.

2.5 The importance of adaptation

The impacts of climate change can be reduced through mitigation and adaptation. Mitigation measures attempt to limit further changes in global climate through reducing emissions of greenhouse gases, whereas adaptation measures attempt to reduce vulnerability and reduce the consequences of inevitable changes. The most robust method for managing the risks of climate change is to apply mitigation and adaptation as complementary strategies. Adaptation can expand the range of climate variability within which a system can cope, while mitigation reduces the extent of climate change to which a system will be exposed (Figure 3). The combination of these approaches minimises the risk of adverse consequences (Preston and Jones 2006).

Mitigation

The first response must be mitigation to reduce greenhouse gases in the atmosphere, as this is the only way to lessen the rate and magnitude of climatic changes. Substantial cuts in greenhouse gas emissions are required in order to avoid reaching dangerous levels of climate change, which would increase the risk of ecological and social disruption to unacceptably high levels (NSW Greenhouse Office 2005). Significant reduction of atmospheric greenhouse gas concentrations is consistent with the goal of the United Nations Framework Convention on Climate Change (UNFCCC).

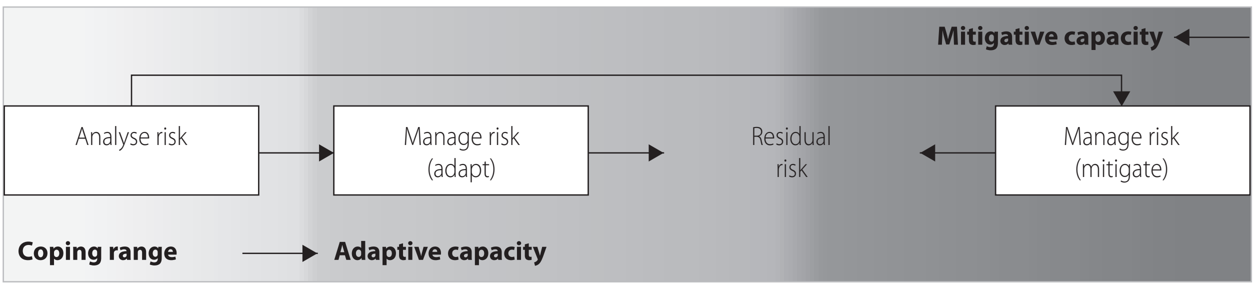
On 11 June 2005, NSW became the first jurisdiction in Australia to commit to ambitious long-term emissions reduction targets (NSW Greenhouse Office 2005). These are:

- a 60% reduction in greenhouse gas emissions by 2050
- a return to year 2000 greenhouse gas emission levels by 2025.

In NSW, the approach to mitigation is outlined in the NSW Greenhouse Plan, which seeks to:

- raise awareness of climate issues within the broader community and gain community support
- limit the growth of greenhouse gas emissions and enhance the establishment of offsets such as trees
- create a long term plan to achieve greenhouse gas emission reduction

Figure 3: The complementary relationship between mitigation and adaptation



Source: Preston and Jones (2006) © CSIRO Marine and Atmospheric Research, reproduced with permission

Adaptive capacity expands the coping range of affected systems reducing their vulnerability, while mitigation reduces the magnitude of climate change to which systems are exposed. Thus, mitigation and adaptation approach risk from opposite directions, but collectively minimise the likelihood of a particular consequence.

- facilitate industry take-up of new business opportunities in growing international markets for low gas emissions goods and services
- work with other governments (both national and international) towards a coordinated global solution
- work with other states and territories on establishment of a national emissions trading scheme.

One of the NSW Government's major policies in this plan is the NSW Greenhouse Gas Reduction Scheme, which establishes a local market for emissions reductions and greenhouse credits with mandatory annual targets based on NSW per capita greenhouse emissions to be met by electricity retailers. Retailers can meet their targets directly or by buying 'credits' that are created through:

- low emission electricity generation (such as natural gas, solar, wind)
- reducing demand and consumption of electricity
- carbon sequestration (the capture of carbon from the atmosphere)
- improving the fuel efficiency of production or other reductions of on-site emissions by users of large amounts of electricity.

An example of how DECC is reducing its own resource consumption is presented in Box 5.

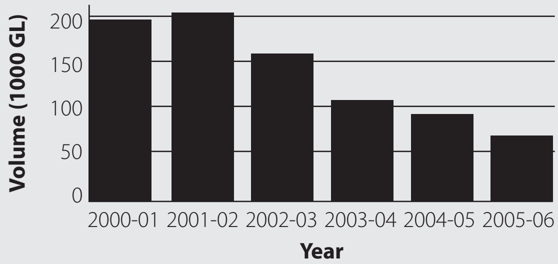
Box 5: Reducing resource consumption within DECC

DECC is committed to decreasing energy and water consumption in order to minimise its impact on the environment and any contribution to greenhouse gas emissions. The Botanic Gardens Trust (BGT) has made water and energy savings resulting from a reduction in resource consumption.

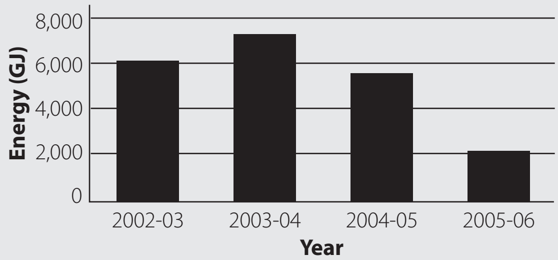
The water savings are based on a reduction in consumption primarily due to water restrictions. However, it is important to note that although there has been a significant reduction in water consumption, the organisation needs to use water, and the reduction has had a substantial impact on the plant collection. An estimate of a sustainable level of irrigation is yet to be determined, but appears to be 140–160 gigalitres per annum: a significant reduction from previous years.

The electricity and gas consumption reductions come from savings from an Energy Performance project, particularly directed at the Brown Building within the Sydney Domain site of the BGT offices.

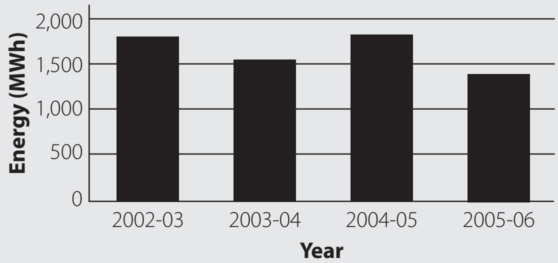
Reduction in energy consumption will continue to be examined by DECC staff.



BGT total water consumption



BGT total gas consumption



BGT total electricity consumption

Adaptation

Mitigation globally can slow the rate of climate change and may eventually limit future change if greenhouse gas concentrations are stabilised. However, very large emission reductions are required if stabilisation is to be achieved within the next century, as carbon dioxide and other greenhouse gases have long atmospheric lifetimes (Whetton 2003). Accordingly, adaptation is a necessary strategy to complement mitigation (IPCC 2001a). Profound impacts of climate change will be felt over the next millennium regardless of emissions reductions, therefore identifying and ameliorating these impacts must be given as high a priority as emissions control (Hughes 2003a).

Adaptation involves adjusting management of the environment to reduce vulnerability to climate change. Adjustments can be made in response to, or in anticipation of, a change in climate. In biodiversity conservation, this should complement programs to reduce pressures from other threats (such as habitat fragmentation, land use change, invasive species, bushfires, pollution and urban expansion).

The UNFCCC stipulates that precautionary measures should be taken to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective (IPCC 2001b).

Assessing the impact of climate change

Most natural systems are sensitive to changes in climate. The extent to which a system will be adversely affected depends on the magnitude and rate of the change, and on the capacity of the system to adapt. An assessment of the vulnerability of a system requires an understanding of the likely changes in climate and its capacity to adapt (see Box 6).

Impacts will increase as the magnitude or rate of climate change increases, regardless of a system's vulnerability. The vulnerability of systems to climate change has largely been expressed relative

Box 6: Climate change vulnerability assessment definitions

Sensitivity is the degree to which a system will respond to a change in conditions.

Vulnerability is the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change, including beneficial and harmful effects) and its ability to adapt.

Adaptability is the extent to which adjustments are possible in response to change.

Resilience is the opposite of vulnerability – a resilient system is not very sensitive to climate variability and has the capacity to adapt.

Adapted from IPCC (2001a)

to average global temperature; however, other climatic variables may be more important. For example, changes in precipitation affect water resources, and sea level rise and storm surge may be more critical than either temperature or precipitation in the coastal zone (Preston and Jones 2006).

In addition, climate variables may be interactive, in that a change in one variable affects the response of the system to another. It is important to acknowledge these complex interactions when assessing the risks of climate change (Preston and Jones 2006). In their report assessing the risk and vulnerability of Australia to changes in climate, the Allen Consulting Group (2005) produced a vulnerability assessment for biodiversity in Australia (Table 1).

Table 1: Assessment of Australia's biodiversity vulnerability

Assessment against framework criteria – biodiversity

VULNERABILITY CRITERION	FINDINGS
Exposure	Increasing temperatures and decreased rainfall in southern Australia and the increases in sea temperatures will impact differentially on flora and fauna. The spread of pests and diseases and changed fire regimes will also expose biota to additional stress.
Sensitivity	Many ecosystems are highly sensitive to climate change especially coral reefs, alpine regions, wetlands and the wet tropics in Queensland. Species most at risk are those at the edge of their temperature limit, or in very specialised habitats. World Heritage listed systems have special importance.
Adaptive capacity	For many species the adaptive capacity is low especially those in isolated or unique habitats. Action to reduce additional stress on ecosystems (for example reduce weed infestation) is feasible. The National Biodiversity and Climate Change Action Plan has identified seven key action areas for improving adaptive capacity.
Adverse implications	Loss of biodiversity is likely to increase especially with rapid climate change. Australia is one of the twelve most biologically diverse nations in the world. Eighty per cent of flora and fauna are unique to Australia.
Potential to benefit	Potential to benefit from planned adaptation varies. There is considerable scope to increase the resilience of many systems by relieving other stresses. A National Climate Change and Biodiversity Action Plan has been agreed by all jurisdictions. Some species may be advantaged while others decline.

Source: Allen Consulting Group (2005)

2.6 The role of adaptation planning

Due to the projected magnitude of impacts and limited research to guide how we manage the environment in the face of climate change, anticipating the potential effects of climate change and implementing adaptation strategies will be increasingly important. The success of various approaches should be continually reassessed and adjusted as new information becomes available. Management may include active intervention to increase adaptive capacity, such as assisted migration, fire management and pest control. A last resort may be ex-situ conservation. Regardless of the management strategy, ongoing monitoring is essential (Hansen and Biringer 2003).

Natural systems will eventually adapt to changes in climate, but the economic, social and environmental costs will be lower if planning is proactive rather than reactive. There will be benefits from early action to build resilience and enable ecosystems to adapt to climate change.

Adaptation planning and risk management

Risk is generally defined as a combination of the likelihood of an occurrence and the consequence of that occurrence. In practice, neither likelihoods nor consequences are known with certainty (AGO 2006). Although we are confident that the climate is changing, we do not know precisely the magnitude of the changes or their associated impacts. Assessments of risk provide a probability of climate change and quantify uncertainty on which to base adaptation planning (Pittock 2003).

Risk management is a tool which can aid decision-making. We do not need conclusive science before action, just a sufficient probability of adverse effects in order to take a risk management approach. A modified version of the Australian Standard for Risk Management (AS4360) can be used to manage uncertainty and risk (AGO 2006). This could include steps such as identifying risk, assessing likelihood and consequences, building and ranking scenarios, and developing options. An example of possible options for risk management is presented in Table 2.

As an example, a risk assessment has been performed for reproduction of waterbirds in the Macquarie Marshes. A critical threshold, above which there is an unacceptable level of harm, was defined as ten successive years of inflows of less than 350 gigalitres per year, which would lead to no breeding during a bird's life cycle. This threshold, taking natural variability such as drought-dominated and flood-dominated regimes into account (Warner 1987), is projected to be exceeded in all scenarios for 2030 and 2070 (Jones 2001).

Overall, there is increasing scientific evidence that climate change will have a pervasive influence and is likely to require resources for management; changes are likely to develop gradually, but could be abrupt (AGO 2006). For example, there is positive feedback between climate and vegetation when climate change is accelerated by consequent vegetation change (Foley et al. 2003). In many natural systems and processes, there are thresholds below which feedback is minimal. Above feedback thresholds, however, potentially damaging events may occur. The collapse of the oceanic circulation that transports relatively warm water to the North Atlantic has an unknown threshold; some scenarios suggest that emissions during the 21st century could trigger this collapse in the following century, and this would have massive global ramifications (Rahmstorf 1999; Schneider and Thompson 2000; IPCC 2001a). A prudent risk management approach suggests that climate change needs to be linked with the development and review of strategic plans and early action will have the most beneficial outcomes.

An important consideration is that the relationship between averages and extremes is often nonlinear. A small change in average values may lead to a large change in extreme events. For example, a shift in average temperature is likely to be associated with significant changes in the number of very hot days. This has major implications if we are calculating risks on the basis of historical records and trends. Future climate change scenarios suggest that past trends may not be applicable to current conditions. When managing future climate variability, we cannot simply rely on the assumption that the prevailing climate will be more or less the same as it was over the past 50 or 100 years (AGO 2006).

Table 2: Possible approaches to risk management

AVOID RISKS
Control emissions to reduce magnitude of total impacts.
Identify and avoid high risk activities in adaptation planning. For example: • avoid investments in hot, dry edge of range areas or isolated remnants other than refuges • avoid naïve responses such as ad hoc translocations, corridors or revegetation.
REDUCE RISKS
Assist natural adaptation of mobile or widely distributed species especially in fragmented landscapes.
Focus on retention and ecological resilience of large natural areas and expand protected areas further to increase adaptive outcomes.
Identify landscape linkages that increase adaptive potential and prioritise off-reserve investment for connectivity and ecological resilience.
Preserve climatic refuge areas and buffer against other threats.
Manipulate habitat to protect species and ecosystems on-site or to accommodate shifting species – prioritise techniques.
Translocate species.
Assess feasibility of simple reserve-based observation stations sampling ecosystem and site characteristics to inform adaptation planning and provide small scale data on thresholds to change.
Maintain and expand efforts to build continental monitoring transects.
ACCEPT RISKS
Abandon at-risk species except for iconic populations.
Abandon isolated, small and vulnerable natural areas unless local conditions indicate resilience to climate change and other threats.
Last resort measures – conservation off-site, in herbariums or museums, or records or gene banking.

2.7 Development of the *National Biodiversity and Climate Change Action Plan*

Our understanding of how the climate will change is growing, but there is still great uncertainty about how individual species and ecosystems will respond. Development and implementation of adaptation options require:

- identifying priority areas for research and monitoring to improve understanding of climate change impacts on biodiversity
- incorporating existing modelling tools into conservation planning and management
- using knowledge about the impacts of climate change and ecological principles to review existing programs and increase their effectiveness in maintaining ecological resilience, increasing habitat connectivity, buffering important ecosystems against other threats and protecting the most vulnerable species in the wild where possible
- improving the level of community and decision makers' awareness and understanding about the impacts of climate change on biodiversity, particularly in relation to conservation, natural resource management and land use planning programs, and local and regional response capacity
- a risk management-based approach to accommodate high levels of uncertainty about consequences.

Recognising these issues, the National Biodiversity and Climate Change Action Plan (the National Action Plan) was released on 11 October 2004. This plan was developed by the Natural Resource Management Ministerial Council and endorsed by all jurisdictions. It was developed to encourage the incorporation of adaptation planning into existing programs. Key strategies include research, promoting ecological connectivity to aid migration and dispersal of species, protecting climatic refuges, creating specific management zones around important habitats and making adjustments to existing programs where information suggests that this would increase ecological resilience and protect vulnerable species and habitats (NRMMC 2004). In addition, the NSW Greenhouse Plan includes support for biodiversity adaptation, including research funding (NSW Greenhouse Office 2005).

3 Priority DECC climate change adaptation actions to reduce biodiversity vulnerability

3.1 Climate change adaptation planning

This document has been produced in order to identify priority actions, programs and responsibilities for implementing the National Action Plan. It allows DECC to incorporate priority actions for biodiversity conservation from the National Action Plan as well as other priorities for DECC programs into one plan. The plan will cross-reference existing programs and key agency strategies, rather than set up new programs.

Uncertainty and adaptive management

The issue of climate change is beset with uncertainty, and definitive conclusions cannot be drawn until further research is undertaken. In biodiversity conservation planning for adapting to climate change, key sources of uncertainty include (but are not limited to):

- the level of detail of modelling
- the ability of species to adapt
- the interaction of climate change with other factors
- nonlinearity of interactions.

Uncertainty makes management challenging. However, although it is clear that further information is required, action should be taken now on the basis of current scientific knowledge using a precautionary approach, with a reassessment as knowledge improves. Beneficial actions that can be taken now include:

- control of invasive species
- ecologically appropriate fire management
- minimisation of habitat fragmentation and degradation
- identification of the most important knowledge gaps and modelling requirements
- development of an integrated research and monitoring framework
- review of the current capacity and development of biodiversity conservation planning tools.

Research in both protected and non-protected areas is essential for understanding how to create resilient ecosystems. Vulnerable ecosystems in particular need monitoring to define thresholds and guide landscape-scale planning. Research about the likely impacts of climate change is essential for reserve planning and management.

Climate change adaptation strategies need to be continually monitored and refined and interdisciplinary research in climate change is essential across all priorities. Scientists have to overcome the challenges of interdisciplinary research, including the integration of different kinds of knowledge, by developing methods to quantify uncertainty and assess risks. In addition, there is an important need to communicate results directly to governments and other policy makers through interactive networks.

3.2 Priorities for biodiversity and climate change adaptation planning

Since much uncertainty still remains about the effects of climate change on biodiversity, we need to first understand the likely impacts on environments and species before we can properly understand the potential effects on human societies and cultures. Therefore, this plan focuses on technical and scientific approaches to increase our understanding of impacts and potential management responses to them and, at this stage, does not address social issues.

Seven priority focus areas have been identified in order to take a practical approach to climate change adaptation planning. These areas link with the National Action Plan and the NSW Greenhouse Plan. They include building and managing the reserve system, addressing threats to biodiversity, cross-tenure connectivity conservation planning, wildlife management, natural resource management and environmental planning, increasing scientific understanding and awareness, and research and monitoring. These focus areas are discussed in more detail in Section 3.3.

Within these seven areas, a number of priority actions have been identified for implementation within the next two years (Section 3.4). They were selected on the basis of urgency, practicality, whether they will achieve multiple benefits, and whether they are critical before other necessary actions can be taken. At the completion of the timeframe of this plan the implementation of these actions will be evaluated. The knowledge gained will be used to guide future adaptation planning. Risk management and adaptive management principles should be applied within each priority focus area and action identified.

A number of principles underpin the identified priority actions listed in this plan.

- Actions need to be practical and able to be implemented during the life of the plan.
- Actions need to be identified as critical first steps, and important in supporting management decisions.
- Actions must be chosen on the basis that they will maximise outcomes.
- A risk management approach is fundamental to adaptation planning.
- Actions need to be targeted to maximise biodiversity conservation and include maintaining ecological resilience, increasing connectivity, buffering important ecosystems against other threats, and protecting the most vulnerable species in the wild where possible.
- Planning and management need to be adaptive, undertaken with a precautionary approach and updated using the best available scientific information gained through monitoring and evaluation.
- Climate change is likely to exacerbate existing threats to biodiversity, and increases the urgency of management and investigation of how they may change and interact.
- Adaptation actions aim to increase the resilience of ecosystems, increasing the likelihood of successful adaptation and decreasing the risk of ecosystem collapse.
- Adaptation planning should lead to increasing community and decision makers' awareness, preparedness and understanding about the impacts of climate change on biodiversity, particularly in relation to conservation, natural resource management and land use programs.

3.3 Priority focus areas for climate change adaptation planning

Seven priority focus areas for biodiversity and climate change adaptation planning within DECC have been identified. These are areas where early and focused actions will have the most beneficial results.

Focus area 1: Building the reserve system

The reserve system in NSW has expanded over the last decade from 4.0 million hectares to 6.5 million hectares, which is 8.5% of NSW. Reserve planning has generally been based on best available information, although this has included little, if any, information on the implications of climate change. Climate change projections suggest that the geographical boundaries of bioregions will shift and more mobile species may migrate to cooler latitudes and higher elevations where this is possible (Hughes 2003c). Therefore, in order to adequately incorporate the impacts of climate change in future reserve establishment, there needs to be consideration of not only the current but also the potential future configurations of habitats, communities and ecosystems.

Future reserves thus need to be designed to protect large landscape areas, as well as climatic refuges, to provide opportunities to maintain diverse species and habitats. However, it is important to note that there are many other drivers of reserve establishment besides climate change, including suitable land, funding, cultural heritage values and recreational opportunities. Additionally, in highly modified landscapes there is often little or no vegetation outside reserve areas and few options for changing reserve establishment selection. Nonetheless, research and modelling of future habitat configurations needs to be undertaken to support reserve establishment.

The retention of natural areas, prevention of further fragmentation and degradation, and increased linkages across the landscape are acknowledged to be effective measures for the conservation of biodiversity that should be incorporated into natural resource planning. It is likely that large, unfragmented reserves will be the most useful means of both adapting to climate change and providing resilience within a landscape, although small and isolated reserves are also important to protect specific conservation values. For example, isolated reserves in the wheat and sheep belt represent the last remaining example of the previous condition of the surrounding area. Importantly, land in the reserve system is protected in perpetuity.

Adaptation strategies that can be included in the design, planning and establishment of reserves include:

- developing conservation planning tools that model the effects of climate change and greenhouse gases on ecosystem dynamics and species responses
- identifying gaps and priorities for new reserves
- establishing regional and continental scale networks of protected areas
- identifying refuges for incorporation into reserves
- identifying locations where buffers, landscape linkages and reserve expansion are needed to maximise conservation of biodiversity.

Refuges can protect small, geographically restricted or remnant populations, and may support species expansion in new climatic conditions. Buffers may significantly increase ecological resilience, minimise threats and maintain viable populations of species.

It is also important to recognise potential risks. For example, increasing the connectivity of habitats will enhance dispersal and adaptation to climate change for most species. However, for many species, one of the greatest threats from climate change is likely to be competitors, predators or pathogens, in which case isolation may increase survival potential (NRMMC 2004). Increasing habitat connectivity in planning for climate change adaptation is therefore both an essential tool and a risk, and requires evaluation for specific locations and species. More information is required to determine how corridors and connectivity in the landscape should be designed to achieve biodiversity conservation without increasing habitat for fire and feral and invasive species (Dunlop and Howden 2003). DECC can build on existing management programs to control these threats.

Focus area 2: Managing the reserve system

Natural systems are already affected by a number of threats, such as habitat fragmentation and loss, water extraction, invasive species and fire. Climate change adds another layer of stress to this complex interaction of processes. Continuing and expanding existing programs that reduce these other threats to improve the health and resilience of natural systems are thus at the core of responding to climate change.

The risks and projected impacts of climate change should be incorporated into parks management plans as they are developed or reviewed. For example, the implications of climate change for the Australian Alps bioregion in NSW are serious, where evidence of impacts have already been observed. This region is the first to explicitly have climate change issues incorporated into its plan of management (see Box 7).

State of the Parks 2004 (DEC 2005) was the first comprehensive report on the management of the reserve system. This report showed that:

- In over two-thirds of the reserve system most natural values are in good condition and their integrity is not at risk.
- Most of the reserve system has pest and weed management programs.
- Eighty-nine per cent of the reserve system is covered by fire management programs.

Box 7: Management of climate change in Kosciuszko National Park

Climate change is one of the greatest potential threats to the ecosystem services and natural values of Kosciuszko National Park (see Box 1).

DECC has implemented a management strategy for Kosciuszko National Park which aims to improve knowledge and understanding of the implications of climate change for the park (NSW NPWS 2004). Strategies include nominating the park for inclusion in the worldwide climate change monitoring program for alpine regions, and developing a long-term research program to measure and understand the effects of climate change on the park. Broadscale and localised climate manipulation will also be investigated.

The plan of management also identifies the need to minimise the effects of all other threats on plant and animal species and communities likely to be influenced by climate change. Strategies for fire management and weed and pest animal control also recognise the impacts of climate change. The plan proposes new systems to reduce the output of greenhouse gases associated with park management, and the development of programs to increase awareness of the impacts of climate change on park values and how visitors can reduce greenhouse gas emissions.

K. Gillett

D. Perryman DECC

Currently, in NSW, invasive pest species have been identified as a threat to 70% of species, populations and communities listed under the Threatened Species Conservation Act 1995. Climate change adds more urgency to the need to control invasive species and requires identification of changes in their distribution, abundance and impact. The effect of invasive species on biodiversity as a result of climate change can be seen through:

- an increase in the number of new incursions
- a change in the distribution and abundance of existing invasive species
- a change in the range of exotic species causing them to become invasive
- a change in the distribution and abundance of native species that are impacted by invasive species.

Climate change is also predicted to have implications for the frequency and intensity of bushfires, as a result of the increased number of hot days, more days of extreme fire risk, alteration of wind patterns and more severe drought periods. There is also likely to be a reduced window for prescribed burning, as well as an increasing shift towards prescribed burning during winter because of higher fire risk in spring, summer and autumn. As a result of changes in climate in the fire-prone landscapes of the Sydney region, fires originating from both natural (lightning) or anthropogenic (arson or accident) ignitions may become more frequent, more intense and larger in size (Hammill and Bradstock 2006).

Overall, current fire, pest and weed management programs need to be continued and enhanced. Research and modelling to investigate the potential impacts of invasive species and changes to fire regimes on biodiversity under the influence of climate change are important to guide future management. There is also a need to greatly increase understanding of species requirements to direct management strategies more effectively. The Threat Abatement Plan for Predation by the European Red Fox (Vulpes vulpes) (NSW NPWS 2001a) is an example of how priority species and habitats within the reserve system can be identified and targeted.

Focus area 3: Cross-tenure connectivity conservation planning

There is a need to increase awareness and acceptance of the importance of connectivity conservation as a mechanism to mitigate the effects of climate change on biodiversity. We must examine options to connect reserves in order to allow species to move to refuges. These options include protecting corridors on a continental scale, and using a combination of conservation measures, including adaptive management of protected areas, other public land and private land. Incentives are essential for achieving outcomes on private land. Connectivity will not guarantee the survival of all species or ecosystems, but it does greatly increase the chances that a large range of species will survive climate change, changing fire regimes, invasive species and altered rainfall patterns.

Connectivity from the Australian Alps to Atherton in far north Queensland is a continental scale land use concept along the Great Escarpment of eastern Australia and parts of the Great Dividing Range (see Box 8). It represents an outstanding opportunity to establish Australia's first continental scale connectivity project. A corridor of protected areas and catchments has already been established along the Great Dividing Range in the Australian Alps and for over 600 km along the southern section of the Great Escarpment from the Victorian–NSW border to the Hunter Valley.

The Great Escarpment is globally and nationally significant, and the Alps to Atherton connectivity initiative provides the only continental scale north–south opportunity to conserve the biodiversity of eastern Australia. Connectivity conservation does not mean creating one big park, but aims to restore connectivity along the Great Escarpment and Great Dividing Range, and to provide the impetus for coordinated action by engaging the community and governments to increase awareness and knowledge of the critical values of biodiversity. Thus, identifying priorities for maintenance and restoration of cross-tenure habitat connectivity, establishing links between reserves and their surrounding landscapes, and fostering cooperative management with all landholders will be important in achieving connectivity conservation.

Box 8: Australian Alps to Atherton

Australian Alps to Atherton involves communities, landowners and governments working together to conserve, protect, restore and link landscapes and ecosystems along the Great Dividing Range and Great Escarpment of eastern Australia. Stakeholders will use cultural knowledge, their own knowledge and the best available science to combine and extend two significant conservation corridors that have been established in south-eastern Australia on public lands during the last 60 years – the Great Dividing Range and the Great Escarpment of eastern Australia conservation corridors.

Linking intact natural ecosystems that include a wide range of habitats will enable plants and animals to move and adapt as climate conditions change, and will reduce habitat fragmentation that has occurred since European settlement.

The objectives of this project are to:

- develop and implement strategies to connect bushland along the NSW section of the Great Escarpment and Great Dividing Range
- develop a vision, objectives and strategies with landholders, stakeholders, government agencies and local government across Australia
- ensure the goals and principles of this project are given high priority in planning and management by all levels of government, and agencies
- link corridors in areas at greatest risk of biodiversity loss.

This project will result in:

- increased awareness of the importance of linking public and privately-owned bushland to help protect biodiversity during climate change
- the implementation of voluntary conservation agreements, revegetation and restoration in high priority areas
- partnerships to include conservation objectives and principles for linking land within conservation planning instruments, plans and investment strategies.


DECC

DECC already recognises that while the reserve system is important to conserve key features of our biodiversity, biodiversity conservation cannot be achieved solely by the creation of parks and reserves. Off-reserve conservation is also important. DECC is working with catchment management authorities, local government, local communities, individual landowners, the private sector and non-government bodies to encourage conservation outside the reserve system. This approach will continue to be a high priority with increasing biodiversity decline.

An example of an existing off-park conservation program is the DECC Conservation Partners Program. This includes establishment of in-perpetuity statutory conservation commitments and the provision of ongoing landholder monitoring and support. The Conservation Partners Program has already established more than 200 in-perpetuity Conservation Agreements over 14,000 hectares and more than 600 wildlife refuges over 1.7 million hectares with more than 1,200 private and other public landholders.

DECC has received a Climate Action Grant for a Climate Action Wildlife Habitats and Corridors Community Conservation Project, which aims to build greater connectivity between protected areas by increasing the amount of protected land in NSW. This project will involve landscape scale assessment and analysis to identify strategic wildlife habitats and corridors. This will strengthen resilience and connectivity of existing protected areas across the State. Specific objectives of this project include:

- creating greater connectivity and buffering by increasing the amount of private and public lands which contain priority wildlife habitats and corridors as formally protected areas, under formal conservation agreements
- increasing community involvement, which is critical to securing conservation gains already achieved and ensuring that strategic wildlife habitats and corridors are developed – partnerships with catchment management authorities, local government and non-government organisations are essential
- maintaining and improving protected areas – their condition, connectivity and resilience – through monitoring and developing models for implementation in priority areas.

Focus area 4: Wildlife management

Climate change necessitates consideration of the dynamic nature of functional ecosystems and of species populations. It may be that attempting to maintain current patterns of species distributions, plant associations and habitat types is impractical. Climate change may cause species redistributions and active management may be required to allow the migration of species and expansion or restoration of habitats. The conservation value of sites is likely to change and guidelines to recognise these changes are needed (Hossell et al. 2000). DECC will incorporate new knowledge and understanding of the projected impacts of climate change on key threats to wildlife into reserve design, voluntary conservation measures, and statewide invasive species programs to enhance wildlife management across NSW.

Long-term monitoring programs and the gathering of data are also vital for managing the impacts of climate change. However, basic information on meteorological factors such as temperature and rainfall is not available for many reserve areas, including areas at risk such as the Gondwana Rainforests of Australia World Heritage Area. Such data are vital for monitoring and threat management, and are fundamental to determine the magnitude of climate change. Options for setting up a coordinated national program to monitor the effects of climate change through partnerships between government, scientists and the community need to be investigated.

Climate change poses challenges to some fundamental concepts in conservation biology, although it is acknowledged that there are many barriers and limitations in addressing these challenges. For example, questions are being raised in the scientific literature as to what extent we should be trying to preserve our present biodiversity and how much we should assist the adaptation of species to the projected changes in climate. For some individual and isolated species, captive breeding and species translocation may be the only options to ensure their survival. Captive breeding programs involve the restraint of individuals by physical means and the provision of conditions suitable for breeding, while translocation is the movement of individuals from one area with release in another by either introduction, re-introduction or supplementation (NSW NPWS 2001b). However, these approaches are expensive, difficult and hazardous (Dunlop and Howden 2003). Plans need to allow consideration of how far and how frequently species need to be moved (Hossell et al. 2000) and follow the policy for translocation of threatened fauna in NSW (NSW NPWS 2001b).

Additionally, research on the predicted changes in plant and animal distributions needs to be interpreted with caution (Lindenmayer and Burgman 2005). Climate is only one of many processes that influence the distribution of organisms. Factors such as competition and predation, the dispersal abilities of species and those they depend on, and the degree of habitat fragmentation are also important. Climate change may lead to new interactions between species, including invasive species. Research examining these possible interactions is vital.

Focus area 5: Climate change adaptation science, research and modelling

There are many requirements for better information to support policy decisions and responses to climate change. Some of the uncertainty stems from a lack of baseline information against which change can be measured. There is thus a need for good data and to ensure that climate change features prominently in natural resource management. Increased links with external research centres and programs are also essential (DEH 2001).

The NSW Government through the NSW Greenhouse Plan allocated $2 million for a Climate Change Impacts and Adaptation Research Program for 2005–08. The program has identified key research priorities for climate change research in NSW. Scientists from DECC, in collaboration with researchers from other agencies, have commenced five priority biodiversity adaptation research projects which focus on the impacts of climate change on bushfires, invasive species, biodiversity including threatened species, inland aquatic ecosystems, and conservation planning software. The results will contribute to increased scientific understanding and awareness of the impacts on species and ecosystems (see Boxes 9–13). Key issues to be addressed through these research projects include:

- identification of the potential effects of climate change on bushfire regimes that affect biodiversity
- a better understanding of likely changes in the distribution, abundance and impacts of invasive species gained through modelling

- determination of the most vulnerable species and ecological communities at risk from climate change
- investigation of the potential effects of climate change on the distributions and life cycles of taxa and ecological communities, and the distribution of habitats identified as likely to be most at risk (for example Kosciuszko National Park, Gondwana Rainforests of Australia and Lord Howe Island)
- assessment of the likely affects of climate change on inland aquatic ecosystems
- development of software to model the effects of climate change on biodiversity.

Additional needs may include:

- identification of natural refuges across marine, terrestrial and aquatic ecosystems and identification of transition habitats that allow for distribution shifts
- identification of the most important knowledge gaps and priority areas, which may include the design and implementation of long-term monitoring and evaluation
- incorporation of climate change projections into catchment hydrological monitoring for aquatic, estuarine and nearshore ecosystems.

Box 9: Fire and climate change

Effects of fire are complex and governed by frequency, intensity and season. While short-term effects of individual fires are important, long-term impacts can only be evaluated by understanding effects of fire on social, economic, ecological and natural resource values.

The necessity for a risk-based approach to fire management is a key recommendation of the recent national COAG inquiry on bushfire mitigation and management.

A DECC-led project will focus on climate change and fire risk in the greater Sydney basin – a key region where climate change effects from bushfires may most acutely affect a wide range of values. In this region, there are areas of highly fire-prone bushland that contain high biodiversity values (such as Blue Mountains National Park which is a World Heritage Area), abut large towns and cities, and affect services, such as water and clean air.

Desired outcomes will be to:

- quantify risk of fire regime changes from predicted changes in climate
- quantify the predicted risks from more intense and frequent fires to biodiversity, ecosystems, people and property
- develop mitigation strategies to deal with these risks
- identify trade-offs that will be needed to adapt to climate change in the Sydney basin.

I. Brown

Box 10: Invasive species and climate change

Invasive plant and animal species are the second greatest cause of biodiversity loss in the world (IUCN 2000) and in NSW (Coutts-Smith and Downey 2006). Invasive animals threaten 14 of Australia's 15 World Heritage Areas and 13 of 15 'biodiversity hotspots'. Invasive plants and animals affect 70% of NSW's threatened species (Coutts-Smith and Downey 2006). Such impacts are likely to increase as a result of climate change (NRMMC 2004).

A DECC-led project aims to project the impacts of climate change on a range of invasive plant and animal species, which can be used to decide how such species should be controlled in the future. The objectives of this project will be consistent with the National Biodiversity and Climate Change Action Plan (NRMMC 2004).

Desired outcomes will be to develop:

- a priority list of invasive species affected by climate change
- models which assess the influence of climate change on invasive species
- recommendations that focus on management of invasive species in NSW
- a list of future research priorities.

M. Cufer, DECC

P. Rebuck

Box 11: Biodiversity and climate change

Human-induced climate change has been listed as a key threatening process under the Threatened Species Conservation Act 1995 and the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth). There is currently little understanding of ways in which climate change may affect biodiversity beyond simplistic bioclimatic modelling. In terms of land management, habitat loss and threats must be minimised, and ecological processes and strategies to minimise disturbance must be maintained in remnant habitats. For species that can move to higher altitudes or to other habitats, there must be sufficient remnant habitat, control of invasive species and vegetation links between habitats.

Before embarking on costly reserve acquisition or restoring cleared land, the best and most cost-effective measures to protect all flora and fauna across diverse landscapes and habitats must be identified. This requires assessing ways in which different species, including threatened species, will be affected by climate change, and ways in which the structure and composition of ecological communities will change.

DECC will identify species and ecological communities at risk from climate change. This will include the methodology used, ways in which climate change will impact on the species and communities, and conservation options. Threatened species and ecological communities in NSW will be examined and reported on. The impacts of climate change on life history will also be examined. In particular, detailed monitoring programs to examine the impacts of climate change will be developed and established in Kosciuszko National Park and Gondwana Rainforests of Australia, and on Lord Howe Island.

T. Auld

P. Honnan

Box 12: Inland aquatic ecosystems and climate change

Regional-scale climate change projections remain uncertain but suggest a reduction in rainfall and increased temperatures over many areas of western NSW (Hennessy et al. 2004a) that will threaten inland wetlands and biodiversity. For example, the reproductive rates of migratory birds that depend on wetlands for their breeding cycle will be affected by drier conditions (Hassall and Associates1998). Current environmental stresses on aquatic and semi-aquatic ecosystems (such as modified flow regimes, habitat destruction, altered patterns of salinity, algal blooms and invasive organisms) will potentially increase the vulnerability of aquatic biodiversity to climate change (NRMMC 2004).

DECC will assess the likely effects of climate change on inland aquatic ecosystems of outstanding value and provide information that will guide future conservation and protection priorities to:

- improve future land and water use conflict resolution
- focus policy and funding to conserve assets of greatest long-term resilience and significance.


DECC

Focus area 6: Natural resource management and environmental planning

Adaptation to climate change needs to be incorporated into routine planning and decision making. As information becomes available, DECC will incorporate projected reductions in rainfall and river flows into existing plans for environmental water use, such as the NSW Wetlands Recovery Plan and NSW RiverBank.

Conservation programs are increasingly being delivered on a regional scale. One important question is whether national-scale climate change projections are useful for regional-scale management (Dunlop and Howden 2003). There is a need to review the existing regulatory and planning instruments to reduce fragmentation and increase connectivity of the reserve system. This might include reviewing the capacity of decision support tools to incorporate the projected impacts of climate change (see Box 13), although it is important to acknowledge the differing levels of confidence associated with climatic variables. For example, we are more confident about projected increases in global mean temperatures, sea level, and intensity and frequency of extreme events, but less confident about changes in rainfall.

Given the high vulnerability of the coastal zone to climate change and the significant amount of coastal land within the reserve system of NSW, DECC has commissioned a pilot risk assessment project to examine the projected impact of climate change in two NSW coastal reserves: Bundjalung National Park and Kooragang Nature Reserve (Box 14).

Box 13: Conservation planning software and climate change

DECC has developed software to evaluate regional land use and management of terrestrial biodiversity. This software is being applied to many assessment and planning activities across NSW including natural resource management projects in conjunction with catchment management authorities, regional strategy and conservation plan development in coastal regions, and multi-species recovery planning.

While the software already considers a variety of pressures and threatening processes (for example, vegetation clearing, urban expansion, grazing, invasive species) it does not yet address climate change. Addition of this capability will enable climate change impacts to be considered when making major land use and management decisions across NSW.

This project will draw on the best available information from related activities (Box 11). In turn, the new software will translate information generated by other activities into a more applicable form for practical planning and decision-making.

Focus area 7: Communication, awareness raising and capacity building

There is a critical need for awareness raising at local and regional levels, as this is where the implementation of adaptation programs will take place. There is a need to disseminate knowledge to catchment management authorities and local councils about projected climate change impacts and adaptation measures. DECC will need to communicate research findings and to collaborate with planning authorities to ensure that the impacts of climate change on biodiversity are seen as integral to general conservation planning.

Options for enhancing communication include the provision of regional climate change information, and incorporation of explicit objectives into catchment action plans to maximise resilience by reducing impacts from threatening processes for species and ecosystems vulnerable to climate change. Influencing catchment action plans to include initiatives such as connectivity and reducing physical barriers to migration and dispersal is an important task for DECC.

DECC has formed an internal climate change network, and has led the establishment of an intergovernmental agency working group to develop and coordinate strategic biodiversity and climate change policy. This has already promoted communication between climate change scientists and policy makers across NSW agencies.

Box 14: Risk assessment approaches in NSW coastal reserves

Climate change, with resultant sea level rise, has the potential to fundamentally disrupt or destroy many intertidal marine ecosystems. This will be exacerbated in areas where there is foreshore development as there is no longer any potential for natural migrations of ecosystems. Changes to the behaviour of current systems (for example the East Australia Current) caused by climate change would affect the 'passive' dispersal of marine species and the location of primary production, and shift the habitats of some species.

Risk assessment can aid planning decisions. Anticipating the effects of climate change and implementing adaptation strategies will become increasingly important. In acknowledgement of the vulnerability of the coastal zone to climate change, DECC has commissioned a pilot risk assessment project to examine the projected impact of climate change, such as sea level rise and coastal recession, in two coastal reserves (Bundjalung National Park and Kooragang Nature Reserve).

This project will test the applicability and value of the method as a decision support tool for DECC activities. The results will lead to the development of projected habitat change risk maps and will produce probability distributions for exceeding sea level thresholds. Probability distributions do not remove uncertainty, but do provide an assessment of the likely ranges of outcomes and the likelihood of particular outcomes within each range. It is anticipated that the results of this pilot project will raise awareness about biodiversity and climate change issues and will demonstrate the value of modelling. This work could be particularly useful in planning coastal reserve design and management and wildlife management.

A. Simpson

3.4 Priority actions across focus areas

Within the identified focus areas for implementing initial climate change adaptation measures in DECC, several priority actions have been identified. These are outlined in Figure 4, with links between the focus areas and the priority actions highlighted.

These priority actions have been identified on the basis that they are essential actions that can be undertaken in the next two years and are necessary in order for DECC to undertake adaptation planning for the projected impacts of climate change.

Future directions

Future directions for biodiversity and climate change adaptation planning in DECC following the implementation of this plan are:

- addressing any limitations identified in natural resource management plans and regulatory arrangements, including development of guidance for biodiversity conservation planning
- incorporation of risk assessment, decision support and modelling tools
- establishment of a coordinated, national indicator program to monitor the impacts of climate change
- identification of priority species threatened by climate change
- development of communication, awareness raising and capacity building programs.

In the interim, the cheapest and best option is to maintain existing conservation reserves and natural areas, avoid further habitat fragmentation and degradation, and maintain strategies to minimise other threats to biodiversity.

3.5 Summary of major limitations in adaptation planning

There are many challenges facing biodiversity and climate change policy. Some of the main ones include:

- lack of scientific certainty
- limited funds for biodiversity conservation
- many ecosystems already degraded, stressed and vulnerable to extreme climatic events such as drought and flood
- many ecosystems characterised by inertia that masks impacts that may not be observed for decades or centuries
- information gaps at all scales
- competing priorities which may not favour biodiversity conservation.

Overall, designing adaptation strategies needs to take account of uncertainties and the risks and benefits of action or inaction. Our initial actions need to focus on both reducing existing threats to biodiversity that will compound the effects of climate change, and increasing our understanding and awareness of the most vulnerable species and ecosystems, the likely impacts, and options to protect them. The actions in this document are thus intended to be the starting point to build our understanding and overall capacity for adaptation planning and are necessary first steps for informing future, more detailed management actions.

The dynamic nature of both human and natural systems demands that climate change policy and management need to be adaptable and flexible. A long-term and strategic approach to adaptation will be required to reduce the risks posed to the biodiversity of NSW associated with a changing climate.

Figure 4: Priority actions across focus areas for biodiversity and climate change adaptation planning

PRIORITY FOCUS AREA (DECC area of responsibility)	PRIORITY ACTIONS
1 Building the reserve system (PWG) 2 Managing the reserve system (PWG) 3 Cross-tenure connectivity conservation planning (CLPG/PWG)	**Addressing land use for biodiversity conservation: (Focus areas 1-5)** **Decision support tools:** • Develop conservation planning tools that can model scenarios and effects of climate change on biodiversity, including the identification of transition habitats. • Identify conflicting climate change projections (such as moisture availability) and factor alternative views into research and modelling. **Coarse modelling of future reserve adequacy:** Model the bioclimatic envelopes for a sample of flora and fauna in existing reserves. The sample needs to be selected to represent different range and niche requirements. Use best available tools such as BIOCLIM and OZCLIM. The aim would be to begin an evaluation of the adequacy of reserves to retain their biota and to support changing biota The modelling should incorporate fire and invasive species. It will be important to avoid naive predictions. **Identify future strategic habitats and corridors:** Undertake landscape scale assessment and analysis to identify strategic wildlife habitats and corridors. The results will help strengthen resilience and connectivity of existing protected areas. **Identify options and requirements for increasing economically functional connectivity in the landscape:** Identify the parameters required for ecologically functional unit links for terrestrial and aquatic species. This should include examining the potential for linkages along temperature and altitudinal gradients and conserving linear aquatic environments, especially in arid areas. Also, assess the feasibility and practicalities of increasing connectivity, and examine potential pitfalls and adverse outcomes, such as spread of invasive species.
4 Wildlife management (PWG)	**Addressing threats to biodiversity conservation: (Focus areas 2-5)** • Maintain remnant vegetation. • Continue to use existing strategies of control for pests, invasive species and pathogens. • Undertake studies to determine the invasive species most likely to be affected by future climates. • Undertake modelling studies to gain a better understanding of the likely changes in the distribution, abundance and impacts of invasive species in order to guide future management. • Undertake research to enable the design and maintenance of ecologically sustainable fire regimes appropriate to biodiversity adaptation requirements.

5 Climate change science, research and modelling (CLPG)

Review DECC climate change science research needs: (Focus areas 1-7)

- Undertake research into the potential effects of climate change on environmental regimes that influence biodiversity and invasive taxa (such as the intensity and frequency of bushfires).
- Through modelling, gain a better understanding of likely changes in the distribution, abundance and impacts of invasive species.
- Undertake research to determine the priority species and communities at risk from climate change.
- Undertake research into the potential effects of climate change on the distributions and life cycles of species and ecological communities, and the distribution of habitats identified as likely to be most at risk.
- Undertake research to assess the likely effects of climate change on inland aquatic ecosystems of outstanding value and provide information tools that will guide future conservation priorities.
- Develop conservation planning tools that can model scenarios and effects of climate change on biodiversity.
- Hold a workshop involving internal and external experts in order to review science and research.

Review DECC monitoring needs: (Focus areas 2-7)

- Examine options for setting up a coordinated national indicator program to monitor the impacts of climate change on natural environments, through partnerships between government scientists and the community.
- Design and implement discrete long-term monitoring projects, in consultation with key experts. This will link with monitoring the responses of common species (wildlife) as part of catchment investment monitoring and evaluation in conjunction with monitoring threatened species and natural resource monitoring for threatened species and wildlife.
- Incorporate climate change projections into catchment hydrological monitoring for aquatic, estuarine and nearshore ecosystems.

6 Natural resource management and environmental planning (CLPG)

Costing *ex-situ* conservation: (Focus areas 4,5)

Undertake preliminary costings of potential *ex-situ* conservation requirements for projected future climate scenarios.

Natural resource management planning: (Focus areas 3,5,6)

- Review existing regulatory and planning instruments and arrangements to reduce fragmentation and increase ecologically functional connectivity under projected changes in climate. This might include reviewing the capacity of decision support tools.
- Undertake pilot projects incorporating risk assessment approaches to examine options for quantifying risks of impacts in terms of their probability of occurrence.

7 Communication, awareness raising and capacity building (CLPG)

Communication and capacity building: (Focus areas 6,7)

- Maintain intra-agency network to discuss biodiversity and climate change management issues.
- Establish and maintain an intranet node for the latest information on climate change research and policies.
- Examine options for communicating the effects of climate change to the community and develop strategies cooperatively with community and expert input. This is likely to enhance community acceptance of changes in protected areas and their management.

Acronyms and abbreviations

AGO	Australian Greenhouse Office
BGT	Botanic Gardens Trust
CLPG	Conservation, Landscape and Policy Group (DECC)
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECC	Department of Environment and Climate Change NSW
IPCC	Intergovernmental Panel on Climate Change
PWG	Parks and Wildlife Group (DECC)
SRES	Special Report on Emissions Scenarios
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

TERM	MEANING IN THIS DOCUMENT
Adaptation	Responses, whether natural or assisted by humans, which enable species and ecological processes to adjust and evolve in response to a changed environment.
Anthropogenic	Resulting from or produced by human activities, such as industry, agriculture, mining, transport and settlement.
Biodiversity	The diversity or variability of living organisms of all types, including genetic, species, and ecosystem diversity.
Buffer zone	An area of land separating natural and modified habitats. It hinders movement of threats and protected species between protected and non-protected areas.
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 timespan 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 UNFCCC definition relates to changes in climate due to anthropogenic factors in addition to changes caused by natural processes.
Connectivity	Connectivity describes the possibility of 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.
Ecosystem	A community of organisms, interacting with one another and with the environment in which they live. It includes all living and non-living components, and the local climate.
Resilience	The ability to withstand or recover from environmental stresses. For example, the healthier an ecosystem is, the greater its resilience, and the lower its vulnerability to environmental threats.
Refuge	A place where species have survived past environmental and climatic changes. Also a place where species may survive the immediate effects of climate change or other threats and from where they may move to new locations if necessary.
Strategic wildlife habitats and corridors	These are important for species persistence or migration, by providing suitable habitat enabling movement across the landscape in response to climate change or other threats.
Weather	The state of the atmosphere, characterised by variables such as temperature, wind, precipitation, clouds, pressure, humidity and sunshine.

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