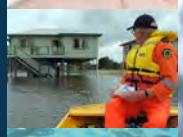
Update 2013

NCCARF
National
Climate Change Adaptation
Research Facility

National Climate Change
Adaptation Research Plan

Terrestrial Biodiversity

Update 2013





National Climate Change Adaptation Research Plan

Terrestrial Biodiversity

Update Report 2013

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This work was carried out with financial support from the Australian Government (Department of Climate Change and Energy Efficiency) and the National Climate Change Adaptation Research Facility.

The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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Executive Summary

Development of National Climate Change Adaptation Research Plans is a key function of NCCARF. These Plans (referred to as NARPs) are produced for nine key sectors where adaptation response is critical in safeguarding against climate and climate change risks to social, economic and environmental well-being.

The purpose of a NARP is to identify priority needs over the next few years in developing knowledge on how governments, businesses and communities can best adapt to the risks of climate variability and climate change. They provide a national blueprint for research investment by research organisations and knowledge-user stakeholders. Development of NARPs involves the active contribution of both the research community and adaptation knowledge users. Implementation plans are produced for each NARP to identify how the research effort can be directed to the identified priority research questions.

The NARP for Terrestrial Biodiversity (Terrestrial Biodiversity NARP) (Hughes *et al*. 2010) is concerned with identifying priority research questions (PRQs) for terrestrial climate change adaptation issues at the national, state, regional and local scales. Research focused on these priority questions should support governments, conservation agencies, businesses, landholders, community organisations and individuals to make sound decisions about climate change adaptation initiatives for terrestrial biodiversity. These decisions should be able to take advantage of opportunities for terrestrial biodiversity that result from climate change and to reduce unavoidable detrimental climate change impacts.

Update of the Terrestrial Biodiversity NARP

NARPs and implementation plans are revisited and updated on a regular basis to maintain their currency as a blueprint for national climate change adaptation research and knowledge development. The Terrestrial Biodiversity NARP and Implementation Plan have been revisited in 2012, as part of NCCARF's review processes. The PRQs are being updated to ensure currency and to provide guidance for research investment over the next five years.

Updated PRQs are identified based on:

- Changes to stakeholder needs since the Terrestrial Biodiversity NARP was completed in 2010;
- Relevant research published since the Terrestrial Biodiversity NARP was completed; and
- Areas of current research focus in relation to the Terrestrial Biodiversity NARP.

Changes to stakeholder information needs

Stakeholders appear to now better appreciate the complexity of the climate, ecological and human systems involved in climate change adaptation for terrestrial biodiversity. This change has resulted to some extent from experience with a series of extreme weather events since 2009 that have also affected Australian interests and concerns about water supplies, primary production, food security, human health and other issues that intersect with biodiversity. The change is broadly in line with a greater international focus on interactions between ecosystem health, resilience and stability and adaptation benefits in other sectors (termed 'ecosystem-based adaptation').

In addition, the implementation of the Australia Government's Clean Energy Future package and associated programs has resulted in increased stakeholder interest in options to protect biodiversity through initiatives that also increase land-based organic carbon.

The main changes in stakeholder information needs about terrestrial biodiversity relate to greater interest in:

- adaptation in association with land based carbon sequestration initiatives;
- adaptation in the context of local or regional management of multiple use subcatchments or catchments;
- the role of biodiversity in managing climate change impacts in other sectors;
- emergency management issues associated with climate change impacts on ecosystems (e.g. fire risk management); and
- adaptation to the concurrent direct and indirect effects of climate change on several existing stressors of ecosystems.

Research published since 2010

Climate change adaptation for terrestrial biodiversity is a rapidly expanding research area. Guitart (2012) reviewed over 170 research articles and other publications which have appeared in the last few years since the Terrestrial Biodiversity NARP was completed. Information from this review was a major contributor to this update, augmented by further publications identified during the update preparation.

Current research

In the past few years Australia has invested in research about climate change and terrestrial biodiversity through a number of programs. This research, when published, will add substantially to the existing knowledge base.

The Adaptation Research Grants Program (ARGP) managed by NCCARF has invested in 10 research projects directly relevant to the terrestrial biodiversity sector. These projects have an NCCARF/ARGP contribution of $3.2 million, and the total value of the research program is more than $6.3 million (including leveraged cash and in-kind). Further research relevant to terrestrial biodiversity has been commissioned through other ARGP research themes and through NCCARF's Synthesis and Integrative Research (SIR) program.

In addition to the NCCARF research program, the Australian Research Council (ARC) is supporting 30 projects relevant to the Terrestrial Biodiversity NARP PRQs. Other organisations investing in research of this type include CSIRO, SEWPaC and state organisations.

Stakeholder input to the Update

A draft of this Update Report was circulated to about 70 key stakeholders nationally, was available for review from the NCCARF website and was reviewed by an international expert. Comments received contributed to this final Update Report.

Outcome of this Update

The outcome of this Update is that all PRQs in the Terrestrial Biodiversity NARP remain 'High' priority. However, one question is broadened, one section is slightly redefined and three PRQs are revised or restated, as set out below:

- One research priority has been broadened to explicitly encompass the issues and opportunities associated with ecosystem-based adaptation:

  5.2.1 ~~What designs of landscapes in regions having different land uses confer maximum resilience for biodiversity in the face of climate change, including the uncertainty associated with future climate scenarios?~~

  What principles should guide ecosystem-based adaptation in Australia and the design of landscapes to support ecosystem resilience?

- One research priority has been restated to reflect recent Australian Government initiatives:

  5.2.3 How can Australia's land-based ~~large-scale~~ carbon mitigation initiatives~~, such as revegetation and forest-related mitigation,~~ be designed to enhance ecosystem

services, ensure appropriate ecological connectivity, ~~maximise~~ deliver biodiversity conservation benefits and ~~to~~ avoid adverse impacts on biodiversity?

- The focus of one section has been expanded and the section has been renamed:

NARP Section 5.4 Managing key species and communities

- Two research priorities in this section have been reworded to reflect this change in focus:

5.4.1 How can investment in climate change adaptation measures to conserve species and communities be prioritised? ~~Which species should be the focus of investment in climate change adaptation~~?

5.4.2 How will climate change affect current management actions for protecting priority species and communities, and what management changes will be required?

The updated set of priority research questions is listed in the table on the next page.

The updated Terrestrial Biodiversity Implementation Plan is available at http://www.nccarf.edu.au/content/narp-terrestrial-biodiversity/

High priority research questions (Update: 2013)

High priority research questions (2013)
5.1 National- / continental scale issues
5.1.1 How will climate change affect existing conservation goals and how should changed conservation goals be promoted and achieved?
5.1.2 How can the existing Australian legal, policy and institutional architecture for land management and biodiversity conservation respond to changes in conservation goals caused by climate change?
5.1.3 What conceptual models and long-term observation systems are needed to support the design, analysis and assessment of active adaptive management and policy experiments at regional and national scales under climate change?
5.2 Regional issues
5.2.1 What principles should guide ecosystem-based adaptation in Australia and the design of landscapes to support ecosystem resilience?
5.2.2 How will climate change interact with other key stressors such as fire, invasive species, salinity, disease, changes to water availability, grazing and clearing, and what are the integrated implications for ecosystem structure and functioning?
5.2.3 How can Australia's land-based carbon mitigation initiatives be designed to enhance ecosystem services, ensure appropriate ecological connectivity, deliver biodiversity conservation benefits and avoid adverse impacts on biodiversity?
5.2.4 How can the major socio-economic trends occurring in many regions of Australia contribute to effective climate change biodiversity adaptation responses?
5.3 Local land management issues
5.3.1 What are the costs and benefits of different climate change adaptation measures in vulnerable ecological communities and ecosystems?
5.3.2 How should fire management adapt to climate change?
5.3.3 How can management of local protected areas incorporate and adapt to climate change?
5.3.4 How can we better integrate conservation plans and actions across landscapes, incorporating protected area management, off-reserve conservation measures and other land uses, in order to maximise biodiversity conservation benefits / outcomes under a changing climate?
5.4 Managing key species and communities
5.4.1 How can investment in climate change adaptation measures to conserve species and communities be prioritised?
5.4.2 How will climate change affect current management actions for protecting priority species and communities, and what management changes will be required?
5.4.3 How will climate change affect current or potential problem species and what management responses will be required?

Introduction

Development of National Climate Change Adaptation Research Plans is a key function of NCCARF. These Plans (referred to as NARPs) are produced for nine key sectors where adaptation response is critical in safeguarding against climate and climate change risks to social, economic and environmental well-being.

The purpose of a NARP is to identify priority needs over the next few years in developing knowledge on how governments, businesses and communities can best adapt to the risks of climate variability and climate change. They provide a national blueprint for research investment by research organisations and knowledge-user stakeholders. Development of NARPs involves the active contribution of both the research community and adaptation knowledge users. Implementation plans are produced for each NARP to identify how the research effort can be directed to the identified priority research questions.

The NARP for Terrestrial Biodiversity (Terrestrial Biodiversity NARP) (Hughes *et al*. 2010) is concerned with identifying priority research questions (PRQs) for terrestrial climate change adaptation issues at the national, state, regional and local scales. Research focused on these priority questions should support governments, conservation agencies, businesses, landholders, community organisations and individuals to make sound decisions about climate change adaptation initiatives for terrestrial biodiversity. These decisions should be able to take advantage of opportunities for terrestrial biodiversity that result from climate change and to reduce unavoidable detrimental climate change impacts.

NARPs and implementation plans are revisited and updated on a regular basis to maintain their currency as a blueprint for national climate change adaptation research and knowledge development. The Terrestrial Biodiversity NARP and Implementation Plan have been revisited in 2012, as part of NCCARF's review processes. The PRQs are being updated to ensure currency and to provide guidance for research investment over the next five years.The revisit and update is informed by:

- a comprehensive review of the literature published since 2010 (Guitart 2012) when the Terrestrial Biodiversity NARP was originally drafted,
- current research addressing research priorities identified in the Terrestrial Biodiversity NARP,
- recent policy initiatives,
- priority needs of terrestrial biodiversity stakeholders in Australia and
- input from the Terrestrial Biodiversity Adaptation Research Network and from other key stakeholders.

Several reports have contributed to this update, including the State of the Environment Report 2011 (State of the Environment 2011 Committee, 2011), 'Australia's Strategy for the Natural Reserve System 2009-2030' (NRMMC 2009) and 'Australia's Biodiversity Conservation Strategy 2010-2030' (NRMMC 2010).

A discussion of each research priority and proposed amendments is set out in Section 4 of this report; changes are summarised in Section 5. An updated table of PRQs resulting from this revisit is provided in Section 6.

A draft of this Update Report was circulated to about 70 key stakeholders nationally, was available for review from the NCCARF website and was submitted to an international reviewer. Comments received contributed to this final Update Report. The updated Terrestrial Biodiversity Implementation Plan is available at http://www.nccarf.edu.au/content/narp-terrestrial-biodiversity/.

Major changes to stakeholder information needs since 2010

Stakeholder awareness of climate change and information needs to support decisions about adaptation have been affected by several factors.

Stakeholders appear to now better appreciate the complexity of the climate, ecological and human systems involved in climate change adaptation for terrestrial biodiversity. This change has resulted to some extent from experience with a series of extreme weather events since 2009, that have also affected Australian interests and concerns about water supplies, primary production, food security, human health and other issues that intersect with biodiversity. The change is broadly in line with a greater international focus on interactions between ecosystem health, resilience and stability and adaptation benefits in other sectors (termed 'ecosystem-based adaptation').

The Commonwealth Government has issued several national policies and strategies that are relevant to biodiversity adaptation to climate change. The implementation of the Australia Government's Clean Energy Future package and associated programs has resulted in increased stakeholder interest in options to increase or protect biodiversity through initiatives that also increase land based organic carbon.

These national strategies include:

'*Australia's Biodiversity Conservation Strategy 2010-2030*' (NRMMC 2010) provides a guiding framework for conserving the nation's biodiversity for the coming decades for all sectors – government, business and the community in 2010. The strategy sets out priorities which include: engaging all Australians in biodiversity conservation, building ecosystem resilience in a changing climate and obtaining measurable results. The Strategy lists climate change as one of several threats to biodiversity, and identifies as one of three priorities for action *Building ecosystem resilience in a changing climate* by*:*

- protecting diversity,
- maintaining and re-establishing ecosystem functions, and
- reducing threats to biodiversity.

- '*Australia's Strategy for the Natural Reserve System 2009-2030*' (NRMMC 2009) provides national guidance for protected area managers and key stakeholders through six key themes: (1) international and national context, (2) protected area design and selection, (3) establishment, (4) planning and management, (5) science, knowledge management, monitoring and (6) performance reporting and strengthened partnerships and community support.

The Australian Government and several other jurisdictions have developed, or are developing, policy statements for biodiversity conservation that contain strong climate change emphasis. For example, the Australian Government Biodiversity Policy (still in consultation draft form; DSEWPaC 2011) aims to deliver a more integrated approach to tackling the challenge of biodiversity conservation in a changing climate. It describes the role of the Australian Government and the principles that will guide the design and delivery of its policies and programs related to biodiversity (DSEWPaC 2011).

In addition to policy, the Australian Government has also taken major program action through the Clean Energy Future package. The package has a number of components, of which four are relevant to biodiversity conservation;

- the Biodiversity Fund,
- the Carbon Farming Initiative,
- the Land Sector Carbon and Biodiversity Board, and
- the Regional Natural Resource Management Planning for Climate Change Fund.

State and territory governments have issued policy and strategy statements concerned with climate change adaptation for biodiversity, such as the governments of Victoria (Government of Victoria, 2009) and New South Wales (Government of New South Wales, 2010).

The main changes in stakeholder information needs for terrestrial biodiversity arising from these and other factors relate to:

- adaptation in association with land based carbon sequestration initiatives;
- adaptation in the context of local or regional management of multiple use subcatchments or catchments;
- the role of biodiversity in managing climate change impacts in other sectors;
- emergency management issues associated with climate change impacts on ecosystems (e.g. fire risk management) and
- adaptation to the concurrent direct and indirect effects of climate change on several existing stressors on ecosystems.

Ecosystem-based strategies for adaptation have become prominent in international approaches to climate change. These integrate the use of biodiversity and ecosystem services into an overall adaptation strategy to help people to adapt to the adverse impacts of climate change (Colls et al. 2009). For instance, the World Bank argues that "*… ecosystem-based approaches to mitigation and adaptation … can offer cost-effective, proven, and sustainable solutions that contribute to, and complement, other national and regional adaptation strategies*" (World Bank, 2010, p.2), and that adaptation that protects natural ecosystems is able to provide social, economic and environmental benefits in both developing and developed nations. These benefits include protecting watersheds and water production, food and soil resources and coastal stability. A UNFCCC report refers to '… a growing recognition of the role that healthy ecosystems can play in increasing resilience and helping people to adapt to climate change through the delivery of the range of services that play a significant role in maintaining human well-being' (UNFCCC 2011, p. 3).

Box 1. Some recent examples of extreme events and impacts on terrestrial biodiversity

THE BIG DRY: The recent 13-year drought in the southern Murray-Darling Basin (MDB) and Victoria was unprecedented compared with other recorded droughts since 1900. This prolonged drought highlighted dwindling river flows and the competition between agricultural, urban and environmental water needs and demand. Concern over the environmental impact of declining rainfall, drought and the overuse of water resources contributed to the development of the Water Act 2007, establishment of the Murray-Darling Basin Authority and preparation of the Basin Plan.

***Sources**: http://www.bom.gov.au/climate/drought/archive/20100408.shtml - extracted 26 January 2012.* Water Act 2007, Part 1, Section 3 Object, http://www.comlaw.gov.au/Details/C2012C00229 Murray-Darling Basin Authority, Proposed Altered Basin Plan, http://www.mdba.gov.au/proposed-basin-plan – accessed 14 November 2012

HEATWAVES and BUSHFIRES: Associated with El Niño conditions, a severe heatwave occurred in southern Australia from 26 January to 7 February, 2009. There was a record run of days above 43°C at Adelaide and Melbourne. Estimates of deaths resulting from the hot conditions range from 424 to 500 people. Power outages resulting from bushfires and transport system disruptions to the Melbourne rail network caused financial losses estimated at $800 million. On 7 February, strong, dry north-westerly winds fanned bushfires which claimed 173 lives, mostly in areas northeast of Melbourne. The Royal Commission established to report on the Victorian fires recommended that the existing program of long-term data collection be upgraded to monitor and model the effects of prescribed burning programs and of bushfires on biodiversity in Victoria; that roadside vegetation be managed to reduce fire risk and protect human lives; and where necessary environment protection legislation be amended to facilitate annual bushfire-prevention activities.

Sources: *Bureau of Meteorology Annual Climate Summary 2009 (2010), http://www.bom.gov.au/climate/annual_sum/2009/index.shtml - extracted 26 January 2012. Teague et al. (2010) 2009 Victorian Bushfire Royal Commission - Final Report, http://www.royalcommission.vic.gov.au/finaldocuments/summary/pf/vbrc_summary_pf.pdf.*

FLOODS OF 2010 and 2011: In early September 2010, associated with a switch to La Niña conditions, there was flooding on many rivers in northern Victoria. In September 2010, a tropical depression formed over the Gascoyne area of Western Australia, producing severe floods in the region. Beginning in December 2010 and early 2011, a series of floods hit Eastern and SE Australia, including river and flash flooding, primarily in the state of Queensland including its capital city, Brisbane. More than 78 per cent of the state (an area bigger than France and Germany combined) was declared a disaster zone. These floods forced the evacuation of thousands of people from towns and cities. Flooding leads to significant losses of domestic and native animals and prolonged water logging can affect soils, soil biota and dry adapted flora. However, short flood periods leave soils deeply saturated and wetlands filled to capacity, leading to an explosion of life as witnessed on Lake Eyre and its tributaries. Flooding also mobilises and transports materials, minerals and nutrients, creates physical habitat; and facilitates connectivity for dispersal and migration of aquatic organisms.

***Sources**: Bureau of Meteorology Annual Climate Summary 2010 (2011), http://www.bom.gov.au/climate/annual_sum/2010/index.shtml - extracted 26 January 2012. http://en.wikipedia.org/wiki/2010_Gascoyne_River_flood, http://www.bom.gov.au/announcements/media_releases/climate/change/20120104.shtml Bureau of Meteorology Annual Climate Summary 2010 (2011), http://www.bom.gov.au/climate/annual_sum/2010/index.shtml and Bureau of Meteorology Annual Climate Summary 2011 (2012), http://www.bom.gov.au/climate/annual_sum/2011/index.shtml - extracted 26 January 2012.* Jenkins, K.M., Kingsford, R.T.,Wolfenden, B.J., Whitten, S., Parris, H., Sives, C., Rolls, R. and Hay, S. 2011. *Limits to climate change adaptation in floodplain wetlands: the Macquarie Marshes*. Final report to the National Climate Change Adaptation Research Facility. Natural Resource Commission (2009). Riverina Bioregion Regional Forest Assessment – River Red Gums and Woodland Forests. Chapter 11, Managing red gum floodplain ecosystem

CYCLONE YASI: In February 2011, Cyclone Yasi was one of the most powerful cyclones to have affected Queensland. Tully Sugar Mill recorded sea level pressure of 929 hPa as the eye passed over, suggesting wind gusts of about 285 km/h were possible, leaving behind significant damage. While the forests of the wet tropics of northern Australia have adapted to the impact of cyclones, their resilience has been undermined by habitat fragmentation. Cassowary populations and the endangered Mahogany Glider (*Petaurus gracilis*) lost key resources.

***Sources**: http://www.bom.gov.au/cyclone/history/yasi.shtml. - extracted 26 January 2012. http://www.news.com.au/business/bananas-sugar-growers-worst-hit-by-tropical-cyclone-yasi/story-e6frfm1i-1226000185348 - extracted 13 November 2012.* TURTON, S. M. (2012), Securing Landscape Resilience to Tropical Cyclones in Australia's Wet Tropics under a Changing Climate: Lessons from Cyclones Larry (and Yasi). Geographical Research, 50: 15–30. doi: 10.1111/j.1745-5871.2011.00724.x

Research findings and activities since 2009

Published findings

Research published since the Terrestrial Biodiversity NARP was completed has been reviewed by Guitart (2012). She reviewed and summarised over 170 relevant research publications and other documents published between 2010 and 2012. Her report was structured around the research priorities of the Terrestrial Biodiversity NARP, allowing an assessment of the extent, nature and coverage of published research against each PRQ. Key findings have been extracted from that report and included in Section 4, with representative references. See Guitart (2012) for publications included in that review. Further research publications identified through the consultation process have augmented Guitart (2012) in this Update Report.

Current research

Australia has invested in research about climate change adaptation and terrestrial biodiversity through a number of programs, many of which are funded by the Commonwealth Government through the Adaptation Research Grants Program (ARGP), the Australian Research Council, the CSIRO, and universities and other research organisations. In addition, research that is relevant to terrestrial biodiversity management under climate change is funded by state and territory governments, industry, conservation and community groups and other organisations This section lists research activities about which we are aware that is contributing to knowledge about climate change adaptation and terrestrial biodiversity.

NCCARF research

The Adaptation Research Grants Program (ARGP), managed by NCCARF, has invested in 10 research projects directly relevant to the terrestrial biodiversity sector (see Box 2). These projects have an ARGP contribution of $3.2 million, and the total value of the research program is more than $6.3 million (cash and in-kind). Further research relevant to terrestrial biodiversity has been commissioned through other ARGP research themes and through NCCARF's Synthesis and Integrative Research (SIR) program (see Boxes 3 and 4). Reports from all of these research projects will be available by June 2013 from the NCCARF website www.nccarf.edu.au.

These research projects are referred to throughout Section 4, where appropriate.

Box 2:

NCCARF ARGP research projects directly relevant to priority research questions in the Terrestrial Biodiversity NARP

(Note: further information about these projects is available in Appendix 3 and at http://www.nccarf.edu.au/research/thematic/400)

Research Project Title	Principal Investigator	Institution
TB11 01 - The architecture of resilient landscapes: scenario modelling to reveal best practice design principles for climate adaptation	Veronica Doerr	CSIRO
TB11 02 - Optimal habitat protection and restoration for climate adaptation	Richard Fuller	University of Queensland
TB11 03 - Climate-resilient revegetation of multi-use landscapes: exploiting genetic variability in widespread species	Margaret Byrne	Department of Environment and Conservation (DEC), WA

Research Project Title	Principal Investigator	Institution
TB11 04 - Adaptation strategies for Australian birds	Stephen Garnett	Charles Darwin University
TB11 05 - Determining future invasive plant threats under climate change: a decision tool for managers	Lesley Hughes	Macquarie University
TB11 06 - Developing management strategies to combat increased coextinction rates of plant dwelling insects through global climate change	Melinda Moir	University of Melbourne
TB11 07 - Determining high risk vegetation communities and plant species in relation to climate change in the Australian alpine region	Catherine Pickering	Griffith University
TB11 08 - The role of refugia in ecosystem resilience and maintenance of terrestrial biodiversity in the face of global climate change	Stephen Williams	James Cook University
TB11 09 - Adapted future landscapes - from aspiration to implementation[1]	Wayne Meyer	University of Adelaide
FW11 09 - Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems.[2]	Michael Dunlop	CSIRO

Box 3:

NCCARF-managed (ARGP) research projects relevant to the priority research questions in the Terrestrial Biodiversity NARP, commissioned under other themes

(Note: further information about these projects is available at http://www.nccarf.edu.au/research/thematic-research-grants)

Research Project Title	Principal Investigator	Institution
FW11 06 - Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management.	Jenny Davis	Monash University
FW11 07 - Identification and characterization of freshwater refugia in the face of climate change	Jeremy VanDerWal	James Cook University
EM11 10 - Changing Perceptions about Climate Change	Joseph Reser	Griffith University
SD11 12 – Valuing adaptation under rapid change: anticipatory adjustments, maladaptation and transformation	Roger Jones	Victoria University
FRDC1 - Changing currents in marine biodiversity governance and management responding to climate change	Michael Lockwood	University of Tasmania

[1] Note that NCCARF/ARGP project TB11 09 [Meyer], concerned with climate change adaptation in multiple use landscapes, was commissioned under three themes (Primary Industries, Terrestrial Biodiversity and Freshwater Biodiversity).

[2] Note that NCCARF/ARGP project FW11 09 [Dunlop], concerned with conservation goals, was commissioned under two themes (Terrestrial Biodiversity and Freshwater Biodiversity).

Box 4:
NCCARF's Synthesis and Integrative Research (SIR) projects relevant to the priority research questions in the Terrestrial Biodiversity NARP

(Note: further information about these projects is available at http://www.nccarf.edu.au/research/s-and-i)

SIR Research Project Number and Title	Principal Investigator	Institution
P1FVA2 - Biophysical impacts of climate change on Australia's forests	Belinda Medlyn	Macquarie University
P1FVA3 - Socio-economic implications of climate change with regard to forests and forest management	Geoff Cockfield	University of Southern Queensland
P1FVA4 - An Assessment of the Vulnerability of Australian Forests to the Impacts of Climate Change: Climate change adaptation options, tools and vulnerability	Steve Turton	James Cook University
P1FVA5 - A Preliminary Assessment of the Vulnerability of Australian Forests to the Impacts of Climate Change – Synthesis Report.	Sarah Boulter	Griffith University / NCCARF
P2LTA2 - Limits to Adaptation project: Alpine areas	Catherine Pickering	Griffith University
P2IMLP - iClimate - Literature review of climate change impacts	Elvira Poloczanska	CSIRO
S3BAM1 – Identifying low risk climate change mitigation and adaptation in catchment management while avoiding unintended consequences.	Max Finlayson	Charles Sturt University

Other research activities

In addition to the NCCARF research program, the Australian Research Council (ARC) is supporting 30 projects relevant to a greater or lesser extent to the Terrestrial Biodiversity NARP PRQs, and other organisations are also investing in research of this type, including CSIRO, SEWPaC and state organisations (see Box 5).

These research projects are referred to throughout Section 4, where appropriate.

Box 5:

Climate change adaptation research projects relevant to the priority research questions in the Terrestrial Biodiversity NARP, commissioned and managed by other organisations

Research Project Title	Principal Investigator	Institution
ARC Grants *(For further information:* http://arc.gov.au/applicants/fundingoutcomes.htm)		
[FL100100066] New approaches for pest control and maintaining healthy environments under climate change	Ary Hoffmann	University of Melbourne
[DP110101929] New methods for improving active adaptive management in biological systems	Nigel Bean	University of Adelaide
[DP110104186] Global climate change and the impacts of temperature extremes on terrestrial biodiversity	Justin Welbergen	James Cook University

Research Project Title	Principal Investigator	Institution
[DE120101533] Understanding faunal responses to climate change and environmental perturbations through the Quaternary in north-eastern Australia	Gilbert Price	University of Queensland
[DE120101263] Assessing the impact of global environmental change on the nutritional ecology of marsupial and insect folivores of Eucalyptus	Karen Ford	Australian National University
[DE120100518] Shifting rainfall from spring to autumn: tree growth and water use under climate change	Melanie Zeppel	Macquarie University
[FT110100951] Integrating evolution and plasticity into predictions of population persistence in a changing climate: adaptation or extinction?	Carla Sgro	Monash University
[FT110100246] Ecosystem response to climate and anthropogenic disturbances: implications for greenhouse gas emissions and nutrient cycling	Daniel Murphy	The University of Western Australia
[FT110100453] Evolution in a changing environment	Loeske Kruuk	Australian National University
[FT100100819] From prediction to adaptation: responding to rapid ecosystem shifts under climate change	Brendan A Wintle	University of Melbourne
[FT100100338] Modelling the potential of large-scale revegetation to reduce the impacts of climate change in semi-arid Australia	Clive McAlpine	University of Queensland
[FT100100200] Systems modelling for synergistic ecological-climate dynamics	Barry Brook	The University of Adelaide
[FT100100237] Drought and death: past, present and future survival limits in the Australian vegetation landscape	Timothy Brodribb	University of Tasmania
[FT100100464] Phenotypic plasticity in plants: evolution, adaptation and its relevance in a changing climate	Adrienne Nicotra	The Australian National University
[FT120100715] Climate-proofing southeastern Australia's native forests: where, when, and how?	Patrick Baker	The University of Melbourne
[FT120100204] Animal response to extreme climatic events	Martijn van de Pol	The Australian National University
[FS110200051] Multi-model predictions of ecosystem flux under climate change based on novel genetic and image analysis methods	Andrew Lowe	University of Adelaide
[LP110100321] Adaptive management of native vegetation condition	Peter Vesk	University of Melbourne
[LP110100721] Species and gene turnover across environmental gradients - a landscape-level approach to quantify biodiversity and resilience for climate adaptation	Andrew Lowe	University of Adelaide
[LP100100600] The return of the native: reintroductions, reinvasions, and a new paradigm in restoration ecology	Peter Banks	University of New South Wales

Research Project Title	Principal Investigator	Institution
[LP100100738] Impact of reforestation on the mitigation of climate extremes in eastern Australia resulting from global warming	Clive McAlpine	University of Queensland
[LP100100356] Testing the potential of integrated vegetation bands to increase water retention, buffer climate extremes, sequester carbon and enhance production	Justin Ryan	University of Queensland
[LP100100467] Best practice temperate woodland assessment, management and monitoring	David Lindenmayer	Australian National University
[LP100200080] Innovative approaches to identifying regional responses of biodiversity to climate change	Daniel Ramp	University of New South Wales
[LP110100527] Predicting climate change impacts on biodiversity: testing and applying new approaches	Mark Ooi,	University of Wollongong
[LP110200229] How will animals respond to climate change? A genomic approach	David Lambert	Griffith University
[LP110200805] Developing best-practice approaches for restoring forest ecosystems that are resilient to climate change	Andrew Lowe	University of Adelaide
[LP120200249] An integrated tool for informing pest management: modelling range shifts for an invasive vertebrate in response to climate change	Damien Fordham	University of Adelaide
[LP120200380] Providing a genetic framework to enhance the success and benefits from forest restoration and carbon plantings in rural landscapes	Bradley Potts	University of Tasmania
[LE120100044] New facilities for multiplex gas-exchange (MGX) measurements of plant performance during climate-controlled growth	Andrew Millar	University of Western Australia
Research and Development Corporation Grants		
[RDC 1] Climate Change and Australia's plantation estate: Analysis of vulnerability and preliminary investigation of adaptation options	Michael Battaglia	Forest & Wood Products Australia and CSIRO
CSIRO Grants and Research		
[CSIRO 1] When might assisted colonisation – actively moving species to introduce them to different areas - be appropriate?	Eve McDonald-Madden	CSIRO, University of Queensland and United States Geological Survey
SEWPaC Grants and Research		
[SEWPaC 1] Change Management Planning for Climate Variability in the Namoi Catchment		Namoi Region of Councils Consortium
[SEWPaC 2] Improving landscape connectivity & biodiversity for climate change adaptation		Hunter-Central Rivers CMA
[SEWPaC 3] The Jaliigirr Project: Connecting communities and cultures through corridors		Northern Rivers CMA

Research Project Title	Principal Investigator	Institution
[SEWPaC 4] Connecting landscapes across the Mount Alexander region		Connecting Country (Mt Alexander Region) Inc.
[SEWPaC 5] Planning for multiple use landscapes on farms		Eyre Peninsula (NRM) Board
States and Territories Grants and Research		
[S&T 1] Building research capability to identify climate change vulnerability and adaptation options for South Australian Landscapes.	Wayne Meyer	University of Adelaide
[S&T 2] Implementing tools to increase adaptive capacity in the community and natural resource management sectors.	Hartmut Fünfgeld	VCCCAR

Updated information for Section 5 of the Terrestrial Biodiversity NARP

Section 4 summarises information that has become available since the Terrestrial Biodiversity NARP was completed. It outlines the consequences of this new knowledge for research topics and prioritisation. This section is based on Guitart (2012), augmented with information from other sources.

This section is structured into four themes (national- / continental-scale issues, regional issues, local land management issues, managing key species). This structure recognises that adaptation for biodiversity needs to match the scale at which climate change impacts are experienced (e.g., Evans et al. 2011). The discussion is organised in relation to each research question in the original Terrestrial Biodiversity NARP, following the same four-theme structure.

All research questions listed in a NARP are priority questions that merit research support. They are prioritised using 6 criteria:

1. Severity of potential impact to be avoided or degree of potential benefit to be derived (essential);
2. Immediacy of required intervention or response (essential);
3. Need to change current intervention and practicality of alternative intervention (essential);
4. Potential for co-benefit (desirable);
5. Cross-sectoral relevance (desirable);
6. Equity considerations (desirable).

In the original Terrestrial Biodiversity NARP the priority of all research questions was assessed to be 'High'. The outcome of this draft update has been to confirm this assessment. However, the relative prioritisation between research questions may differ between regions, stakeholders and research investors, a matter that is not considered here.

NARP Section 5.1 National- / continental-scale issues: Priority research questions

NARP PRQ *5.1.1 How will climate change affect existing conservation goals and how should changed conservation goals be promoted and achieved?*

The vision of Australia's Biodiversity Conservation Strategy 2010-2030 (NRMMC 2010) is that 'Australia's biodiversity is healthy and resilient to threats, and valued in its own right and for its essential contribution to our existence' (page 8). Climate change is listed as one of six threats to the resilience of Australia's ecosystems, and a threat to the achievement of existing conservation goals.

Policy statements on conservation goals and strategies, whether at the national or state scales, reflect community understanding and values, and the political processes that express such understanding and values as goals and strategies. Thus, as community and government understanding of climate change and its impacts on biodiversity changes, support for particular conservation goals and strategies will be affected.

The success of conservation activities to achieve these goals can be affected by climate change, ranging from high level strategies such as the establishment and maintenance of a reserve system that is comprehensive, adequate and representative (Dunlop 2012a,b), to more local and direct activities such as fire management (Williams et al. 2009). Thus, new strategies may be required or existing strategies may need to be reviewed and revised (e.g. Mooney et al. 2010; Steffen et al. 2009a). Several factors other than climate change have contributed to conservation goals not being achieved, including other human impacts and vague goals (Mace et al. 2010), further complicating the assessment and inclusion of climate change in conservation strategies. Clear goals focused on ecosystem services (Mooney et al. 2010) and their economic values, (Butchart et al. 2010) with clear and measurable targets (Dunlop et al. 2012a, b) acting through agile, innovative and flexible governance systems with necessary resources (Steffen et al. 2009a) have been advocated as ways of overcoming these challenges. Consideration of how conservation goals address all levels of biodiversity (i.e. ecosystem to genetic) is also required. Prober and Dunlop (2011) argue that a key outcome of plans and investments around climate change adaptation and biodiversity must be the retention of the essence of what Australians value about the biodiversity of their nation.

Current research:

- One NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (**FW11 09)** (See Box 2).
- Two NCCARF/ARGP research projects from other themes are relevant to this topic (**EM11 10; FRDC1)** (See Box 3).
- No NCCARF Synthesis and Integrative Research project is relevant to this topic (See Box 4).
- Two ARC research projects **(FT100100819; DP110104186)** are relevant to this topic to some degree (See Box 5).

Summary: Several publications have addressed this PRQ, and current NCCAF research project FW1109 is designed to do so. It is likely that following the completion of the current project, further research will be required to guide the evaluation of existing conservation strategies and the development of new approaches to achieving Australia's conservation goals. Research on conservation goals needs to include all aspects relevant to conservation policy development.

Update outcome: Retain PRQ 5.1.1 unchanged with a 'High' priority.

NARP PRQ *5.1.2 How can the existing Australian legal, policy and institutional architecture for land management and biodiversity conservation respond to changes in conservation goals caused by climate change?*

New policy options include economic instruments that allow nationally productive synergies between mitigation and adaptation initiatives (Ring et al. 2010; Van Oosterzee et al. 2010, Mansergh 2010a), incorporating adaptation into new or existing biodiversity conservation plans (e.g. Groves et al. 2012), national conservation assessments (e.g. Game et al. 2011), and state land-use policies (e.g. Government of Victoria 2009). Integrated landscape planning may restrict some uses on private lands (McDonald 2010) and result in mixed use landscapes (e.g. Smith et al. 2012).

Regional and local organisations will continue to have a key role in responding to climate change (Steffen et al. 2009a). However, these bodies differ in their organisational arrangements and capacity to deliver natural resource management programs, including their ability to access and use new scientific results. Institutional arrangements for effective collaboration between different levels of government and other organisations are not well developed (Steffen et al. 2009a). Recommended institutional changes include reforms to Australia's land management, monitoring and regional response capabilities (Lindenmayer et al. 2010), changes to conservation legislation to facilitate ecosystem adaptation in response to climate change (McDonald 2010), and an enhanced role for non-government organisations (Steffen et al. 2009a). Including biodiversity conservation into rural re-structuring and land-use change in the context of adapting landscapes to changing climates has been advocated in south eastern Australia (Mansergh 2010a).

Many of these matters are recognised in the recently published 'Australia's Biodiversity Conservation Strategy 2010-2030' (NRMMC 2010), which lists climate change as one of several threats to biodiversity.

The national Biodiversity Conservation Strategy is being complemented by an Australian Government Biodiversity Policy (in consultation), which aims to provide an integrated approach by the Australian Government to biodiversity conservation in a changing climate (DSEWPaC 2011).

Australia's new greenhouse mitigation programs will generate a need for management approaches that seek to accommodate both increased carbon in landscapes and adaptation to climate change impacts.

Current research:

- One NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (**FW11 09)** (See Box 2).
- No NCCARF/ARGP research project from another theme is relevant to this topic.
- One NCCARF Synthesis and Integrative Research projects is relevant to this topic (**P1FVA5**) (See Box 4).
- No non-NCCARF research projects are relevant to this topic (See Box 5).

Summary: Some aspects of this research topic have been explored, and the recent national Biodiversity Conservation Strategy takes account of this knowledge. However, as climate change is a continuing issue and there remains considerable uncertainty about how it will affect different regions over different time-frames, and what will be the appropriate policy and institutional response, further research is required.

Update outcome: Retain PRQ 5.1.2 unchanged with a 'High' priority.

NARP PRQ *5.1.3 What conceptual models and long-term observation systems are needed to support the design, analysis and assessment of active adaptive management and policy experiments at regional and national scales under climate change?*

Existing research findings and approaches for climate change adaptation and land management form a useful basis for policy development (e.g. Beier and Gregory 2012). However, new conceptual approaches are being suggested. Thus, while species distribution models remain useful for initial impact analysis, they have limited capacity to represent key biological and ecological factors such as interspecies interactions, dispersal, hysteresis, evolution, and sampling of niche space (Sinclair et al. 2010), and to assess specific outcomes such as extinction or future species range (Dawson et al. 2011; Austin and Van Neil 2011; Reside et al. 2010). More realistic dynamic species distribution models, that integrate disturbance, dynamic population processes, species interactions and transient climates (Yates et al. 2010a; Venn et al. 2011), may enable the complexity of ecological systems and their interactions with climate to be represented in climate impact analyses and adaptation planning. Similarly, advocacy for and use of mechanistic models (e.g. Kearney et al. 2010; Mok et al. 2012; Mokany and Ferrier 2011) reflects an acceptance that climate change impacts will be driven by underlying ecological processes as well as by changes to climate conditions, as will be the success of adaptation initiatives. Qualitative process models, such as Bayesian belief networks may be more useful with novel climate conditions (Catford 2012).

Other conceptual approaches for understanding ecosystem behaviour, that may have application for climate change adaptation, emerge from analysis of genetics and evolutionary processes and change (Dawson et al. 2011; Hoffmann and Sgrò 2011; Bennington et al. 2012), from consideration of key lifecycle vulnerability points (Renton et al. 2012b) and from phylogeographic and landscape genetic analyses (Scoble and Lowe 2010; Yates et al. 2010a; Weeks et al. 2012). Some of these approaches enable the role of genetics in adaptation to be considered as part of adaptation analysis and planning (e.g. Weeks et al. 2012).

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Data management and monitoring are key factors in sound analysis, decision-making and investment in climate change impacts and adaptation (McMahon et al. 2011; Abbott and le Maitre 2010; Gioia 2010). A key recommendation of a recent meeting about climate change and fire was that investment in targeted ecosystem monitoring should be increased in preference to building models that may not be able to predict the responses of ecosystems to climate change impacts and other factors (Williams and Bowman, in press). For indicators of climate change impacts on and adaptation by species and ecosystems to reflect the complexity discussed above, they may need to track whole ecosystem processes (Green 2010) or use a cross-disciplinary, coordinated, focused and integrated approach (Likens and Lindenmayer 2011). The use of early botanical records can help identify species and phenological phases that responded to variations in climate and so may be effective indicators for future climate changes (Chambers and Keatley, 2010a), as might avian movement or breeding patterns (Chambers 2010; Gibbs et al. 2011). Monitoring ecosystem qualities would support assessments such as the vulnerability of different ecosystem components to changes in fire regimes (Williams et al. 2009). Ecosystem models may be informed and evaluated by comparing how ecosystems have responded to past climate conditions that were similar to projected climate conditions (Catford et al. 2012).

Considerable information required for policy and management of environmental issues (particularly species-specific information) is already available (Morton et al. 2009) but needs to be managed to enable access and use (Gioia 2010). A 'Long Term Environmental Monitoring (LTEM) Network for Australia' has been proposed (Likens and Lindenmayer 2011) that would take account of these suggestions and extend the information available to support policy- and decision-making and investment. Australia's Terrestrial Ecosystem

Research Network (TERN) was established in 2010 to enable the integration and sharing of information and knowledge and thus to support the integration of data into knowledge and management, with an objective to establish a framework that promotes scientific interaction and planning for a long-term ecosystem observation network.

Current research:

- No NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**FW11 06)** (See Box 3).
- No NCCARF Synthesis and Integrative Research project is relevant to this topic (See Box 4).
- Ten ARC research projects **(DP110101929; FT100100237; FT110100951; FT110100453; FT100100464; FS110200051; LP110100721; LP100100467; LP100200080; LP110100527)** are relevant to this topic to some degree (See Box 5).

Summary: Considerable research effort has focussed on various options for modelling climate change impacts and distribution projections to support policy development, and conservation planning and management. Several recent publications indicate progress in (a) the development and assessment of conceptual models for climate change and biodiversity adaptation and (b) monitoring impacts and adaptation. However, few publications address the focus of this PRQ. Further research is thus required to generate knowledge to support decisions about what conceptual approaches are suitable for different issues and circumstances, and the structure and management of effective national and regional monitoring systems.

Update outcome: Retain PRQ 5.1.3 unchanged and with a 'High' priority.

NARP Section 5.2 Regional issues: Priority research questions

NARP PRQ *5.2.1 What designs of landscapes in regions having different land uses confer maximum resilience for biodiversity in the face of climate change, including the uncertainty associated with future climate scenarios?*

This PRQ has a similar objective to PRQs in the Primary Industries and Freshwater Biodiversity NARPs – that is, to generate information to support climate change adaptation at a catchment or subcatchment scale in areas having several land uses and tenures. Limited research has been identified that addresses the broad objective of the PRQ (e.g. for south eastern Australia, see Walker et al. 2009; Mansergh 2010a,b), but a considerable amount of research has been found that is relevant to aspects of this broad question.

Ideally, a landscape that has different land uses could allow a commercial return while protecting biodiversity values and supporting resilience for all systems. One suggested management option involves proportional land use mixes (e.g. Smith et al. 2012). This has been explored on a trial basis in Victoria over a 10,000 ha region (URL: http://www.sustainabilityreport.vicsuper.com.au/www/html/1884-case-study-future-farming-landscapes.asp). A broad approach to landscape design and integrated adaptation planning and response would seek to ensure that biodiversity adaptation contributes to and benefits from adaptation in other sectors, rendering human societies and their needs, including ecosystem services, more resilient to climate change impacts; this is termed ecosystem-based adaptation (e.g. see World Bank 2010; UNFCCC 2011).

Design features that aim to support resilience are recommended (e.g. Steffen et al. 2009b), such as buffers for small reserves, expanding reserves that lack adequate environmental heterogeneity, prioritizing protection of likely climate refugia, and managing forests for multi-

species and multi-aged stands (Galatowitsch et al. 2009). Of these features, managing and protecting refugia has received the greatest amount of research attention (e.g. Medail and Diadema 2009; Steffen et al 2009a; Game et al. 2011; Keppel et al. 2011; Adams-Hosking et al. 2012; Keppel and Wardell-Johnson 2012).

Landscape features that provide appropriate connectivity may support direct adaptive responses by species in the form of movement between areas of remaining bush (Steffen et al. 2009a; Doerr et al. 2010; 2011; Lindenmayer et al. 2010; Mackey et al. 2010; Worboys et al. 2010; Groves et al. 2012; Gilbert-Norton et al. 2010). Strategic restoration to support species persistence has been advocated for taxa having limited dispersal capacity (Renton et al. 2012a). Restoration of connectivity may provide an alternative to approaches to conservation management that solely focus on protection *in situ*, that could, over time and with ongoing climate change, result in species loss (Mackey et al. 2010). However, basic studies of the positive and negative ecological effects of habitat connectivity are only slowly emerging (Spies et al. 2011). Given the increasing investment by governments and others in programs designed to enhance or rebuild landscape connectivity (e.g. the Great Eastern Ranges initiative, see: http://www.environment.nsw.gov.au/ger), research is needed to guide management actions.

Promoting carbon in the landscape could result in integrated investments having synergistic beneficial outcomes for biodiversity and production (e.g. Harvey et al. 2009; Strassburg et al. 2010; Neumann et al. 2011; Polgase et al. 2011; Witt et al. 2011) or in undesirable outcomes that threaten ecological processes (Van Oosterzee et al. 2010). (See also the discussion in PRQ 5.2.3, 5.2.4 and 5.3.4, below.) There is urgent need to better understand the balance of these two.

Current research:

- Two NCCARF/ARGP Terrestrial Biodiversity theme research projects are relevant to this topic (**TB11 01; TB11 09)** (See Box 2).
- Two NCCARF/ARGP research projects from another theme are relevant to this topic (**FW11 06; FW11 07)** (See Box 3).
- Two NCCARF Synthesis and Integrative Research projects are relevant to this topic **(P1FVA4; P1FVA5)** (See Box 4).
- Nine ARC research projects **(FT100100338; FT100100200; FT120100715; LP110100321; LP100100738; LP100100356; LP100100467; LP100200080; LP110200805)** are relevant to this topic to some degree (See Box 5).

Summary: Recent publications relevant to this PRQ offer insights and options for integrating resilience thinking in landscape-scale climate change adaptation assessments. Further publications were found that were relevant to individual landscape features that could contribute to effective landscape designs. Current projects are likely to expand this experience and understanding, as they are completed and reported. Nevertheless, further research is required on this topic, in light of the vast complexity of circumstances in Australia, new Australian government programs associated with the Clean Energy Future package and emerging international agendas around ecosystem-based adaptation. Noting the similarity between this PRQ and PRQ 5.3.4, this PRQ should be amended to more explicitly encompass the broad set of issues associated with ecosystem-based adaptation.

Update outcome: Replace PRQ 5.2.1 with new text below and with 'High' priority.

PRQ 5.2.1 as amended:

> *5.2.1 ~~What designs of landscapes in regions having different land uses confer maximum resilience for biodiversity in the face of climate change, including the uncertainty associated with future climate scenarios?~~*

What principles should guide ecosystem-based adaptation in Australia and the design of landscapes to support ecosystem resilience?

NARP PRQ *5.2.2 How will climate change interact with other key stressors such as fire, invasive species, salinity, disease, changes to water availability, grazing and clearing, and what are the integrated implications for ecosystem structure and functioning?*

Fire: While climate change is expected to result in larger and more frequent wild fires in most regions (Cochrane and Barber 2009; Flannigan et al. 2009a; King et al. 2011), significant local variation or even a decline in fire occurrence is projected in some areas (Flannigan et al. 2009b). These climate change impacts will be both direct, such as from increased temperatures and lower rainfall, and indirect, such as from the influence of changes to fuel loads and structure and fire behaviour (Williams et al. 2009; Pausas and Paula 2012). The effects of changed fire regimes on ecosystems are likely to be complex (Brennan et al. 2009; Reside et al. 2012).

Detailed studies of the effects of climate change on fire behaviour for four ecosystems, (alpine ash forests of Australia's south-east highlands, forests and shrublands of south-west Western Australia, tropical savannas of northern Australia and sclerophyllous forests and woodlands of the Sydney Basin) demonstrated that different species, ecosystems and regions will experience different impacts, result in different adaptation outcomes and require different adaptation management (Williams et al. 2009).

Water availability and salinity: Climate change impacts will affect vegetation through changes to surface and groundwater systems, with this effect likely to be most pronounced in wetlands. These direct effects will be further complicated by human responses to changed water availability (Dunlop 2012a,b). Predicted impacts include changes over various time scales to water availability, resulting in growth or loss of some ephemeral wetlands, changes in species distributions, possible extinctions and (in southern Australia where salinity may already be a problem) shifts to salt-tolerant communities where salinity increases (Nielsen and Brock 2009). The effectiveness of conserving free-flowing river ecosystems (Pittock and Finlayson 2011) would be enhanced if the requirements of flood-dependent species and ecosystems were identified, guiding the delivery of limited water resources (Aldous et al. 2011).

Lower annual rainfall and increased temperatures will change soil water storage and groundwater levels, and in turn affecting seasonally dry ecosystems (i.e. jarrah forest), vegetation communities dependent on access to shallow water tables (i.e. banksia woodlands) and groundwater-dependent terrestrial ecosystems. These impacts may be amplified by increased groundwater abstraction (Froend and Sommer 2010; Yates et al. 2010b). Options to better understand climate change impacts on soil water storage and groundwater resources include combining climate change scenarios with linked surface-subsurface water models (Godemiaux et al. 2009) to model groundwater discharge (Doll 2009; Crosbie et al. 2010).

Invasive species: Climate change will affect the relative competitive capacity of invasive species both directly and indirectly (Bourdot et al. 2010; Bradley et al. 2009) with some effects already recorded (Bradley et al. 2009). The interaction of climate change impacts and invasive species on vulnerable communities poses a significant threat (e.g. Pauchard et al. 2009; McDougall et al. 2011; Low 2011; O'Donnell et al. 2012). The characteristics of an invasive species will influence its response to changes in climate conditions (Bourdot et al. 2010; Bradley et al. 2009, 2010; Kriticos et al. 2010; Sims-Charlton et al. 2010), with tropical invasive species more likely to expand their ranges and cool-climate invasive species more likely to retract under most climate projections. Similarly, the effect of climate change on weed or pest species will be affected by other factors such as soils and land use change (e.g. Mansergh 2010b).

Grazing: Climate change affects existing biodiversity impacts caused by grazing. These impacts include the introduction and spread of exotic species, consumption of palatable species of native plants, alteration of vegetation structure and soil properties, and removal of key food resources for native species (Driscoll et al. 2012). Through these impacts, grazing reduces ecological resistance or resilience to climate change impacts through the loss of diversity and redundancy, ecosystem simplification and reduced population sizes of grazing-sensitive species (Prober et al. 2012). Many of these impacts or their consequences are exacerbated by extreme weather conditions such as drought (Driscoll et al. 2012).

Other impacts: Research has also been found relating to interactions of climate change impacts and adaptation options with past and potential land clearing (Yates 2010b), the impacts of sea level rise on terrestrial biodiversity (Menon et al 2010) and changes to snow cover resulting from climate change (e.g. Pickering and Green 2009; Green and Pickering 2009a,b; Venn et al. 2011).

Current research:

- Three NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (**TB11 05; TB11 07; TB11 08)** (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**FW11 06)** (See Box 3).
- Four NCCARF Synthesis and Integrative Research projects **(P1FVA2; P1FVA3; P1FVA4; P1FVA5)** are relevant to this topic (See Box 4).
- Nine ARC research projects **(FT100100819; FT100100200; FT100100237; FL100100066; DP110104186; FT110100246; LP110100321; LP100100356; LP100100467)** are relevant to this topic to some degree (See Box 5).

Summary: There has been some significant research effort into the interactions of climate change with fire in the Australian context and the response of invasive species to a changing climate. However, relatively less is understood about the impact of changes in water availability on individual species and about the impacts on ecosystem structure and functioning of climate change acting with, or on, other stressors.

Update outcome: Retain PRQ 5.2.2 unchanged with a 'High' priority.

NARP PRQ *5.2.3 How can large-scale carbon mitigation initiatives, such as revegetation and forest-related mitigation, be designed to maximise biodiversity conservation benefits and to avoid adverse impacts on biodiversity?*

Mechanisms to promote synergies between increased landscape carbon and biodiversity values are included in the Australian government's Clean Energy Future package. The package has a number of components, of which four are relevant to biodiversity conservation: the Biodiversity Fund, the Carbon Farming Initiative, the Land Sector Carbon and Biodiversity Board and the Regional Natural Resource Management Planning for Climate Change Fund.

Increasing carbon sequestration through revegetation or forest protection can deliver co-benefits additional to climate change mitigation, including forest biodiversity conservation (e.g. Harvey et al. 2009; Strassburg et al. 2010).

Factors likely to protect forest-based biodiversity values include good forest governance (Sasaki and Putz 2009), and recognition of ecosystem services (Corbera et al. 2010) linked to economic instruments such as tradable permits (Ring et al. 2010), and better understanding of the relationship between the carbon cycle and biodiversity (Midgley et al. 2010). Management features that help maintain biodiversity values include identifying and addressing threats, monitoring impacts, planning and preparing adaptation and mitigation

measures, education and training and integrating private and public programs (Singh et al. 2010).

While forests have been relatively well studied from the perspective of carbon sequestration, there has been less attention given to other ecosystems such as grasslands or tropical savannahs, with the exception of temperate box gum grassy woodlands (Michael and Lindenmayer 2011).

Potential management approaches to address the complex set of overlapping but potentially conflicting objectives and programs involved in linking carbon sequestration and biodiversity protection include adaptive management (Ogden and Innes 2009), ecosystem-based management (Gardner et al. 2009; Pfund 2010) and decentralised forest management (Pfund 2010).

Current research:

- One NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (**TB11 09)** (See Box 2).
- No NCCARF/ARGP research project from another theme is relevant to this topic (See Box 3).
- Four NCCARF Synthesis and Integrative Research projects are relevant to this topic **(P1FVA3; P1FVA4; P1FVA5; S3BAM1)** (See Box 4).
- Eight ARC research projects **(DP110101929; FT100100338; FT120100715; LP100100738; LP100100356; LP100100467; LP110200805; LP120200380)** and one RDC research project **(RDC 1)** are relevant to this topic to some degree (See Box 5).

Summary: Significant changes have occurred to Australia's approach to carbon mitigation through land management initiatives and associated measures to protect or enhance biodiversity. Implementation of these changes and initiatives will benefit from up-to-date research into key focal issues, including monitoring of outcomes and application of adaptive management approaches.

Recent changes in Australian government policy and programs have created incentives for carbon mitigation activities that offer opportunities to enhance biodiversity conservation but could also have unintended adverse outcomes for biodiversity. Research that supports optimising biodiversity outcomes from these and any new programs is therefore important and useful. The PRQ should be amended to highlight this.

Update outcome: Retain PRQ 5.2.3 as amended below with a 'High' priority.

PRQ 5.2.3 as amended:

> *5.2.3 How can Australia's land-based ~~large-scale~~ carbon mitigation initiatives~~, such as revegetation and forest-related mitigation,~~ be designed to enhance ecosystem services, ensure appropriate ecological connectivity, ~~maximise~~ deliver biodiversity conservation benefits and ~~to~~ avoid adverse impacts on biodiversity?*

NARP PRQ *5.2.4 How can the major socio-economic trends occurring in many regions of Australia contribute to effective climate change biodiversity adaptation responses?*

Potential options for biodiversity conservation to build on existing and projected socio-economic trends include large-scale trajectories toward post-agricultural landscapes (e.g. amenity), carbon sequestration as land use, tourism, urban redevelopment, low density peri-urban development, retiree interest in rural or local conservation, greater management and use of traditional knowledge, and private organisation conservation investments (Steffen et al. 2009b). Recent mechanisms to promote synergies between increased landscape carbon

and biodiversity values through Australia's Carbon Farming Initiative (noted above in relation to PRQ 5.2.3) are a further recent impetus for adaptation in some regions. Water property rights, such as those being implemented through the Murray Darling Basin Plan (MDBA 2012), will similarly provide conservation management opportunities for improved aquatic and riparian ecosystems.

Adaptation opportunities arising from socio-economic trends are likely to be region-specific, as regional land use patterns are likely to respond to challenges and arising from long term climate change impacts, changes in the valuations of ecosystem services, commercial and other lands uses and economic and demographic trends (Mansergh 2010a). Increased resources and an expanded role for natural resource management (NRM) planning are becoming available through the Clean Energy Future package and as a result of greater involvement of NRM bodies in regional environmental planning. These opportunities would benefit from priority-setting and decision-support tools, especially those that could inform resilience analysis.

Current research:

- Three NCCARF/ARGP Terrestrial Biodiversity theme research projects are relevant to this topic (**TB11 01; TB11 02; TB11 09)** (See Box 2).
- No NCCARF/ARGP research project from another theme is relevant to this topic (See Box 3).
- One NCCARF Synthesis and Integrative Research project **(P1FVA3)** is relevant to this topic (See Box 4).
- Three ARC research projects **(FT120100715; LP100100738; LP120200380)** and five SEWPaC research projects **(SEWPaC 1 to SEWPaC 5)** are relevant to this topic (See Box 5).

Summary: It is clear that some current socio-economic trends could contribute to effective climate change adaptation for terrestrial biodiversity. However, specific instances of how this could occur have not been explored through published research and few instances are the subject of current research.

Update outcome: Retain PRQ 5.2.4 unchanged with a 'High' priority.

NARP Section 5.3 Local land management issues: Priority research questions

NARP PRQ *5.3.1 What are the costs and benefits of different climate change adaptation measures in vulnerable ecological communities and ecosystems?*

Few publications were found that directly addressed the specific focus of this research question; an exception is an assessment of the costs of management actions in endangered box gum grassy woodlands (Michael and Lindenmayer 2011). A recent Australian Government publication (DCCEE 2012) describes an economic framework that aims to enable 'the costs and benefits of each adaptation option to be assessed against other options and the cost of inaction' (p.1), generating information about preferred timing to implement adaptation options. This framework involves combining scientific knowledge about climate change impacts, technical expertise about adaptation options and a cost-benefit analysis. The framework was tested in case studies about infrastructure, and sought to include social as well as economic costs and benefits, but makes no reference to environmental costs or benefits, let alone biodiversity values, that are the focus of this PRQ.

Cost-benefit analysis has limited application in circumstances of high levels of uncertainty and complexity, as are typical in evaluating adaptation measures for climate change and

biodiversity (Macintosh 2010). High biodiversity ecosystems, such as those found in Mediterranean-type regions, present particular challenges for analysis of all types (Yates et al. 2010a). MacIntosh (2010) suggests that relevant costs and benefits should be identified during decision-making processes, with only market-linked factors being considered in monetary terms. One example in which the cost effectiveness of conservation measures was assessed concerned translocations for increasing genetic resilience, that were shown to be cost-effective compared to captive breeding (Weeks et al. 2012).

While all ecological communities and ecosystems are potentially affected by climate change, several have been assessed as particularly at risk. These include regions (i.e. the Australian Alps, the tropical rainforests of Australia's Wet Tropics World Heritage Area and south west Western Australia; Hughes 2011) and ecosystems vulnerable to tipping points (Laurance et al. 2011). Within some of these regions and ecosystems, vulnerable communities and species have been identified (e.g. Pickering and Green 2009; Green and Pickering 2009 a, b; Prober et al. 2012; Cox and Underwood 2011).

Current research:

- One NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (**TB11 02)** (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**SD11 12)** (See Box 3).
- One NCCARF Synthesis and Integrative Research project **(P1FVA3)** is relevant to this topic (See Box 4).
- Four ARC research projects **(FT100100819; FT100100338; FT120100715; LP100100738)** and one CSIRO research project **(CSIRO 1)** are relevant to this topic to some degree (See Box 5).

Summary: This PRQ remains virtually unaddressed, and no current research projects explore its specific focus.

Update outcome: Retain PRQ 5.3.1 unchanged with a 'High' priority.

NARP PRQ *5.3.2 How should fire management adapt to climate change?*

A review of climate change and fire in Australia (Williams et al. 2009) concluded that climate change is likely to result in greater uncertainty and complexity in fire behaviour in Australia, in interactions between fire and ecosystems and thereby in fire management. Adopting an adaptive management approach would enable fire managers to take account of complexity and uncertainty and efficiently learn from experience, as circumstances change. However, in addition to the complex biophysical issues inherent in fire management, equally complex psychological, social, economic and institutional issues need to be understood and addressed, for effective management options to be available and implemented.

Prescribed burning could be used to reduce forest fuel loads and thus the effects of climate change on fire regimes (Penman and York 2010), suggesting an ongoing role for prescribed burning under future climate conditions. Williams et al. (2009) identified seven priority areas to address potential shortcomings of current approaches to fire management for Australia's ecosystems:

1. Determine Australia's fire regimes;
2. Determine how climate change might change fire weather in Australia;
3. Evaluate how elevated fire danger, elevated atmospheric CO_2, and changing moisture availability could affect future fire regimes;
4. Understand fauna vulnerability to changes in fire regimes;
5. Understand current capacity to accommodate change;

6. Explore approaches to management options such as fire intervals ;
7. Undertake benefit-cost analyses of potential management responses.

Other recent publications provide more local or specific findings about interactions between climate change and fire behaviour and management. The likely impacts of changes to fire intervals in the forests of south west Western Australia would depend on the nature of the changes: while occasional short intervals (3-5 years) between fires would not result in a persistent effect on community composition, a series of short or long intervals may alter species composition and/or abundance (Wittkuhn et al. 2011). However, frequent low intensity prescribed fires were found to have no detectable effect on key attributes of a Eucalypt forest in coastal NSW (Christie and York 2009).

A co-evolutionary view of fire regimes and ecosystems remains poorly grounded in theory or empirical observations (Bowman et al. 2012), lending weight to caution in considering increased fire frequency as an adaptation management response to fire risk (Bradshaw et al. 2011).

A meeting sponsored by the NCCARF Adaptation Research Network for Terrestrial biodiversity and CSIRO's Climate Adaptation Flagship was held in 2012 to explore the complex issues associated with climate change, fire and biodiversity interactions (Williams and Bowman, in press). This meeting built on an understanding that as Australia is 'megadiverse with respect to both biodiversity and fire regimes' the continent can be seen as a laboratory for examining 'interactions between climate change, fire regimes, ecosystems and people' (Williams and Bowman, in press, p.1). The meeting noted that 'Current management of fire is complex, and contested, and fire management at landscape scales is being made more complicated by climate change' (Williams and Bowman, in press, p.2). It considered several contrasting examples, finding that adaptive strategies were required. Findings of the meeting included focusing research investment on monitoring (in preference to modelling), tailoring fire management to regional circumstances and seeking co-benefits from fire management, such as reduced greenhouse gas emissions and local livelihood support.

Current research:

- No NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (See Box 2).
- No NCCARF/ARGP research project from another theme is relevant to this topic (See Box 3).
- One NCCARF Synthesis and Integrative Research project **(P1FVA2)** is relevant to this topic (See Box 4).
- Two ARC research projects **(FT100100338; FT120100715)** and one CSIRO research project **(CSIRO 1)** are relevant to this topic to some degree (See Box 5).

Summary: Fire is a key feature of many of Australia's ecosystems. Further research is required to generate the information necessary to guide the future use and management of fire for biodiversity conservation. The focus of this topic needs to include biophysical, social, economic and institutional research.

Update outcome: Retain PRQ 5.3.2 unchanged with a 'High' priority.

NARP PRQ *5.3.3 How can management of local protected areas incorporate and adapt to climate change?*

Management of local protected areas involves three key actions: creating protected areas, managing them and ensuring that policies support their goals and purposes (Ervin 2011). Dunlop et al. (2012a) have recently published an assessment of the implications of climate

change for biodiversity conservation and the National Reserve System, with an associated report that explores implications for management of protected areas at the national and local scale (Dunlop et al. 2012b). These two reports address many of the key issues in this research topic and provide insight for future research priorities.

Locating new local protected areas. Recent research has highlighted some clear management recommendations to meet the challenge of climate change:

- Australia's reserve system should be expanded and continually reassessed in light of new information (Dunlop 2012a, b).
- Future conservation initiatives should be assessed under projected climate change scenarios (Baron et al. 2009; Mansourian et al. 2009).
- Ecological gap assessments, from which new protected areas might be identified, should take account of climate change impacts, and the layout of new protected areas should consider climate related design features (Ervin 2011).

A four-step approach has been suggested as a practical means of incorporating climate change in assessments of the effectiveness of protected areas, comprising bioclimatic, hybrid and process-based modelling and testing of conservation management options (Sieck et al. 2011). Establishing new reserves relatively close to existing reserves would facilitate inter-reserve movement and thus broader ecological benefits from a protected area network (Lindenmayer et al. 2010). Other suggestions include using 'land facets' to guide protected area network design (Beier and Brost 2010; Brost and Beier 2012) and replacing some existing protected areas with new protected areas able to better contribute to the system as a whole (Fuller et al. 2010).

Managing local protected areas: Climate-related issues need to be included in all aspects of management, including capacity building programs (Ervin 2011), with effective knowledge transfer between scientists and managers (Baron et al. 2009). Potential changes in the range of currently protected or endangered species need to be explicitly addressed in management planning (Hole et al. 2011; Kleinbauer 2010).

Most potential management responses involve reconsidering existing approaches, rather than developing new techniques (Mawdsley et al. 2009), but need to be tested for practicality (Lemieux and Scott 2011). Suggested adaptation options include:

- Increasing the number, size and extent of protected areas (Beier and Brost 2010; Hole et al. 2011; Mawdsley et al. 2009; Lindenmayer et al. 2010);
- Establishing or maintaining suitable inter-reserve connectivity facilitated by off-reserve conservation and landscape permeability (Lindenmayer et al. 2010; Beier and Brost 2010; Mawdsley et al. 2009);
- Improving representation and replication within protected area networks (Mawdsley et al. 2009);
- Improving management and restoration of existing protected areas to facilitate resilience, including controlling exotic species and restoring areas after disturbance (Mawdsley et al. 2009);
- Establishing a range of conservation options, including conservation easements (Hole et al. 2011);
- Increasing the heterogeneity of individual patches and landscapes (Verboom et al. 2010; Godfree et al. 2011);
- focusing management efforts on keystone habitats (Olson et al. 2009);
- integrating conservation planning across terrestrial, marine and freshwater ecosystems and habitats (Beger et al. 2010; Alvarez-Romero et al. 2011); and
- accommodating and managing the establishment of indigenous species and ecosystems that may be new to a locality or region (Dunlop 2012a,b).

Policies and other factors: Local area management can be significantly affected (facilitated or constrained) by policies or investments arising at a broader scale or from other sectors. 'Australia's Strategy for the Natural Reserve System 2009-2030' (NRMMC 2009) provides national guidance for protected area managers and key stakeholders organised around six key themes: (1) international and national context, (2) protected area design and selection, (3) establishment of the protected area network, (4) planning and management, (5) science, knowledge management, monitoring and (6) performance reporting and strengthened partnerships and community support. However, policies or initiatives generated at a national or state level will need to be assessed by local managers for their effectiveness or practicality in the field and in the local environmental and other conditions (Lemieux and Scott 2011; Dunlop 2012b).

Protected area planning needs to take account of and influence planning and initiatives in other sectors such as transportation and energy or initiatives that are focussed on risks such as invasive species. The economic value of local conservation initiatives in terms such as food and water security needs to be assessed and communicated (Ervin 2011).

Current research:

- Seven NCCARF/ARGP Terrestrial Biodiversity theme research project are likely to be relevant to this topic (**TB11 01; TB11 02; TB11 03; TB11 04; TB11 06; TB11 07; TB11 08)** (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**FW11 07)** (See Box 3).
- Two NCCARF Synthesis and Integrative Research projects are relevant to this topic **(P1FVA4; S3BAM1)** (See Box 4).
- Seven ARC research projects **(DP110101929; FT100100819; FT100100200; FL100100066; FT120100715; LP100100738; LP110200805)**, five SEWPaC research project **(SEWPaC 1; SEWPaC 2; SEWPaC 3; SEWPaC 4; SEWPaC 5)**, and two State and territories research projects **(S&T 1; S&T 2)** are relevant to this topic to some degree (See Box 5).

Summary: Considerable new knowledge has been generated about climate change and local protected areas. However, the effectiveness of proposed management approaches will need ongoing testing and revision.

Update outcome: Retain PRQ 5.3.3 unchanged with a 'High' priority.

NARP PRQ *5.3.4 How can we better integrate conservation plans and actions across landscapes, incorporating protected area management, off-reserve conservation measures and other land uses, in order to maximise biodiversity conservation benefits / outcomes under a changing climate?*

Steffen et al. (2009a) proposed five broad approaches for climate change adaptation, all of which are applicable at the local scale:

1. Enhance resilience of ecological systems;
2. Create landscapes that maximise adaptation opportunities;
3. Expand and augment the reserve system;
4. Undertake specific *in situ* conservation actions; and
5. Undertake *ex situ* conservation actions where appropriate.

Increasing connectivity is a frequently advocated initiative for climate change adaptation for terrestrial biodiversity (Heller and Zavaleta 2009; Krosby et al. 2010; Game et al. 2011; Doerr et al. 2010; 2011; Lindenmayer et al. 2010; Mackey et al. 2010; Worboys et al. 2010; Groves et al. 2012). Corridors can help increase movement between habitat patches

(Gilbert-Norton et al. 2010). A conservation connectivity approach underpins a proposal for a conservation corridor in New South Wales (Mackey et al. 2010). A guide to connectivity conservation management has been prepared (Worboys et al. 2010). The Draft National Wildlife Corridors Plan (2012) identifies guiding principles and objectives and proposes a framework for progressively creating a network of corridors at different scales, local to national, across Australia (National Wildlife Corridors Plan Advisory Group 2012). However, the full benefit to Australian species and conservation effort and investment of increased connectivity might be realised if there were better understanding of the processes involved (Doerr et al. 2010).

Scientific debate about the *relative* conservation value of connectivity versus habitat quality (e.g. Hodgson et al. 2009, 2011, Doerr et al. 2011) indicates a need for evidence to support conservation planning, decision-making, and implementation. While Beier and Gregory (2012) noted the dearth of long-term studies testing corridor effectiveness for genetics and demography, they cited the restoration of ecological connectivity at Mt Hotham as a notable exception (Mansergh and Scotts 1986); further and more current evidence is required. Given the scale of upcoming investment in revegetation in Australia, further research is thus a priority.

Current research:

- Nine NCCARF/ARGP Terrestrial Biodiversity theme research projects are relevant to this topic (**TB11 01; TB11 02; TB11 03; TB11 04; TB11 05; TB11 06; TB11 07; TB11 08; TB11 09)** (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**FW11 06)** (See Box 3).
- Two NCCARF Synthesis and Integrative Research projects are relevant to this topic **(P1FVA4; P1FVA5; S3BAM1)** (See Box 4).
- Nine ARC research projects **(FT100100819; FT100100338; FT100100200; DE120100518; LP100100738; LP100100467; LP100200080; LP110200805; LP120200380)** are relevant to this topic to some degree (See Box 5).

Summary: Integrated conservation initiatives will become increasingly applied as climate change affects existing conservation reserves, and as the Australian Government's Biodiversity Fund supports revegetation at the catchment scale. Further research is required to develop practical design principles for revegetation, including conservation connectivity investments, and to assess the relative benefits and effectiveness of revegetation options in different circumstances. Other aspects of this research topic also require greater investment.

Update outcome: Retain PRQ 5.3.4 unchanged with a 'High' priority.

NARP Section 5.4 Managing key species: Priority research questions

Species are components of communities and contribute to their processes and services; they also are dependent on these processes and services. This section is therefore expanded to include consideration of 'species and communities', as set out below:

Update outcome: Retitle: ***NARP Section 5.4 Managing key species and communities***

NARP PRQ *5.4.1 Which species should be the focus of investment in climate change adaptation?*

Many species and communities are likely to be vulnerable to climate change impacts. Factors that have been identified as likely to indicate vulnerability to climate change include tight relationships between plants and their specific pollinators (Hegland et al. 2009), dependence on particular nutrient sources (Green 2010), habitat fragmentation and

endemism (Gibson et al. 2010). While some research exists on identifying species or communities at risk from climate change impacts, prioritising investment in species or communities at risk has received little attention (e.g. Wilson et al. 2011). Priorities will also be affected by changes to conservation policies resulting from climate change (the subject of PRQ 5.1.1, above) and other social factors.

Current research:

- Six NCCARF/ARGP Terrestrial Biodiversity theme research projects are relevant to this topic (**TB11 02; TB11 03; TB11 04; TB11 05; TB11 06; TB11 07)** (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**FW11 06)** (See Box 3).
- One NCCARF Synthesis and Integrative Research project is relevant to this topic **(P2LTA2)** (See Box 4).
- Seven ARC research projects **(FT100100819; FT100100237; FL100100066; DP110104186; DE120101533; FT120100204; LP110200229)** are relevant to this topic to some degree (See Box 5).

Summary: This topic will require ongoing research to generate more specific information about species and communities warranting conservation investment, and about prioritisation mechanisms.

Update outcome: Retain PRQ 5.4.1 as set out below with a 'High' priority.

PRQ 5.4.1 as amended:

> *5.4.1 How can investment in climate change adaptation measures to conserve species and communities be prioritised? ~~Which species should be the focus of investment in climate change adaptation?~~*

NARP PRQ *5.4.2 How will climate change affect current management actions for protecting priority species, and what management changes will be required?*

Most terrestrial biodiversity adaptation strategies involve the review of existing approaches, rather than the development of new techniques (Mawdsley et al. 2009). These include focusing conservation resources on species that might become extinct, translocating species at risk of extinction, establishing captive populations of species that would otherwise go extinct, and reducing pressures on species from sources other than climate change.

Of these approaches, increased or extended translocation (including for increasing genetic resilience) has received the greatest research attention. The value of managed relocation for species conservation has been recognised (Sax et al. 2009; Richardson et al. 2009; Vitt et al. 2010; Thomas 2011; Weeks et al. 2011; Weeks et al. 2012) and associated risks have been described as predictable and often low (Willis et al. 2009; Thomas 2011). However, translocating species could result in perverse outcomes, or could fail (Ricciardi and Simberloff 2009; Seddon 2010). Other considerations have also been raised, such as the need to ensure high genetic variety in translocated populations (Klein et al. 2009; Sgrò et al. 2011), and to clarify the objective of the translocation investment and initiative (Weeks et al. 2011). While the costs and benefits of assisted translocation or managed relocation as a climate-adaptation strategy remain a matter of scientific debate (Lawler and Olden 2011) some new effective lower cost techniques have been developed (Weeks et al. 2012).

Several proposed decision frameworks for determining whether translocation should occur incorporate relevant ecological, socioeconomic, legal and ethical considerations (Joly and Fuller 2009; Richardson et al. 2009; Sandler 2010; Burbidge et al. 2011; Minteer and Collins 2010), or include information about climate change impacts and factors specific to the species concerned, habitat availability and costs (McDonald-Madden et al. 2011). However,

the very basis for a species-oriented approach to conservation has been questioned, with inter- and intra- specific levels of diversity being suggested as preferable (Klein et al. 2009; Sgrò et al. 2011).

Other approaches have also been explored, including very local and specific mechanical or physical initiatives such as manipulating water levels or canopy cover, retaining or supplementing shelters or creating habitat (Shoo et al. 2011).

Current research:

- Eight NCCARF/ARGP Terrestrial Biodiversity theme research project is relevant to this topic (**TB11 02; TB11 03; TB11 04; TB11 05; TB11 06; TB11 07; TB11 08; FW11 09)** (See Box 2).
- No NCCARF/ARGP research project from another theme is relevant to this topic (See Box 3).
- No NCCARF Synthesis and Integrative Research projects are relevant to this topic (See Box 4).
- Seven ARC research projects **(FT100100819; FL100100066; DP110104186; DE120101263; LP100100600; LP100200080; LP110200229)** are relevant to this topic to some degree (See Box 5).

Summary: The need to prioritise conservation investment and to invest effectively will continue, but the focus of this investment will need to include both the species scale and the community scale. Species-orientated investment will need to take account of the functional importance of species when assessing relative priority for conservation investment.

Update outcome: Retain PRQ 5.4.2 as set out below with a 'High' priority.

PRQ 5.4.2 as amended:

> *5.4.2 How will climate change affect current management actions for protecting priority species and communities, and what management changes will be required?*

NARP PRQ *5.4.3 How will climate change affect current or potential problem species and what management responses will be required?*

The effect of climate change on species (all taxa) through changing temperature, water availability and other factors will depend on the species, location, and the magnitude and seasonality of changes to climate parameters, and may result in range expansions or contractions (Bradley et al. 2009, 2010; Bourdot et al. 2010; Kriticos et al. 2010; Sims-Chilton et al. 2010). Some species will spread beyond their existing range and become invasive while others will change their ecosystem role and function. Increased threats from invasive species benefiting from climate change may exceed the threats of climate change to many native species (Steffen et al. 2009a).

Care is required when extrapolating from climate-envelope assessments to identify range changes, as plant species may exhibit greater climate tolerances in new locations than would be anticipated from their achieved range in their native habitats (Gallagher et al. 2010; Beaumont et al. 2009). No single species-specific factor has been associated with this change in climate tolerances (Gallagher et al. 2010). Suggestions to improve range projections include using data from species' entire distributions (Beaumont et al. 2009) and incorporating evolutionary potential (Clements and Ditommaso 2011). A weed risk assessment to assess proposed plant imports and to prioritise management of exotic species already present incorporates dispersal and climate change impacts (Crossman et al. 2011).

Climate change effects on weeds are likely to have significant impacts on vulnerable communities (Pauchard et al. 2009; McDougall et al. 2011; O'Donnell et al. 2012), indicating the importance of understanding how this factor could interact with existing stressors and other climate change-altered stressors (see also PRQs 5.2.2 and 5.3.2).

Many introduced animals are invasive, including foxes, cats, rabbits, rats, goats, pigs and camels, and have already caused significant environmental damage (Steffen et al. 2009a). Some of these species will benefit from climate change and thus increase their impacts on species, communities and ecosystems (Low 2011). Management options targeted to address potential climate change impacts on actual or potential invasive species include:

- applying biosecurity strategies for invasives species projected to benefit from climate change (Sims-Chilton et al. 2010);
- focussing monitoring and control measures on areas of projected range expansion (Sims-Chilton et al. 2010), on hotspots such as where vulnerable communities could be affected (O'Donnell et al. 2012; McDougall et al. 2011) or where levels of uncertainty render projection or prediction unhelpful (Likens and Lindenmayer, 2011); and
- analysing proposed introductions of new species through assessing the species' 'projected dispersal envelope', comprising the locations where a species is or could survive without human intervention, and incorporating information about biogeography and niche theory with existing knowledge of the behaviour of invasives (Webber and Scott 2012).

A broader consideration of weeds has been advocated, in the context of past, current and potential roles of introduced plants in Australia's landscapes (Mansergh 2010b). This approach would take account of changes to landscapes and ecosystems arising from societal trends towards long-term sustainability and intergenerational landscape equity.

Current research:

- Two NCCARF/ARGP Terrestrial Biodiversity theme research projects are relevant to this topic (**TB11 05; TB11 07)** (See Box 2).
- One NCCARF/ARGP research project from another theme is relevant to this topic (**FW11 06)** (See Box 3).
- Three NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P1FVA2, P1FVA4, P1FVA5**) (See Box 4).
- Six ARC research projects **(FT100100819; FL100100066; FT120100204; LP100100600; LP110200229; LP120200249)** are relevant to this topic to some degree (See Box 5).

Summary: Considerable research has been conducted or is currently being undertaken on the potential impacts of climate change on invasive plants, but no new research was found about potential climate change impacts on invasive fauna and little new research was found about interactions between invasive species and other stressors under climate change.

Update outcome: Retain PRQ 5.4.3 unchanged with a 'High' priority.

Changes to the research topics and priorities

The outcome of this Update report is that all existing PRQs in the Terrestrial Biodiversity NARP are retained with a 'High' priority. However, one PRQ is broadened, one section is slightly redefined and three PRQs are revised or restated, as set out below:

- One research priority has been broadened to explicitly encompass the issues and opportunities associated with ecosystem-based adaptation:

  5.2.1 ~~What designs of landscapes in regions having different land uses confer maximum resilience for biodiversity in the face of climate change, including the uncertainty associated with future climate scenarios?~~

  What principles should guide ecosystem-based adaptation in Australia and the design of landscapes to support ecosystem resilience?

- One research priority has been restated to reflect recent Australian Government initiatives:

  5.2.3 *How can Australia's land-based ~~large-scale~~ carbon mitigation initiatives~~, such as revegetation and forest-related mitigation,~~ be designed to enhance ecosystem services, ensure appropriate ecological connectivity, ~~maximise~~ deliver biodiversity conservation benefits and ~~to~~ avoid adverse impacts on biodiversity*?

- The focus of one section has been expanded and the section has been renamed:

  NARP Section 5.4 Managing key species and communities

- Two research priorities in this section have been reworded to reflect this change in focus:

  5.4.1 How can investment in climate change adaptation measures to conserve species and communities be prioritised? ~~Which species should be the focus of investment in climate change adaptation?~~

  5.4.2 How will climate change affect current management actions for protecting priority species and communities, and what management changes will be required?

High priority research questions (2012)

High priority research questions (2012)
5.1 National- / continental scale issues
5.1.1 How will climate change affect existing conservation goals and how should changed conservation goals be promoted and achieved?
5.1.2 How can the existing Australian legal, policy and institutional architecture for land management and biodiversity conservation respond to changes in conservation goals caused by climate change?
5.1.3 What conceptual models and long-term observation systems are needed to support the design, analysis and assessment of active adaptive management and policy experiments at regional and national scales under climate change?
5.2 Regional issues
5.2.1 What principles should guide ecosystem-based adaptation in Australia and the design of landscapes to support ecosystem resilience?
5.2.2 How will climate change interact with other key stressors such as fire, invasive species, salinity, disease, changes to water availability, grazing and clearing, and what are the integrated implications for ecosystem structure and functioning?
5.2.3 How can Australia's land-based carbon mitigation initiatives be designed to enhance ecosystem services, ensure appropriate ecological connectivity, deliver biodiversity conservation benefits and avoid adverse impacts on biodiversity?
5.2.4 How can the major socio-economic trends occurring in many regions of Australia contribute to effective climate change biodiversity adaptation responses?
5.3 Local land management issues
5.3.1 What are the costs and benefits of different climate change adaptation measures in vulnerable ecological communities and ecosystems?
5.3.2 How should fire management adapt to climate change?
5.3.3 How can management of local protected areas incorporate and adapt to climate change?
5.3.4 How can we better integrate conservation plans and actions across landscapes, incorporating protected area management, off-reserve conservation measures and other land uses, in order to maximise biodiversity conservation benefits / outcomes under a changing climate?
5.4 Managing key species and communities
5.4.1 How can investment in climate change adaptation measures to conserve species and communities be prioritised?
5.4.2 How will climate change affect current management actions for protecting priority species and communities, and what management changes will be required?
5.4.3 How will climate change affect current or potential problem species and what management responses will be required?

Acronyms

ARC	Australian Research Council
ARGP	Adaptation Research Grant Program *(Commonwealth Funding to support adaptation research commissioned against priorities identified in NARPs, supporting research managed by NCCARF)*.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCCEE	Department of Climate Change and Energy Efficiency (Commonwealth)
NARP	National Climate Change Adaptation Research Plan
NCCARF	National Climate Change Adaptation Research Facility
NRM	Natural resource management
PRQ	Priority research question
NRMMC	Natural Resource Management Ministerial Council
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth)
SIR	Synthesis and Integrative Research *(NCCARF funded and managed research program)*.

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Appendix 1: Criteria for setting research priorities

The criteria listed below will guide the research planning process to set research priorities.

1. **Severity of potential impact or degree of potential benefit**

   What is the severity of the potential impact to be addressed or benefit to be gained by the research? Potentially irreversible impacts and those that have a greater severity (in social, economic or environmental terms) will be awarded higher priority.

2. **Immediacy of required intervention or response**

   Research will be prioritised according to the timeliness of the response needed. How immediate is the intervention or response needed to address the potential impact or create the benefit? Research that must begin now in order to inform timely responses will receive a higher priority than research that could be conducted at a later date and still enable a timely response.

3. **Need to change current intervention and practicality of intervention**

   Is there a need to change the intervention used currently to address the potential impact being considered. If yes, what are the alternatives and how practical are these alternative interventions? Research that will contribute to practicable interventions or responses will be prioritised. Does research into the potential impact of the intervention being considered contribute to the knowledge base required to support decisions about these interventions?

Desirable

4. **Potential for co-benefits**

   Will the research being considered produce any benefits beyond informing climate adaptation strategies?

5. **Potential to address multiple, including cross-sectoral, issues**

   Will the research being considered address more than one issue, including cross-sectoral issues?

6. **Equity considerations**

   Will the research being considered address more than one issue, including cross-sectoral issues?

Appendix 2: Current NCCARF (ARGP) research projects commissioned for the Terrestrial Biodiversity NARP

NCCARF is supporting ten research projects commissioned to address the PRQs in the original Terrestrial Biodiversity NARP.

Project Title and Description	Principal Investigator and Institution
TB1101 The architecture of resilient landscapes: scenario modelling to reveal best-practice design principles for climate adaptation One of the most cost-effective ways to help Australia's native species survive climate change is to ensure their populations are as large and connected as possible. This means that management to protect Australia's biodiversity will need to happen over whole landscapes, not just in national parks. So do we need lots of corridors or more habitats? This project will evaluate different approaches to managing biodiversity across landscapes and calculate how likely they are to improve the resilience of native species.	**Veronica Doerr** **CSIRO**
TB1102 Optimal habitat protection and restoration for climate adaptation Research has shown that many species are likely to go extinct because of climate change, but which species these will be, and what we can do to prevent these extinctions remain uncertain. This project will predict how species and habitats will move in response to climate change over the next century, then work out how much it will cost to protect existing habitat and restore new habitat where this would help species survive.	**Richard Fuller** **University of Queensland**
TB1103 Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species. Multi-million dollar investments in ecosystem maintenance through restoring Australia's degraded landscapes currently take little account of climate change. Until recently there has been a strong focus on maintaining local genetic patterns for optimal restoration. In a changing climate this paradigm will no longer be relevant. This project will undertake pioneering research at the interface between molecular genetics, plant physiology and climate adaptation, targeting the question 'What new genetic frameworks can facilitate adaptive restoration in changing environments?' Addressing this question will ensure optimal outcomes for Australia-wide investment in ecological restoration and provide solutions to ecosystem adaptation in changing environments.	**Margaret Byrne** **Department of Environment and Conservation, WA**
TB1104 Adaptation strategies for Australian birds Climate is likely to change so much that many birds may need human help to survive. For some, dispersal corridors may be needed. Others may need help to cross barriers as their favoured habitat shifts across the landscape. Some may even need to be taken into captivity. This project will identify what needs to be done in the next 20-50 years to enable our children to appreciate the same birds that we inherited.	**Stephen Garnett** **Charles Darwin University**
TB1105 Determining future invasive plant threats under climate change: an interactive decision tool for managers This project will provide the first comprehensive, national assessment of the risks of weeds emerging from naturalised plants. In Australia, invasive plants cost the economy at least $4 billion annually, not including the cost to terrestrial biodiversity. As many invasive species may be advantaged by climate change, this figure will increase significantly. Of the 29,000 introduced plant species in Australia, approximately 400 have become significant weeds and a further 2,700 have become 'naturalised' - established self-sustaining populations in the wild. With around 15	**Lesley Hughes** **Macquarie University**

Project Title and Description	Principal Investigator and Institution
species added to this list each year, these species represent a ticking time bomb of future weed problems.	
TB1106 Developing management strategies to combat increased co-extinction rates of plant dwelling insects through global climate change Co-extinction occurs when a species goes extinct as a result of the extinction of the species it depends on. As 30-40% of plant-dwelling insects and other species depend on a host, losses to biodiversity may be extremely high if host species disappear. Climate change is predicted to reduce the population size and range of many plants, so there is the potential for climate-induced co-extinction to threaten Australia's biodiversity. This project will develop indicators of the degree to which insect species might be prone to co-extinction across Australia and identify cost-effective conservation strategies to combat this.	**Melinda Moir** **University of Melbourne**
TB1107 Determining high risk vegetation communities and plant species in relation to climate change in the Australian alpine region The Australian Alps are one of the three most vulnerable ecosystems to climate change in Australia. It's an important biodiversity ark with more than 400 species of plants, 25 of which occur nowhere else. Snow cover is already 30% less than in the 1950s. With longer, warmer, summers come other threats including bushfires, weeds and feral animals. There is nowhere higher for Australian alpine plants to go – how can we conserve them in a warmer world? This project will prioritise strategies to increase the resilience of plants to these threats. It will assess the characteristics of plants such as their height, leaf size and shape and how they reproduce to determine which will decline with less snow and which will move in. This will enable resource allocation to maintain key refuges, control weeds and feral animals, and manage increased recreational use of the area.	**Catherine Pickering** **Griffith University**
TB1108 The role of refugia in ecosystem resilience and maintenance of terrestrial biodiversity in the face of global climate change This research will maximise the protection of Australia's terrestrial biodiversity by improving our understanding of what parts of the landscape provide natural refugia from the impacts of global climate change. Researchers will assess, map and quantify the vegetation types and species associated with each refugium and assess their relative vulnerability and likelihood of persistence across a range of future climate scenarios. This research will form the basis for systematic conservation planning, enabling management actions to be prioritised to ensure cost-efficient allocation of resources.	**Stephen Williams** **James Cook University**

Project Title and Description	Principal Investigator and Institution
TB1109 Adapted future landscapes – from aspiration to implementation Regional adaptation to climate, market and social changes is possible by changing what we do and where we do it on the land. Both productivity and conservation goals can be achieved by farming to land capability, changing land use to capitalise on the emerging carbon market and identifying land use practices that provide a mosaic of production and conservation uses. This project will work with two regions in South Australia to develop an experimental process that uses future land use projections to assess different policy and guidance incentives. If the experimental process is successful, it could be adopted for land use planning in other regions in Australia.	**Wayne Meyer** **University of Adelaide**
FW1109 Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems. Likely changes in climate and ecological processes due to climate change mean it may not be possible to retain biodiversity and ecosystems in the same form or place. This project seeks to establish a broadened set of goals and objectives for NRM management that will accommodate these inevitable changes of biodiversity in response to climate change and other pressures.	**Michael Dunlop** **CSIRO Climate Adaptation Flagship**

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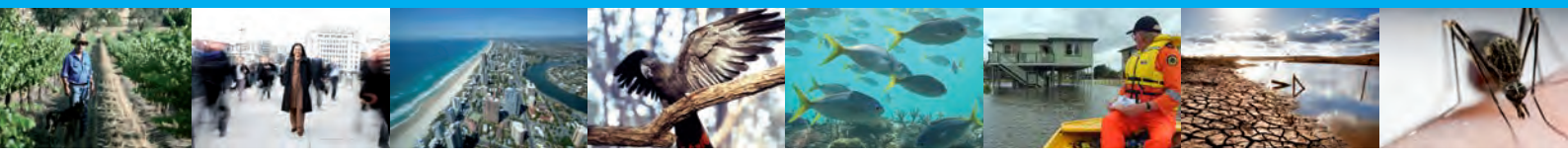

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Murdoch UNIVERSITY