RANGELANDS NRM CLUSTER

CLIMATE CHANGE IN AUSTRALIA

IMPACTS & ADAPTATION INFORMATION FOR AUSTRALIA'S NRM REGIONS

Australian rangelands and climate change – native species

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Key points

- Macro-ecological modelling indicates that the impacts of climate change will vary across biological groups and, for a number of these groups, will be greater in some regions of the Rangelands Cluster.
- The three groups that will be most impacted by climate change are plants, snails and reptiles; impacts on mammals will be moderate, whereas impacts on birds and frogs will be low.
- Future climate refugia are modelled to occur in the MacDonnell and Central Ranges (NT Arid Lands sub-region, WA Rangelands and Alinytjara Wilurara regions), the Channel Country (Desert Channels and SA Arid Lands regions), Mount Isa Inlier (Desert Channels region), the Gibson Desert, the Pilbara (both WA Rangelands), the Nullarbor (WA Rangelands and Alinytjara Wilurara regions) and parts of inland Queensland and NSW (Western LLS and South West Queensland regions).

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1. Introduction

Australia supports a unique and globally significant diversity of plants and animals. An important component of this diversity occurs within the Rangelands Cluster region. The interim results from the latest global climate modelling suggest likely changes in a range of climate variables within the region by 2090 (Watterson et al. in press). These changes in climate are likely to have significant impacts on the native flora and fauna.

In response to these projected changes, this report is tasked to cover the three topics described below.

1. To provide ecological interpretation and synthesis of existing macro-ecological models projecting broadscale changes in distribution of major biological groups (plants, vertebrates).
2. To provide ecological interpretation of existing macro-ecological models projecting the locations of climate change refuges of major biological groups (plants, vertebrates).
3. To provide a planning synthesis focusing on adaptation options in the face of climate change.

2. Approach and methods

2.1 Summary of methods

The approach used in this report has involved the following steps. First, published reports summarising macro-ecological modelling projects were obtained and interpreted with respect to the Rangelands Cluster region. These reports have been interpreted within the framework of the latest global climate modelling, which predicts changes in a range of climate variables within the region by 2090 (Watterson et al. in press). A summary of the key changes predicted for the region is given in Table 2.1.

The next step was to examine existing macro-ecological models projecting the locations of climate change refuges of major biological groups (plants, vertebrates). This modelling is currently available at a national scale. The opportunity to 'downscale' the national-scale assessments to spatial scales appropriate for NRM regions and sub-regions was investigated. This task involved discussions with the team undertaking Project 5 (Scaling Biodiversity Data) of the Monsoon Cluster (J. VanDerWal, D. Burrows, A. Reside, all James Cook University).

All land tenures are considered in these assessments.

Table 2.1 Summary of the predicted changes in a range of climate variables within the Rangelands Cluster region by 2090

CLIMATE VARIABLE	PROJECTED CHANGE
Temperature	**Increase in all seasons**
Extreme temperatures	**Increase in hot days**, decrease in cold days
Rainfall variability	**Remain high**
Extreme rainfall events	**Increase in intensity and frequency**
Winter and spring rainfall	A decrease more likely than an increase
Summer and autumn rainfall	Trend is unclear
Potential evapotranspiration	**Increase in all seasons**, most strongly in summer

Source: Watterson et al. (in press).
Bold indicates the changes of most importance when considering impacts on native species

2.2 Explanation of the two main modelling approaches

The available macro-ecological modelling examined as part of this work used two discrete analysis methods. These methods are described briefly below in the context of assessing species responses to a changing climate.

1. **Species Distribution Modelling**. The most widely used method is Species Distribution Modelling (SDM). This is a species-specific approach whereby observational records are used to model the current potential distribution of a species. Under this method, current climate is defined as the average for a period centred on a particular year (e.g. the 30-year average centred on 1990, thus covering 1976 to 2005). The data are then used to project into the future to reveal the distribution expected using future climate data. The projection focuses on a particular year (such as 2030, 2070 or 2085), and the projections of future climate are based on a combination of global circulation models (GCMs) and representative concentration pathways (RCPs). The models produce a simultaneous measure of climate suitability for the species that ranges from 0 to 1 (1 being the most suitable).
2. **Generalised Dissimilarity Modelling**. A second, less commonly used method is Generalised Dissimilarity Modelling (GDM). This method is based on compositional turnover of a group of species at a location. It is performed reasonably differently from SDM and considers whole biological groups rather than individual species. It has been argued that this approach is more useful where the whole ecosystem is the target of planning and management rather than individual species.

3. Data sources and availability of data

The major sources of data for this report have been key reports that have been completed since 2012. Additional modelling has also been provided directly by James Cook University.

The key reports are as follows:

- A recent study looking at the location of refugia for terrestrial biodiversity in the event of climate change at a national scale (Reside et al. 2013).
- An analysis of the impacts of climate change for conservation of biodiversity within Australia's National Reserve System (Dunlop et al. 2012).
- Within the Dunlop et al. (2012) project, an analysis that specifically looked at the hummock grasslands biome of arid and semi-arid Australia and assessed the impacts of a changing climate on plants, vertebrates and snails (Smyth et al. 2012).
- A recent analysis that examined the sensitivity and exposure of each taxon of Australian birds to climate change, modelled future climate space and developed adaptation options (Garnett et al. 2013; Garnett & Franklin 2014).

4. Broadscale changes in distribution of major biological groups

The impacts of climate change on major biological groups across the Rangelands Cluster region have been assessed in a number of national-scale macro-ecological modelling projects. These projects are summarised in the section above, and full citations (including web-links) to the reports from the projects are provided in the references.

The macro-ecological modelling study that is most relevant to the Rangelands Cluster region is one published in 2012 (Smyth et al. 2012), which assessed the impacts of climate change on fauna and flora within the hummock grasslands biome. The distribution of this biome overlaps broadly with that of the Rangelands Cluster region (Smyth et al. 2012). Other reports in the same series that were assessed covered a) the tropical savanna woodlands and grasslands biome (Liedloff et al. 2012), which is relevant to the NT tablelands sub-region and the eastern edges of the Desert Channels and South West Queensland regions, and b) the temperate grasslands and grassy woodlands biome (Prober et al. 2012), which is relevant to the south-eastern edge of the Western LLS region (see Figure 4.1).

Each of these studies used the GDM approach to assess impacts of climate change for four time-emissions scenarios: 2030 Medium, 2030 High, 2070 Medium and 2070 High. The analyses examined six groups of native species: plants, snails, frogs, reptiles, birds and mammals.

The modelling shows clearly that the impacts of climate change will a) vary across biological groups, and b) for a number of these groups, will be greater in some regions (Table 4.1). The three groups that will be most impacted by climate change are plants, snails and reptiles. The changes in composition will be moderate by 2030 (under both medium and high emissions scenarios) and then high for reptiles and very high for plants and snails by 2070 (Figure 4.2). These impacts will occur broadly across the Rangelands Cluster region.

Another group that will be impacted by climate change within the region is the mammals. The modelled compositional change in mammals will not be as dramatic as for plants, snails and reptiles. However, moderate compositional change will be experienced under the 2070 high emissions scenario in the NT arid lands and NT tablelands sub-regions and in the Desert Channels and South West Queensland regions.

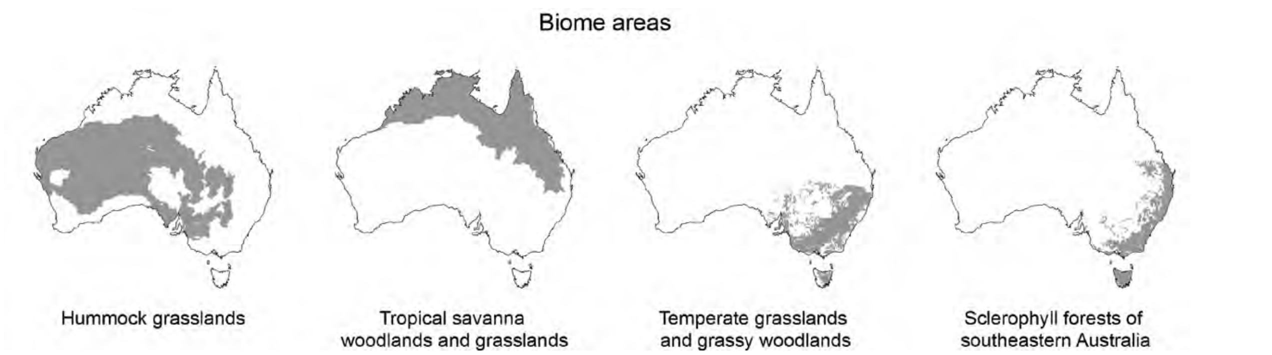

Figure 4.1 The four biomes covered in the macro-ecological modelling project of Dunlop et al. (2012). The first three are relevant to the Rangelands Cluster region.

The projected low impact of climate change on birds within the Rangelands Cluster region (Table 4.1) is corroborated by another study that used Species Distribution Modelling (SDM). This study produced a climate change adaptation plan for Australian birds (Garnett et al. 2013; Garnett and Franklin 2014). The project assessed all 1,232 taxa (i.e. species and sub-species) of Australian birds and concluded that 59 taxa were both highly sensitive and highly exposed to climate change. Of these 59 species only eight species occurred within the Rangelands Cluster region. Of the eight species, climate suitability by 2085 was expected to decline for five taxa (red-tailed black-cockatoo, *Calyptorhynchus banksii*; Western bowerbird, *Ptilonorhynchus guttatus*; short-tailed grasswren, *Amytornis merrotsyi*; slender-billed thornbill, *Acanthiza iredalei*; and Western whipbird, *Psophodes nigrogularis*), to increase for two taxa, and remain stable for the remaining taxon.

The similar prediction of Australian birds' response to climate change produced by the two studies gives confidence in the results. This is especially the case because one study used the GDM modelling approach (Smyth et al. 2012) and the other the SDM modelling approach (Garnett and Franklin 2014).

Table 4.1 A summary of projected compositional change using GDM modelling of six major biological groups within the Rangelands Cluster region at two time periods (2030 and 2070) and two emissions scenarios (medium and high).

BIOLOGICAL GROUP	2030 MEDIUM	2030 HIGH	2070 MEDIUM	2070 HIGH	REGIONS MOST IMPACTED
Plants	moderate	moderate	high	very high	All regions and sub-regions
Snails	moderate	moderate	high	very high	All regions and sub-regions
Frogs	low	low	low	low to moderate	NT arid lands and NT tablelands sub-regions, WA rangelands
Reptiles	moderate	moderate	high	high	All regions and sub-regions
Birds	low	low	low	low	None
Mammals	low	low	low	moderate	NT arid lands and NT tablelands sub-regions, Desert Channels, South West Queensland

'Low' indicates a GDM dissimilarity score of 0 to 0.3 across the majority of the Rangelands Cluster region. 'Moderate' indicates a GDM dissimilarity score of 0.4 to 0.6. 'High' indicates a GDM dissimilarity score of 0.7 and 0.8 whereas 'very high' represents scores of 0.9 and 1.0. The closer the GDM dissimilarity score is to 1.0 the greater the change in composition of that group in response to climate change.

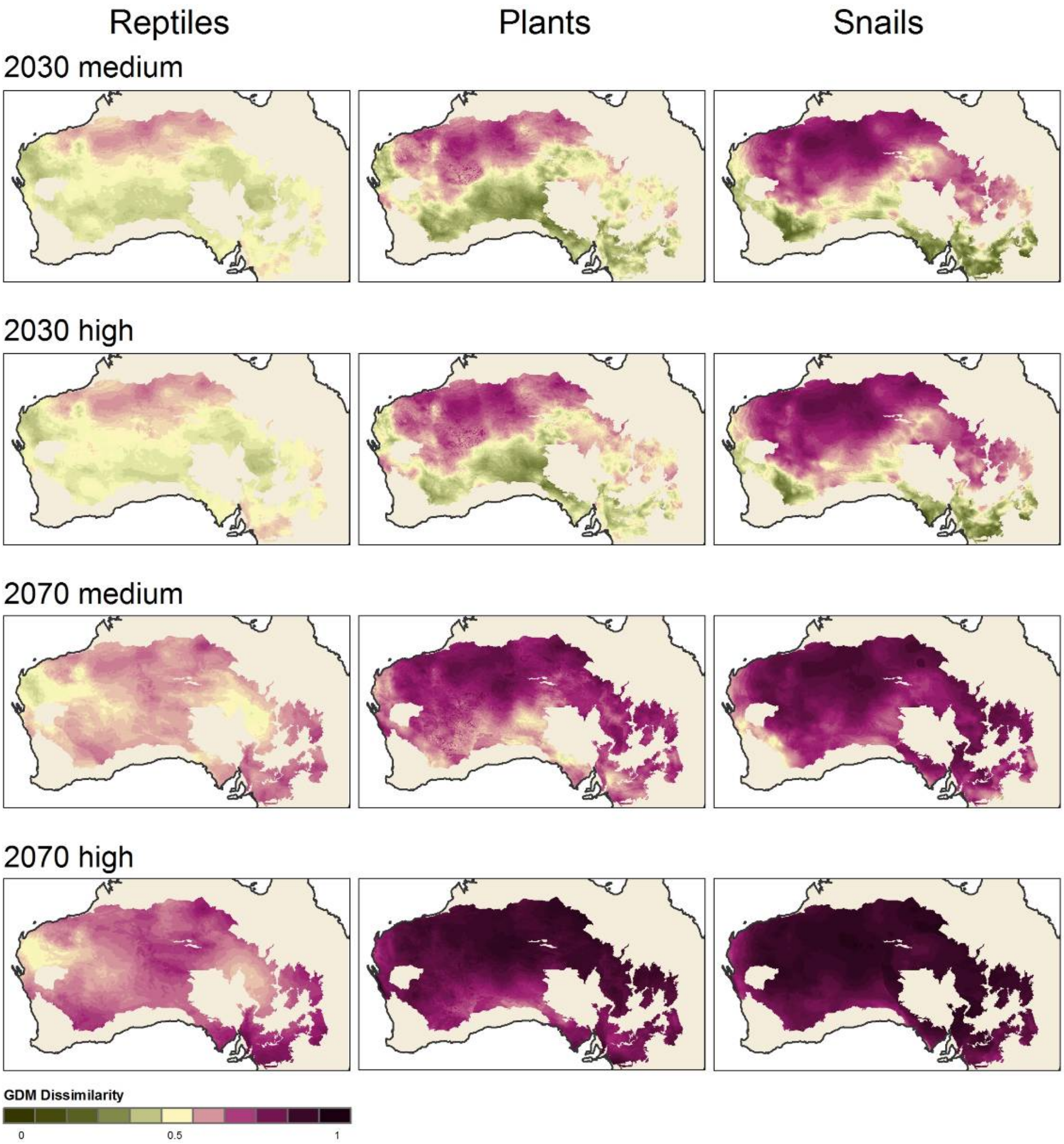

Figure 4.2 Projected compositional changes from GDM modelling under four time-emissions scenarios for plants, snails and reptiles within the hummock grassland biome.

Green represents low levels of compositional change; dark purple represents very high levels.

5. Location of climate change refuges

5.1 Summary of national scale modelling projects

The impetus for identifying climate change refugia is that these are the parts of the landscape where species can retreat to and persist in the future. Thus by focusing management on these key sites it should be feasible to minimise species loss.

A recently completed study examined the location of refugia for terrestrial biodiversity in the event of climate change at a national scale (Reside et al. 2013). This type of analysis is new and the study should be seen as the start of attempts to identify refugia at a broad scale. This study used both GDM and SDM modelling approaches to identify climate change refugia.

Few locations within the Rangelands Cluster region were identified as refugia using both approaches (Figure 5.1). Rather, concentrations of refugia were found in coastal areas around Australia and were particularly prevalent along the east coast. Both approaches identified most of Tasmania to contain refugia (Reside et al. 2013).

The GDM approach identified more refugia locations within the Rangelands Cluster area (Figure 5.1). Concentrations were apparent in the Channel Country (Desert Channels and SA Arid Lands regions), Mount Isa Inlier (Desert Channels region), the Gibson Desert and the Pilbara (both WA Rangelands). In contrast, the SDM approach found concentrations along the Nullarbor (WA Rangelands and Alinytjara Wilurara regions), and parts of inland Queensland and NSW (Western LLS and South West Queensland regions). Both approaches indicated the importance of the MacDonnell and Central Ranges (NT Arid Lands sub-region, WA Rangelands and Alinytjara Wilurara regions) as sites of future climate refugia.

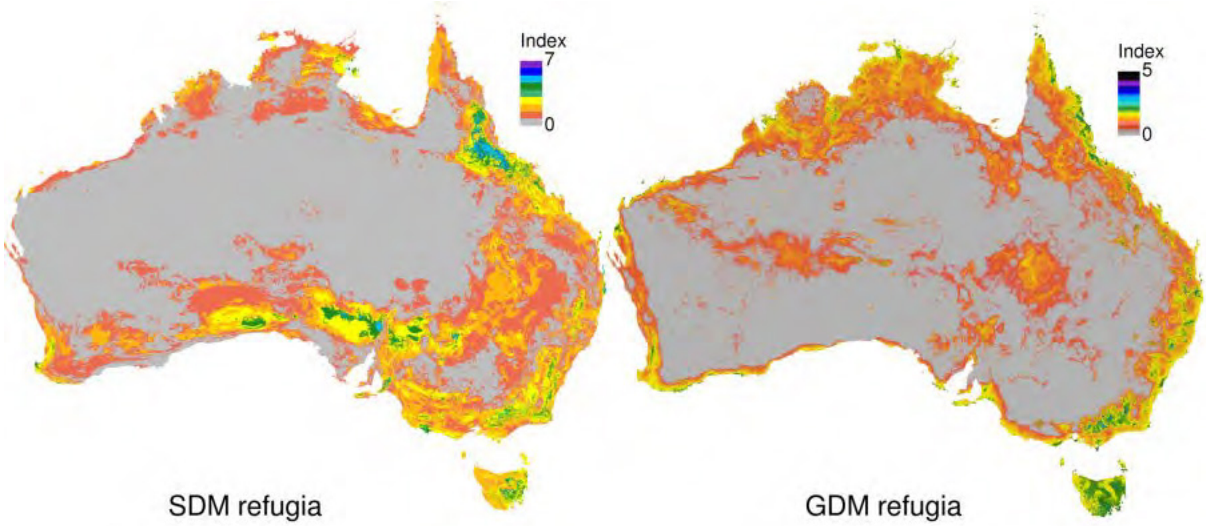

Figure 5.1 Suitability of sites as climate change refugia based on SDM and GDM modelling approaches.

Higher index values represent higher suitability. Note that the scales between the two maps differ.

Source: This figure is a reproduction of Figure 66 of Reside et al. (2013).

6. Adaptation principles and strategies

6.1 Planning under uncertainty

Climate change adaptation strategies are management actions that are developed to deal with the consequences of climate change (Smithers and Smit 1997). Planning under climate change is a difficult and challenging task. Among the challenges is the lack of precise information on the future directions for climate change and the subsequent high levels of uncertainty. For example, projections for changes in rainfall in arid Australia variously suggest an increase or possibly a decrease. To some extent this uncertainty has been reduced through the detailed analysis undertaken and presented in Watterson et al. (in press). However, uncertainty remains.

There are a number of important design considerations for adaptation under uncertainty (Hallegatte 2009; Addison 2013). These are framed around reducing vulnerability to current and future threats, as well as to future exposure to climatic change. These strategies are covered in detail below.

1. 'No-regret' strategies are an important group of strategies for dealing with uncertainty because they yield benefits even if there is not a change in climate. An example of a no-regret strategy to be used in the conservation of native species is to include a large area of natural habitat within the national reserve system that currently both supports a high diversity of species and in the future has been identified as a climate refuge. Such an approach will have benefits for fauna and flora conservation regardless of whether or not the climate changes.
2. Reversible strategies are flexible and can be changed if predictions about climate change are incorrect. Such strategies minimise the cost of being wrong about future climate change. Reversible strategies should be favoured over irreversible choices, all other factors being equal. An example of this strategy is to manage a large area of natural habitat for a threatened species and to provide a buffer around this within which disturbance is not allowed. There may be a cost of setting aside the buffer area but if in the future the buffer is shown to be not needed then the decision to ban disturbance can be instantly reversed.
3. Safety margin strategies are those that reduce vulnerability at little or no cost. For example, the area of impact of climate change can be estimated to be 50% greater than available models indicate. Conserving this additional area will account for any unexpected negative change in the estimated impacted area.
4. Soft strategies are those that involve the use of institutional, educational or financial tools to reduce species vulnerability to climatic change. An example in wildlife conservation is to educate homeowners about the biodiversity impacts associated with keeping cats within a peri-urban area or to introduce new lease conditions to prevent new water points from being established on pastoral leases that may be within identified climate refugia.
5. Strategies that reduce time horizons are an option for dealing with the uncertainty in predicting future climate conditions. This approach reduces the lifetime of particular investments. For example, win-win and no-regrets strategies may be appropriate when uncertainty levels about future climate change scenarios are high, but high cost, high risk strategies such as assisted colonisation may only be appropriate if they are attempted as a last resort once future climatic conditions are more certain.

6.2 Adaptation options

Providing advice in terms of adaptation options in a generic sense is difficult to do and potentially misleading. There is a wide range of adaptation options available (Table 6.1). One type of management is to maintain and enhance habitat of native species. This approach can be achieved by expanding the protected area network and/or incentivising conservation management outside of the protected area network, maintaining and improving habitat quality, identifying and protecting refugia, maintaining and extending landscape connectivity and creating new habitats.

A second type of management is more intensive and involves facilitating the responses of wild populations. Available options to achieve this type of management include assisted colonisation to new areas using translocation, enhancing the genetics of populations and enhancing the population growth rate while managing threatening processes (e.g. by predator control).

The most intensive and expensive type of management involves ex-situ conservation, where the focus in on preserving populations. Options here include captive breeding and storage of germplasm.

A final group of management approaches are those that focus on understanding on what is happening to animal and plant populations and using this information to predict what may happen. Perhaps the most widely used approach here is to monitor populations and their threats. Other options include investigating the ecology of species and assemblages of interest, modelling of habitat and climate suitability and modelling management options.

Table 6.1 Potential adaptation strategies for native plants and animals in response to climate change.

APPROACH	SPECIFIC ACTIONS
In-situ management	Expand the protected area network
	Maintain and improve habitat quality
	Identify, protect and expand refugia
	Maintain and extend ecological connectivity
	Create new habitats
Facilitate responses of wild populations	Assisted colonisation
	Enhance genetics
	Enhance population growth rate
Ex-situ management	Captive breeding
	Store germplasm
Monitoring and research	Monitor populations
	Monitor habitats and threatening processes
	Study ecology of species and assemblages
	Model habitat and climate envelopes
	Model management options

Source: The structure and content are based on Garnett et al. (2013)

Abbreviations

IN THIS REPORT	
TERM	**DEFINITION**
GCM	General Circulation Model
GDM	Generalised Dissimilarity Modelling
NRM	natural resource management
RCP	Representative Concentration Pathways
SDM	species distribution modelling
Western LLS	Western Local Land Service

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
ABS	Australian Bureau of Statistics
ACRIS	Australian Collaborative Rangelands Information System
AFCMP	Australian Feral Camel Management Project
BoM	Bureau of Meteorology
BS	bare soil
CMA	Catchment Management Authority
DKCRC	Desert Knowledge Cooperative Research Centre
DSI	Dust Storm Index
EI	Ecoclimatic Index
EMU	Ecosystem Management Understanding™
ENSO	El Niño Southern Oscillation
FIFO	fly in, fly out
GAB	Great Artesian Basin
GHG	greenhouse gas
GW	Groundwater
GWW	Great Western Woodlands
IBRA	Interim Biogeographic Regionalisation for Australia
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
LEB	Lake Eyre Basin
LGM	last glacial maximum
MOF	manual observation frequency
mya	million years ago
NAFI	North Australian Fire Information
NCCARF	National Climate Change Adaptation Research Facility
NPV	non-photosynthetic vegetation: senescent pasture and litter
OH&S	occupational health and safety
PV	photosynthetic vegetation: green
SAAL	South Australia Arid Lands
SW	Surface water
TGP	total grazing pressure
TM	Thematic Mapper
Western CMA	Western Catchment Management Authority

Glossary

IN THIS REPORT	
TERM	**DEFINITION**
'No regrets' strategies	These strategies yield benefits even if there is not a change in climate
Generalised Dissimilarity Modelling (GDM)	A method of modelling based on compositional turnover of a group of species at a location; it considers whole biological groups rather than individual species
Reversible strategies	Flexible strategies that can be changed if predictions about climate change are incorrect
Safety margin strategies	Strategies that reduce vulnerability at little or no cost
Soft strategies	Strategies that involve the use of institutional, educational or financial tools to reduce species vulnerability to climatic change
Species Distribution Modelling (SDM)	A species-specific approach whereby observational records are used to model the current potential distribution of a species
Strategies that reduce time horizons	Strategies that reduce the lifetime of particular investments

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
Adaptive capacity	The ability to change and therefore reduce gross vulnerability; includes issues such as mobility, financial resources and education
Bioregion	A large, geographically distinct area of land that has groups of ecosystems forming recognisable patterns within the landscape

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
C_3 and C_4 plants	The different methods plants use to convert carbon dioxide from air into organic compounds through the process of photosynthesis. All plants use C_3 processes; some plants, such as buffel grass and many other warm climate grasses, also use C_4 processes. C_4 plants have an advantage in a warmer climate due to their higher CO_2 assimilation rates at higher temperatures and higher photosynthetic optima than their C_3 counterparts
Contentious species	A species that presents special challenges for determining the adaptation response to climate change, because it is both a threat and a beneficial species (Friedel et al. 2011, Grice et al. 2012)
Dust Storm Index (DSI)	The Dust Storm Index is based on visibility records made by Bureau of Meteorology (BoM) observers. The DSI provides a measure of the frequency and intensity of wind erosion activity at continental scale. It is a composite measure of the contributions of local dust events, moderate dust storms and severe dust storms using weightings for each event type, based upon dust concentrations inferred from reduced visibility during each of these event types.
DustWatch	DustWatch is a community program that monitors and reports on the extent and severity of wind erosion across Australia and raises awareness of the effects of wind erosion on the landscape and the impacts of dust on the community.
Ecological refugia	Refugia defined according to the water requirements of the species they protect. The conservation significance of ecological refugia, and the priority assigned to their conservation, depends on the level of knowledge available for the species they support.

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
Evolutionary refugia	Those waterbodies that contain *short-range endemics* or *vicariant relics*. Evolutionary refugia are most likely to persist into the future and should be accorded the highest priority in NRM adaptation planning.
Gross vulnerability of a system	The combination of exposure and sensitivity of system
Heatwave	Continuous period beyond a week when a particular threshold temperature is exceeded
Hyporheic water flows	Below-surface flows
Indicators of exposure	Factors such as days above a certain temperature, days without rainfall, population density
Indicators of sensitivity	How sensitive a system is to hazards; indicators include the types of dwellings people live in and the percentage of the population with certain health characteristics
Novel ecosystem	Species occurring in combinations and relative abundances that have not occurred previously within a given biome (Hobbs et al. 2006)
Rainfall event	One or more closely spaced rainfalls that are large enough to produce a significant vegetation response
Refugia	Habitats that biota retreat to, persist in and potentially expand from under changing environmental conditions
Return period	The number of days from the end of one rainfall event to the start of the next
Short-range endemics	Species that occur only within a very small geographical area

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
Species invasiveness	A species that causes environmental or socioeconomic impacts, is non-native to an ecosystem or rapidly colonises and spreads (see Ricciardi and Cohen 2007). In the Invasive animals report it refers to non-native species (that is, those introduced to Australia post-1788) that have caused significant environmental or agricultural changes to the ecosystem or that are believed to present such a risk.
Vicariant relicts	Species with ancestral characteristics that have become geographically isolated over time

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