Trends in the biodiversity of the Nullarbor region: a comparison between 1984 and 2012

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EXECUTIVE SUMMARY

Climate change is predicted to influence the Aliny tjara Wiluраra region by raising average air temperature by 1.6 – 3.5 °C, and decreasing annual rainfall by 10 – 14% by 2070 (Suppiah et al., 2006, Alcoe et al., 2012). These changes are likely to alter the ecology of the Nullarbor landscape. Plants and animals might respond by adjusting their natural ranges and migrating towards refuges, such as the Nullarbor coastline, where the influence of the ocean reduces climate extremes. Biological surveys of the Nullarbor region that were conducted in 1984 and 2012 provide information on the environmental assets in the region at two different points in time. Data were analysed to detect trends in the cover of plants, and the abundance of mammals, birds and reptiles, and to investigate the link between temporal and spatial changes in rainfall and temperature with changes in the Nullarbor biota. Comparisons between 1984 and 2012 indicate there have been some changes in the coastal zone in terms of composition of plants and birds that characterised the HOT/DRY climate zone, but these biotic changes could not be definitively linked to changes in rainfall and temperature. Long-term monitoring programs are required to further track trends in the biota of the Nullarbor landscape and these programs should be linked directly to priority assets for the AW NRM, such as important biota or systems that are likely to be affected by climate change. This study can be enhanced and improved to provide informative trajectories of biodiversity that can then be used to inform planning and future management decisions in the Nullarbor region in accordance with the priorities of the Aliny tjara Wiluраra Natural Resource Management Board.
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INTRODUCTION

The Earth’s surface is warming and the global climate is changing with impacts already evident to the present generation. Rising air temperatures, increased heatwaves, changing rainfall patterns, more extreme and frequent drought and flood, altered ocean temperature and chemistry and sea-level rise present potential significant risks to the economy, society and way of life (Meehal et al., 2007). Future challenges include securing a reliable water supply, the effects of higher temperatures, reduced rainfall and more frequent extreme weather events on agricultural productivity and biodiversity, an increased number of heatwaves impacting human health and infrastructure and sea-level rise and storm surge impacts on coastal settlements, infrastructure and coastal ecosystems (Hughes, 2003; Steffen, 2009). Past temperature changes have affected the world, altering atmospheric and ocean circulation, rainfall and water availability, ice-cover, vegetation, ocean acidity and sea level. Indeed, past climate change shows us that global climate is sensitive to small influences and similar processes can act to amplify current human influences (Australian Academy of Science, 2010).

South Australia is becoming warmer. Southern coastal areas are now drier but rainfall is increasing in the state’s northern half. The global surface temperature has increased by 0.7°C in the last century, but in Australia (0.89°C) and in particular South Australia (0.96°C) the increase has been greater. The rate of increase has become more rapid since 1950. The Commonwealth’s Scientific and Industrial Research Organisation (CSIRO) has reported on climate conditions and outlined climate projections for 2030 and 2070 for South Australia (CSIRO, 2007). The CSIRO predict that South Australia will see:

- higher temperatures, including more extreme hot days, with spring and summer warming more than winter and autumn
- decreased rainfall in agricultural regions (especially in winter and spring)
- greater frequency and severity of drought
- decreased flows in water supply catchments including the Murray-Darling
- increased flood risk (despite drier average conditions)
- shifts in conditions affecting viability of crops and biodiversity
- increased incidence and severity of bushfires
- coastal hazards related to the effect of ocean warming on sea levels combined with storms of possibly increased intensity
- damage to infrastructure, for example from coastal erosion, flooding and extreme heat

Arid regions potentially provide a useful location for examining the impacts of climate change on biodiversity. Plants and animals that use these regions are typically adapted to cope with climatic extremes and it may be possible to make comparisons along broad scale climatic and environmental gradients.

Research shows that plants and animals can be negatively or positively impacted by climatic changes. Plants that have limited spatial ranges, narrow habitat requirements and poor dispersal abilities have less capability of adaption and can become extinct if the environment changes beyond their limitation (Box et al., 2008). On the other hand, some woody shrubs are likely to increase in range because they have evolved to require little water, and are likely to have accelerated biomass productivity in an enriched CO$_2$ environment (Hughes, 2003). The contrasting findings of these researchers indicate the variable response of plants and animals to a changing climate.

By 2070, South Australia is expected to increase in temperature by between 1.4 - 2.85 °C (Suppiah et al., 2006). In the Alinytjara Wilućara (AW) region the average air temperature is expected to rise by 1.6 – 3.5 °C between now and 2070 (Figure 1; Suppiah et al., 2006). Total annual rainfall is generally predicted to decrease by 10 – 14% in the AW region (Figure 2; Alcoe et al., 2012). It is likely that the change will not be distributed evenly because the AW
region spans from the coast (the Nullarbor Plain) to the arid centre of Australia (Alcoe et al., 2012). The coastal section of the AW region receives relatively more rainfall and has relatively lower average temperatures. As a result, the coastal region is expected to show a temperature increase and rainfall decrease toward the lower end of range for the entire AW region (approx 0.8°C and -15 mm). Some plants and animals that are adapted to this relatively moderate coastal region may be at the edge of their climatic range and so these species provide a natural experiment to test the impacts of climate change.

Figure 3 Annual Rainfall for the Nullarbor bioregion from 1891 to 2011. Rainfall year is April to March, for example total annual rainfall is taken from April 2011 to March 2012, inclusive. The calculated mean annual rainfall is 201 mm with a standard deviation of +/- 65.04. (Source: Bastin, 2012).

Table 1 Rainfall in the three years preceding the 2012 and 1984 surveys, with mean and standard variance. Source: Bastin 2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Total rainfall calculated from April to March (mm)</th>
<th>Year</th>
<th>Total rainfall calculated from April to March (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>241</td>
<td>2009</td>
<td>234</td>
</tr>
<tr>
<td>1982</td>
<td>189</td>
<td>2010</td>
<td>205</td>
</tr>
<tr>
<td>1983</td>
<td>201</td>
<td>2011</td>
<td>376</td>
</tr>
<tr>
<td>Mean</td>
<td>210.3</td>
<td>Mean</td>
<td>271.7</td>
</tr>
<tr>
<td>Standard Variance</td>
<td>741.3</td>
<td>Standard Variance</td>
<td>8374.3</td>
</tr>
</tbody>
</table>
The climate experienced in the Nullarbor region is highly variable, with total annual rainfall ranging from 71 to 437 mm (Figure 3). Rainfall is likely to be the most important factor, limiting the ecosystem processes and functions in the Nullarbor region, where precipitation is the principal source of water (Dube & Pickup, 2001). According to climatic records for the Nullarbor (see Table 1), the rainfall 3 years prior to the 1984 survey was less than the rainfall preceding the 2012 survey. This is a direct contrast to the climate change prediction that describes a drying of the landscape. Short-term pulses of rain, and long-term trends control plant growth, carbon fixation and net primary production (Sala et al., 1997). How these two different rainfall cycles interact will need to be addressed in future monitoring so that trends in biota can be linked to both short-term pulses, and long-term climatic fluctuations.

The Nullarbor region has been divided into two climate zones for this study based on predominant patterns of rainfall and temperature. These zones are approximately located south of Cook to the Nullarbor coast, - COLD/WET zone, and north of Cook to beyond the northern Nullarbor border - HOT/DRY zone. The northern climate zone experiences 200 mm mean annual rainfall and 21°C mean temperate. The southern climate zone experiences 300 mm mean annual rainfall and 18°C mean temperature (figure 4).

Figure 4 Average Rainfall maps based on standard 30-year climatology (1961 – 1990). Rainfall gradient is indicated with a blue line, and temperature gradient is indicated with an orange line. Note IF sites are below rainfall gradient but above temperature gradient.
Climate is a broad scale variable that influences the distribution and abundance of plants and animals but soils, landform and aspect can also be important. Temperature gradients influence the distribution of C3/C4 grass varieties (Epstein et al., 1997). Consistent rainfall gradients often determine broad vegetation patterns and biomass production (Morgan et al., 2008). Arid land plants have evolved to exploit intermittent and irregular rainfall events by quickly responding to rain by germinating, growing and producing seed (Westoby, 1980; Morton et al., 2011). The duration of precipitation and in which season it falls is therefore an important aspect of rainfall in arid environments. Most animal species do not fluctuate in a direct relationship with rainfall. This can be due to various forms of buffering, for example fruits for birds may provide a secondary moisture resource after rainfall (Birds: Reid, 1991; Prinzinger & Schleucher, 1998. Insectivorous marsupials: Dickman et al., 2001. Lizards: James, 1994). Monitoring ecosystem function and health in response to climate change needs to be well planned to answer the question: How has the ecology of the landscape changed in response to temporal and spatial changes in rainfall and temperature? (Woinarski, 2004).

A report by Bardsley and Wiseman (2012) highlighted the influence that climate change is likely to have on the AW region and made several recommendations to improve the region’s capacity to adapt and flourish under climate change, in both a natural resource management and social context. Key recommendations that are addressed in this report include the repeat of biological surveys and the investigation of the relationship between biodiversity and climate. These actions will inform the AW region of possible trends in the abundance and cover or plants and animals, and assist in the selection of regional assets that should be used to define long term monitoring programs for the Nullarbor region.

Monitoring in the arid lands has been a subject of debate, particularly in areas where there is low density of biodiversity, low populations of humans and where the land is not used for agricultural production (Eyres, 2011). It is largely accepted that monitoring programs need to be clearly articulated and directed toward landscape management, rather than simply tracking the extinction and decline of ecosystems (Steffen et al., 2009; Field et al., 2004). A key message from Lindenmeyer et al. (2012) is to design monitoring programs to specifically answer management questions, rather than use monitoring to detect change with questions added post-hoc.
A common approach taken by the Feral Camel Action Plan (NRM, 2010) is to focus management on an asset, and to monitor the state of the asset in response to pressures. An asset can include systems or locations of importance, whether built or natural, for example biodiversity hotspots, water points, threatened species or ecosystems, or built structures. All monitoring programs can use this basic template to articulate regional assets and pressures, according to land-use, environmental priorities, and resources available. Making explicit predictions about how management will mitigate impacts and monitor responses is likely to assist in informing whether a management practice is effective or not and to indicate how/when alterations to management plans are needed.

Some key natural assets in the Nullarbor region, include but are not limited to, species that are regionally important, water points, and areas where biodiversity is relatively high. There are 14 species of plants and animals listed by the EPBC Act 1999 as threatened taxa in the South Australian portion of the Nullarbor region. Acanthiza iredalei iredalei is one example of a significant species that is common throughout the Nullarbor landscape. There are numerous naturally occurring water points in the Nullarbor region, including dongas, paleochannels and natural rockholes that accumulate and hold water. These areas are often important because; they host relatively high numbers of plants and animals, because these biodiversity hotspots are occasionally unique to the environment surrounding them as in the case of a dongas, and because water points are often more susceptible to overgrazing, trampling, fouling, and competition.

Climate change is likely to exacerbate threatening processes that affect Australian ecosystems but many outcomes remain unforeseen (Prowse & Brooks, 2011). Key threats in the Nullarbor landscape include, but are not limited to, buffel grass and the impacts of large introduced herbivores such as camels (Biosecurity SA, 2012; Vertebrate Pest Committee, 2010). Changed fire regimes may also be an issue due to both changes in vegetation structure and composition linked to weeds and pests, as well as changed burning practices (Myers et al., 2004).

The impacts that each of these pressures have in the Nullarbor region are not well recorded, but it is likely that each threat is wide-spread given the suitability and climate of the Nullarbor. Accurately quantifying the impacts of individual threats is challenging, as is defining interactions and the interrelationships between them. Climate change represents
another layer of complication because it acts over large areas and its affects can be difficult to decouple from shorter term and cyclic processes. Uncertainties remain globally about how ecosystems are responding to climate change due to the high level of complexity inherent in defining causes and consequences (Prato, 2008).

The arid environment in the Nullarbor region was the focus of this study to explore possible changes in biodiversity attributed to temporal and spatial changes in rainfall and temperature. As suggested by Bardsley & Wiseman (2012) a repeat of biological surveys was used to attempt to detect changes across the landscape and to then inform the selection of assets that require management and monitoring. The Nullarbor study area is defined by McKenzie & Robinson (1987) using biogeographic boundaries created for South Australia by Laut et al. (1977) and adapted for the Interim Bio-regionalisation of Australia (IBRA – Thackway & Creswell, 1995) (Figure 5). The South Australian section of the Nullarbor Bioregion was the study site for a biological survey in 1984 and 2012. The key aims of this project were; to detect trends in the cover of plants, and the abundance of mammals, birds and reptiles, on the basis of a comparison of an historical survey from 1984 with the current survey from 2012, and to investigate the link between temporal and spatial changes in

Figure 5 Nullarbor Bioregion with the IBRA subregions: Carlisle, Nullarbor Plain, and Yalata.
rainfall and temperature with changes in the Nullarbor biota. Secondary to these aims were: 1) the investigation of potential for historical biological survey data to be used for monitoring trends in biodiversity over time, 2) the documentation of methods investigated and adapted for current data collection, including suggested improvements for future surveys, and 3) discussion of recommendations for future sampling and the relative value of the different monitoring actions for managers.

We predicted that some plants and animals in the coastal region may be at the edge of their climatic range, therefore, we analysed the data to compare changes at sites that were north versus south along the temperature and rainfall gradients. To make these comparisons, we classified sites to the north of the temperature and rainfall gradients as HOT/DRY (sites HU and MU) and sites to the south as COLD/WET (sites CA, IF, KD, KO, YA and ME). The IF sites were located in the COLD/DRY band between the average temperature and rainfall gradients and it was decided that these would be included in the COLD/WET zone because rainfall has a greater influence on plant and animal distribution in the arid zone where water availability is the predominant limiting factor.

If plants and animals are adapted to a coastal climate (COLD/WET), their available habitat may shrink as temperatures increases and rainfall decreases. In contrast, the available habitat may increase for species that are adapted to drier and hotter regions. These broad predictions provide a natural experiment to test the impacts of climate change on plants and animals in this arid environment. We tested two hypotheses to examine whether bioclimatic differences were reflected in the abundance and distribution of species. We predicted that over the last 28 years, plants and animals that characterise the HOT/DRY zone would become more abundant in the COLD/WET zone. We also predicted that species characterising the COLD/WET zone would become relatively less abundant in that zone. We examined these predictions by testing for differences in the abundance of plants and animals from the HOT/DRY zone in the COLD/WET zone in 1984 or 2012. Likewise, we tested for differences in the abundance of plants and animals from the COLD/WET zone in 1984 or 2012.
METHODS

SAMPLING METHOD

Sites were clustered around eight disparate camps for the 1984 survey to sample an accessible array of discrete vegetation units and surface types (Figure 6). These sites formed the basis of the 2012 re-sample. The 8 camps are Catacombs (CA), Ifould (IF), Hughes (HU), Koonalda (KD), Colona (KO), Merdayerah (ME), Muckera (MU), Yalata (YA). In 1984, five sites were selected per camp (40 sites in total). In 2012 there was an additional site at each camp. Sites are 2 km by 2 km and are divided into 2 or 3 patches that are selected because they represent different vegetation communities within each site. For a full list of patches and the corresponding vegetation description see table 2. Sample patches are 100 x 100 m; some are linear and the square is adjusted to a rectangle (eg. 50 x 200 m). Naming convention for samples are camp – site – patch, for example CA – 001 – A or CA001A. Two surveys were conducted in 1984, while in 2012 only one survey was conducted. Biological data collected in autumn 1984 and autumn 2012 are used in this survey. Where plants are compared, only perennial species are included to reduce the effect of high variation in annual species. Vegetation survey methods broadly follow Heard and Channon (1997) and are detailed below. Data collected includes: site description, location details, physical description, disturbance, and soils. Not all data captured in 1984 or 2012 was consistent, due to time constraints.

Figure 6 Overview of survey area with location of patches from all sites indicated with red crosses.
Table 2 List of patches surveyed in 1984 and 2012 in autumn. Patches may have been surveyed for vegetation, birds, and vertebrates in either or both years. The vegetation structural description and dominant vegetation species related with each patch reflects observations in 2012 only. These factors were not consistently recorded in 1984.

<table>
<thead>
<tr>
<th>Patch ID</th>
<th>Surveyed In</th>
<th>Vegetation Structural Description</th>
<th>Dominant Vegetation Species: o = overstorey, u = understorey, e = emergent.</th>
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<tbody>
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<td>Atriplex vesicaria ssp. (o), Austrodanthonia sp. (u), Sclerolaena obliquicuspis (u), Tecticornia disarticulata (o)</td>
</tr>
<tr>
<td>CA001B</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA001C</td>
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<td>Low Shrubland</td>
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<td>Atriplex vesicaria ssp. (o), Austrodanthonia sp. (u), Maireana sedifolia (o), Tecticornia disarticulata (o)</td>
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<tr>
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<tr>
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<tr>
<td>CA005B</td>
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Table 2 continued: List of patches surveyed in 1984 and 2012 in autumn

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</tr>
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</tr>
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Atriplex vesicaria ssp. (o), Austrostipa nitida (u), Maireana sedifolia (e), Salsola tragus (u)
Atriplex vesicaria ssp. (o), Sclerolaena patenticpis (u)
Atriplex vesicaria ssp. (o), Enneapogon caerulescens (u), Maireana sedifolia (o), Sclerolaena obliquicuspis (u)
Atriplex vesicaria ssp. (o), Austrodanthonia sp. (u), Maireana sedifolia (o), Sclerolaena obliquicuspis (u)
Acacia papyrocarpa (o), Alectryon oleifolius ssp. canescens (e), Atriplex vesicaria ssp. (u), Maireana integra (u), Maireana sedifolia (u), Maireana trichoptera (u), Rhagodia spinescens (u)
Acacia papyrocarpa (o), Atriplex vesicaria ssp. (u), Maireana sedifolia (u), Santalum acuminatum (u), Sclerolaena diacantha (u), Sclerolaena obliquicuspis (u)
Acacia papyrocarpa (o), Atriplex vesicaria ssp. (u), Maireana sedifolia (u), Eremophila scoparia (o), Eucalyptus oleosa ssp. ampliata (o), Scaevola spinescens (u)
Acacia papyrocarpa (o), Alectryon oleifolius ssp. canescens (o), Atriplex vesicaria ssp. (u), Maireana sedifolia (u), Myoporum platycarpum ssp. platycarpum (o)
Acacia papyrocarpa (o), Atriplex vesicaria ssp. (u), Austrostipa nitida (u), Maireana integra (u), Maireana sedifolia (u), Sclerolaena obliquicuspis (u)
Acacia papyrocarpa (o), Atriplex vesicaria ssp. (u), Maireana sedifolia (u), Eremophila scoparia (o), Eucalyptus oleosa ssp. ampliata (o), Scaevola spinescens (u)
Atriplex vesicaria ssp. (o), Austrostipa nitida (u), Maireana sedifolia (o), Sclerolaena obliquicuspis (u), Vittadinia gracilis (u)
Atriplex vesicaria ssp. (o), Enneapogon avenaceus (u), Enneapogon cylindricus (u), Maireana sedifolia (o), Vittadinia gracilis (u)
Hemichroa diandra (u), Lawrenia squamata (o), Nitraria billiardierei (o), Trichanthodium skirrophorum (u)
Frankenia sessilis (u), Lawrenia squamata (o), Nitraria billiardierei (e), Trichanthodium skirrophorum (u)
Atriplex vesicaria ssp. (u), Cratystylis conocephala (u), Eucalyptus yalatensis (o), Exocarpos aphyllus (e), Geijera linearifolia (u), Melaleuca lanceolata (o), Olearia muelleri (u)
Atriplex vesicaria ssp. (u), Cratystylis conocephala (u), Eucalyptus socialis ssp. victoriensis (o), Eucalyptus yalatensis (o), Geijera linearifolia (u), Olearia muelleri (u), Westringia rigidia (u)
Atriplex vesicaria ssp. (u), Eucalyptus yalatensis (o), Maireana erioclada (u), Melaleuca pauperiflora ssp. mutica (o), Myoporum platycarpum ssp. platycarpum (e)
Atriplex vesicaria ssp. (u), Lawrenia squamata (o), Lycium australe (u), Tecticornia disarticulata (u)
Atriplex vesicaria ssp. (u), Lawrenia squamata (u), Lycium australe (u), Nitraria billiardierei (e)
Atriplex vesicaria ssp. (u), Austrodanthonia caespitosa (u), Austrostipa puberula (u), Lawrenia squamata (u)
Atriplex vesicaria ssp. (o), Austrodanthonia sp. (u), Austrostipa nitida (u)
Atriplex vesicaria ssp. (o), Austrostipa eremophila/puberula (u), Austrostipa nitida (u), Maireana sedifolia (e)
### Table 2 continued: List of patches surveyed in 1984 and 2012 in autumn

<table>
<thead>
<tr>
<th>Code</th>
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<th>Vegetation</th>
</tr>
</thead>
<tbody>
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<td>KD005D</td>
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</tr>
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</tr>
<tr>
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<td>Low Open Shrubland</td>
</tr>
<tr>
<td>KO001B</td>
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<td></td>
</tr>
<tr>
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</tr>
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<td>Open Mallee</td>
</tr>
<tr>
<td>ME004B</td>
<td>✓ ✓</td>
<td>Very Low Woodland</td>
</tr>
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</table>

---


*Eremophila weldii* (u), *Eucalyptus calcaraea* (o), *Eucalyptus gracilis* (e), *Eucalyptus socialis* ssp. *viridans* (o), *Melaleuca quadrifaria* (o), *Rhadogia crassifolia* (u), *Westringia rigida* (u)

*Eremophila weldii* (u), *Eucalyptus graciulisi* (o), *Geijera linearifolia* (u), *Melaleuca lanceolata* (o), *Westringia rigida* (u)

*Eremophila weldii* (u), *Eucalyptus calcaraea* (o), *Eucalyptus graciulisi* (o), *Eucalyptus yaltensis* (o), *Melaleuca lanceolata* (o), *Pomaderris forestiana* (u), *Westringia rigida* (u)

*Atriplex nummularia* ssp. *spathulata* (u), *Eremophila weldii* (u), *Eucalyptus calcaraea* (o), *Eucalyptus yaltensis* (o), *Geijera linearifolia* (u), *Scaevola spinescens* (u), *Westringia rigida* (u)

*Eucalyptus calcaraea* (o), *Eucalyptus graciulisi* (o), *Eucalyptus yaltensis* (o), *Scaevola spinescens* (u), *Westringia rigida* (u)

*Acacia papyrocarpa* (o), *Atriplex nummularia* ssp. *spathulata* (u), *Eremophila weldii* (u), *Eucalyptus graciulisi* (o), *Geijera linearifolia* (u), *Olearia muelleri* (u), *Westringia rigida* (u)

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Table 2 continued: List of patches surveyed in 1984 and 2012 in autumn

<table>
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<tr>
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<th>Species</th>
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<td>Acacia anura var. intermediata (o), Maireana sedifolia (u), Pittosporum angustifolium (o)</td>
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<td>Acacia anura var. intermediata (o), Acacia ligulata (u)</td>
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Vegetation sampling

Vegetation sampling was based on the Biological Survey of South Australia methods detailed in Heard and Channon (1997). All vascular plants were recorded, along with a measure of their cover/abundance and a structural classification of life form at each patch. Dominant species in both the overstorey and understorey were also noted at each patch, as well as the structural formation description of the vegetation community. In addition to the standard methods, there were more intensive cover-abundance measures for dominant perennial overstorey and understorey species, and measures of camel browsing impacts (see below).

The methods of collecting the cover/abundance measures of plants differed between 1984 and 2012. In 1984 the percent cover was recorded, where each sample patch equalled 100%. This data was stored in the Biological Database of South Australia and was transformed into a category. A category was associated to each individual according to the percent cover:

- N not many, 1 – 10 individuals**
- 1 sparsely or very sparsely present; cover very small (less than 5%)
- 2 plentiful, but of small cover (less than 5%)
- 3 any number of individuals covering 5 – 25% of the area
- 4 any number of individuals covering 25 – 50% of the area
- 5 any number of individuals covering 50-75% of the area
- 6 any number of individuals covering 75 – 100% of the area

** where large shrubs or trees were involved a category to reflect the cover rather than abundance was chosen.

In 2012, the above categories were used and no definitive percent cover was allocated. Both sets of cover/abundance records from 1984 and 2012 where transformed into absolute numbers to allow for the multivariate analyses of cover. Category N = 1% cover, category 1 = 0.5% cover, category 2 = 2.5% cover, category 3 = 15% cover, and category 4 – 37.5% cover. No individuals were recorded in categories 5 and 6.

Transects/segments in the dominant cover measures and quadrats in the browse evaluations were referenced to the corners of the vegetation patch quadrat. Trap-lines and
photopoints were nearer the quadrat edge and linked corners 1 & 4. The schematic plan (Figure 7) is a typical layout of the quadrats (Photopoints lay either side of trap-line and trap-line might not be contained entirely within quadrat). The location of camel browse transects in relation to the sample patch is shown in figure 9.

**Dominant perennial vegetation cover**

For woody species listed as overstorey/understorey dominants, cover measures were undertaken as follows:

1. For trees and tall shrubs listed as dominant overstorey/tree forms and species that are emergent: The height of each individual was recorded as the vertical distance above ground level to the highest foliage. The width of an individual was recorded in line with the main trunk for tree forms, and across the point where multi-stems meet near ground level for shrub forms. The direction of width measurement changed with each successive measure of the same species. The first observation was measured at 280 degrees, second at 310 degrees, third at 340 degrees, fourth at 10 degrees, fifth at 40 degrees, sixth at 70 degrees, the seventh returned to 280 degrees and the cycle repeated, i.e. eighth at 310, ninth at 340, and so on. Only the dominant trees/tall shrubs that were rooted inside the quadrat were measured. If the crown width extended outside the quadrat the full width was recorded (we assumed this overhang out of the quadrat matches the overhang in to the quadrat of other plants that are rooted outside).

2. For Shrubs and low shrubs listed as dominant overstorey or understorey species: Six 4 m wide segments (A to F) were surveyed along 3 parallel strip transects, refer to figure 7B for spatial design in quadrat. Within each segment measurement of distance apart, crown, height and width were taken for six individuals of each shrub species listed as a dominant in the overstorey or understorey. Segment length varied with shrub density, and on occasions, extended outside the quadrat but were always a minimum of 50 m apart of each strip axis. Figure 8 illustrates the procedure for locating six individuals of a species.
Figure 7 A shows schematic 100 x 100 m sample patch with trapline and photopoint; and quadrat corners. Track is mostly “near” side and links corners 1 & 4. B shows three strip transects each with two segments for dominant perennial cover measures (this representation is a typical fit for shrub or low shrub dominants).

Figure 8 Construction of segments and measures on dominants around Segment A. Axis of strip transect and segment is coincident with sampling quadrat.

8 A shows small bush A₀ (of Species X) selected near Corner 4. Locate A₁, nearest same species along transect and within 2 m of strip axis. Measure separation distance from bush perimeter of A₀ to bush perimeter of A₁. Measure height and width of A₁. Locate A₂, the nearest individual of same species, along transect and within 2 m of strip axis. Continue until A₇. Only A₁ to A₇ are measured for height and width.

8 B shows width measure is taken along same line of separation distance from previous bush. This figure represents a typical arrangement for shrub/low shrub dominants (relatively abundant either as Overstorey or Understorey). For some Overstorey dominants, strip transect may have to extend forward to accommodate long segment length (in small or odd-shaped vegetation patches) but should not cross track, fence or other disturbance.

Figure 9 Belt transects for camel browse evaluations also correspond to vegetation quadrat edges and mid-line transects. Quadrats numbered 1 to 15 are arranged in groups of 5 as shown.
Perennial species browse

Browse impacts of exotic herbivores (camels and rabbits) were appraised along belt transects established along the edges (1-2 / 4-3) and mid-line (T-M) of the 100 x 100 m quadrat, the same axes as the dominant species cover measures. Camel browse was recorded in 15 (20 m x 4 m) quadrats systematically located along the margins and the mid-line of a 100 x 100 m quadrat, five per belt transect. See figures 7B and 9 for a layout of the camel browse quadrats and figures 10 and 11 for a description of how to distinguish the different types and intensities of camel browse.

All woody, perennial species that were greater than 2 m and rooted within 2 m of a transect were examined including saplings, plus mistletoe below 4 m. On each 20 x 4 m browse quadrat the browse intensity above 2 m was recorded for each perennial species present. Browsing intensity can vary on a given plant so two degrees of browse class were recorded, using codes that reflected branch tip diameters as in table 3. Where camels had stripped foliage and bark from twigs, the diameter of thickest part of the stripped twig was recorded.

Table 3 Branch tip diameter classes for browse intensity

<table>
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<tr>
<th>Browse Class Code</th>
<th>Reference Object</th>
<th>Branch Tip Diameter Range (mm)</th>
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<tbody>
<tr>
<td>IT</td>
<td>Intact</td>
<td>No browsed tip</td>
</tr>
<tr>
<td>TP</td>
<td>Toothpick</td>
<td>&lt; 1.5 *</td>
</tr>
<tr>
<td>MS</td>
<td>Match</td>
<td>1.5 – 3</td>
</tr>
<tr>
<td>DS</td>
<td>Soft-Drink Straw</td>
<td>3.1 – 5</td>
</tr>
<tr>
<td>PC</td>
<td>Pencil (wooden)</td>
<td>5.1 – 9</td>
</tr>
<tr>
<td>LF</td>
<td>Little Finger (across base of fingernail)</td>
<td>10 – 15</td>
</tr>
<tr>
<td>TB</td>
<td>Thumb (across thumbnail base)</td>
<td>16 – 25</td>
</tr>
<tr>
<td>TB+</td>
<td>Thumb and finger</td>
<td>&gt; 25</td>
</tr>
</tbody>
</table>

* This class was naturally absent from some species.

Tallies were made of the number of individuals per browse class per species for each browse quadrat.
Figure 10 A. An intact shrub or tree is browsed back to the positions marked L and forms B. Perimeters to evaluate are outlined in grey. C. New shoots (N) only grow from very thick stems (T1) and some thick branches (T2), which sprouted after intense browse, but were also eaten back. All three diameters occur at the perimeter — new growth has not extended beyond an older browse episode, because of the constant or intense browse pressure. Record the diameter of T3, and diameter of T2. In these instances, newest shoots are inevitably browsed.

D. The earlier heavy browse episode is preserved on the bush as in C. In D1, some growth has occurred and perimeter is basically defined by browsed T2 branches and tips of N, that don’t extend much beyond T2, so record T2 and N diameters (N may be browsed). In D2, new shoots extend beyond T2 size branches and even have some axillary shoots — base recording on diameter of N, which may or may not be browsed. Two episodes of past browse are preserved on this bush.

E. The earlier heavy browse episode is preserved on the bush as in C, but growth has resumed undisturbed. Branch diameters taper from T2 through T1 to N, which also has some axillary growth. Observation records are based on the diameter of N, which may or may not be browsed.

Figure 11 F, G, H, I represent the branch of a shrub or tree.

F. The branch tip and terminals of closest axillary shoots have been lightly browsed. If all branches of shrub/low tree are like this record as browsed using diameter of the shoot tips. If most branches are like this, record primarily as browsed (using diameter at the shoot tips) and secondarily as intact. Vice versa if more branches are intact (like I) and only a few show browse.

G. A branch tip has been bitten off, and axillary growth has become vigorous. If on most branches, axillary shoots do not much extend beyond the browsed tip, then record primarily as browsed (using the tip diameter) and secondarily as intact. If axillary shoots vigorously extend beyond the browsed tip on most branches, then record primarily as intact with some secondary browse.

H. A branch tip was browsed, and its axillary growth has generated new terminals which have extended way beyond the old browse point. New axillary shoots are vigorously growing on these new leaders. Treat this as essentially intact, with some preservation of previous browse episodes.

I. An unbrowsed branch in which branch diameters taper gradually to every tip. Twigs at end of branches have terminal leaves and any axillary growth is restricted to suppressed foliage, the inflorescence, smaller twigs that are shorter and more slender than the terminal twig.
Photopoint Surveys

Digital photographs were taken at all patches to enable visual quantitative and qualitative comparisons to be made of identical scenes over many time intervals. In 1984, 40 photopoints in total were recorded, with one photopoint associated with each site (located within the A, B, or C patches). In 2012, photopoint positions were installed in all patches at all sites, with a total of 55 photopoints. There was no consistent relationship between trap-line and photopoint position, though generally the photopoint was slightly offset from pitfalls 1 or 2 with a bearing slightly divergent from trap-line orientation (Pitfalls in each trap-line were generally named 1 to 6, starting nearest the access track).

Photopoint orientation was generally from north (camera) to the south (target) to avoid photographing into the sun. To increase the data captured, and therefore the power of the time-sequenced comparative base, three images were taken at each location: (1) the standard survey image with the target board at the centreline of the image, (2) to the left with the target board on the far right of the image, and (3) to the right with the target board in the far left of the image. The collection of three photos provides a panoramic view for comparison with good registration of the three adjacent images for digital analysis. Each photo angle was recorded as accurately as possible using a compass, and the camera lens was set to the focal length equivalent of 50 mm in 35 mm format.

Site photos were compared over time according to the growth or decline of species seen in the field of view. Key species or vegetation structural communities were ranked according to change in cover/abundance over time, and allocated a trend using the following categories:

1. **cover/abundance increase**: Density and cover have increased. Or
2. **cover/abundance increase**: Growth has occurred, density is approximately equal.
3. **cover/abundance unchanged**: same individual plants still present. Or
4. **cover/abundance unchanged**: species population turnover, density and cover same.
5. **cover/abundance decrease**: Density and cover have declined. Or
6. **cover/abundance decrease**: Defoliation occurred, density is approximately equal.

**U** unable to confidently define a specific trend
The Nullarbor photopoints were assessed according to the cover, density and recruitment of low shrubs, tall trees, and grasses/herbs that were visible. Extra assessments were recorded for *Maireana sedifolia* and *Acacia aneura* where they occurred in the field of view, because they are species of interest in the area, for example; trends observed in *A. aneura* could indicate the presence and impact of camels in the area.

Results from photopoint surveys between 1984 and 2002 are discussed in this report. Photopoint data collected in 2012 were not in scope for this project.

**Mammal and Reptile Surveys**

Methods for trap checking, handling and animal welfare broadly conformed to the “Guidelines for Vertebrate Surveys in SA” (Owens, 2000). Specific modifications are detailed below.

Each sample patch contained a permanent pitfall trap line and an Elliott trap line. Pitfall trap lines were 50 m long, with 6 traps along a drift fence in each. The pits measured 125 mm in diameter and 600 mm deep. Elliott traplines included 15 traps. The general layout included two rows of 7 Elliott traps positioned either side of the pitfall trap-line, with a distance of 20 m between pitfall and the trap. An additional Elliott trap was placed in line with the pitfall traps (Figure 12). Traps were open for 4 consecutive nights.

Cage and funnel traps were not used in the 1984 or 2012 survey.
The 2012 survey included a survey of scats, tracks, diggings and warrens of large mammals, in particular macropods, wombats, cats, camels, rabbits, foxes, and dingos. The perimeter of each vegetation quadrat (100 x 100 m) was surveyed using a frequency measure for each sign of each mammal. The perimeter was divided into sixteen 25 m sections and the presence or absence of a sign (track, scat, digging or warren) for each mammal was recorded. Each sign was then given a frequency, by dividing the number of occurrences of that sign by the total number of sections surveyed.

Some additional mammal and reptile searches were conducted throughout the survey periods, including spotlight searches. These searches were limited to sampling quadrats and all animals observed were recorded as opportunistic sightings.

No formal trapping or netting of bats was done in 1984 or 2012. Where traps, nets or Anabats were used, the data was recorded as opportunistic sightings.
Bird Surveys

In 1984 bird surveys occurred at each site, but the boundaries of the sampling area and time spent were not documented. In addition, while birds observed in different vegetation types were recorded against the corresponding patch, it is not clear whether each patch was sampled in a consistent manner. In 2012, birds were surveyed within a 20 ha quadrat associated with each vegetation patch. Each quadrat was searched for 40 minutes, on four occasions over 4 days (twice on different mornings and twice on different afternoons).

Taxonomy

Plants and animals, where possible, were classified to the lowest taxonomic denomination in this study. In some instances, this was not possible because of identification difficulties, e.g. grasses that were not in a reproductive cycle could not be conclusively identified. Where this occurred the lowest known classification was used. Some species surveyed in 1984 have since had changes to their taxonomic classification. Corrections were made where possible, but for some plants, it was not possible to rename them. These particular species are acknowledged as non-current with (NC) proceeding the name. Caution was used when comparing the cover or abundance of non-current species or those that are not identified to lowest taxonomic denomination. Differences in cover or abundance is likely to reflect naming and identification issues rather than on-ground differences between 1984 and 2012. From here on the label species will be used in place of taxa.
STATISTICAL ANALYSES

To eliminate biases that might have been introduced by the different methods in 1984 versus 2012 surveys, the cover of plants were standardised by site, and then by climate zone. This was done by calculating the proportion of cover of each species within each site (i.e. sum of site cover = 100). The cover was further standardised by calculating the proportion of cover of each species within the climate zone (i.e. the sum of cover in each climate zone = 100. The sum of each site is now less and depends on the number of sites within each climate zone). The abundance of birds and mammals were standardised by the same process, by site, and then by climate zone. The abundance of reptiles were standardised according just to site.

Standardising by site allows differences in relative cover or abundance to be analysed. The species richness of plants and animals could not be standardised between years as sample effort in 1984 was poorly defined and not repeated in 2012, where a more systematic approach was used (comparisons have been made nonetheless). Species richness is an important aspect of biodiversity and it is generally accepted that the higher the diversity, the more stable the ecosystem. The species richness of plants, birds, and small mammals were compared between 1984 and 2012, by grouping all the sites within each climate zone. One-way ANOVA were used to test whether the change in species richness was significant.

Multivariate analyses were performed using PRIMER (PRIMER version 5.1.2, PRIMER-E Ltd., Plymouth, UK) (Catalan et al., 2006). Analysis of similarity (ANOSIM) was used to define and test the difference in abundance and assemblages for birds, mammals, and reptiles in the following groups: between temperature and rainfall gradients, between and among vegetation structural communities and over time. Differences in the percent cover of vegetation were tested between temperature and rainfall gradients, between sites, and over time. ANOSIM is a non-parametric, hypothesis testing procedure, based on Bray–Curtis dissimilarities, which generates a test statistic (R), which is scaled between -1 and 1, and a probability value (p < 0.05 indicating significant differences) (Catalan et al., 2006). Significance is determined by randomly relocating samples within classes and calculating sample R values. The percent of times that R is greater than the sample R, indicates whether the samples are significantly different. Significant R-values are typically close to 1 and indicate greater variation in plant and animal species among zones than within zones.
Significant R-values that are negative occur when outliers are present or when there are high levels of within-group variability. R values that are close to 0 and non-significant, indicate that the null hypothesis cannot be rejected (Clarke & Warwick, 1994; Quinn & Keogh, 2002).

Hierarchical cluster analysis was performed to detect significantly different groups based on similarity of cover/abundance of vegetation, birds, mammals and reptiles within and between samples (Bulman et al., 2001; Jaworski & Ragnarsson, 2006). Using clusters obtained from hierarchical group-average clustering, groups of similar vegetation structural communities were identified and compared using SIMPROF analyses (Jaworski & Ragnarsson 2006).

Similarity Percentages (SIMPER, Plymouth Routines in Multivariate Ecological Research) were conducted after each ANOSIM and SIMPROF. SIMPER looks for similarities between samples and identifies the species that are contributing most to the average dissimilarity (Catalan et al., 2006).

To test the hypotheses that there would be; 1) an increase in species that characterized the HOT/DRY in the COLD/WET sites, and, 2) relatively fewer COLD/WET species in the COLD/WET sites, the abundance of particular species were compared across time. The abundance and distribution of species defined by SIMPER as characterising the COLD/WET climatic zone in 1984 were compared between 1984 and 2012 in the COLD/WET zone. Likewise, the abundance and distribution of species defined by SIMPROF as characterising the HOT/DRY climatic zone in 1984 were compared between 1984 and 2012 in the COLD/WET zone. These tests were repeated for each group: vegetation, birds, mammals, and reptiles.

Means are presented as ± standard deviation and all statistical tests are two-tailed, unless stated, with the α level of statistical significance set at 0.05.
RESULTS

VEGETATION

There were 223 species of plants recorded in autumn 2012, which included 7 weed species, and 212 species of plants in autumn 1984, including 17 weed species. A full list of plants are included in appendix B, table 29 and table 30. The species richness were compared within each climate zone, between 1984 and 2012 (Table 4) using a one-way ANOVA. The difference in the HOT/DRY zone approached significance ($p = 0.08, F = 3.545$) and there was no difference detected in species richness in the COLD/WET zones ($p = 0.67, F = 0.183$).

Table 4 Species richness at each site in 1984 and 2012, with HOT/DRY zone (left) separated from COLD/WET zone (right). (Only data from Autumn in 1984 and 2012 are included)

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<td>Standard Deviation</td>
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</table>
ANOSIM was used to examine differences between vegetation (based on percent cover contribution), which occurred in different climates: HOT/DRY versus COLD/WET. The vegetation differed significantly (In 2012 $R = 0.6$, $p < 0.001$, in 1984 $R = 0.644$, $p < 0.001$). Tables 5 and 6 indicate the plants that contributed the greatest difference between climate zones in 2012 and 1984. The species that represented the greatest differences in 1984 form the foundation of the next analyses to test for changes between time periods.
Table 5 The plant species that contributed the greatest difference between HOT/DRY and COLD/WET zones in 2012, based on percent cover contribution. The species are grouped according to whether they had a higher proportion of cover in the HOT/DRY zone (above the line) or COLD/WET zone (below the line).

<table>
<thead>
<tr>
<th>Species</th>
<th>Proportion of standardised cover in HOT/DRY zone</th>
<th>Proportion of standardised cover in COLD/WET zone</th>
<th>Contribution that each species made to the difference between climate zone (%)</th>
</tr>
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<td>0.01</td>
<td>3.48</td>
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<td>0.81</td>
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<td>Sida spodochroma</td>
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<tr>
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<td>0.04</td>
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</table>
Table 6 The plant species that contributed the greatest difference between HOT/DRY and COLD/WET zones in 1984, based on percent cover contribution. The species are grouped according to whether they had a higher proportion of Cover in the HOT/DRY zone (above the line) or COLD/WET zone (below the line).

<table>
<thead>
<tr>
<th>Species</th>
<th>Proportion of standardised cover in HOT/DRY zone</th>
<th>Proportion of standardised cover in COLD/WET zone</th>
<th>Contribution that each species made to the difference between climate zone (%)</th>
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<td>Maireana pentatropis</td>
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<td>0.05</td>
<td>0.56</td>
</tr>
</tbody>
</table>

^ It is important to note the taxonomic issues when comparing samples, such as “Austrostipa sp.”. These plants were only identified to genus and comparisons will indicate differences in naming or identification not true differences in cover between sites or time periods.
We expected to see an increase in the species that characterised the HOT/DRY zone in 1984, within the COLD/WET zone. We tested this prediction by comparing the cover of plant species (Table 6, above the line) between 1984 and 2012. The difference in species cover in the COLD/WET zone between 1984 and 2012 was significant (R = 0.337, p < 0.001). The species that were the main drivers of this change are shown in table 7. Note that some species have increased as predicted in the hypothesis, but others have decreased.

Table 7 The plant species that characterised the HOT/DRY zone in 1984 that contributed most to a change in cover in the COLD/WET zone between 1984 and 2012. The sum of proportion of cover is calculated across all sites within the HOT/DRY zone, e.g. all proportions of all plants in the HOT/DRY zone in 1984 equal 100. Order of species is based on how much they contributed to the difference between the time periods (Percent Contrib)

<table>
<thead>
<tr>
<th>Species that characterised the HOT/DRY zone in 1984</th>
<th>Proportion of standardised cover in 1984</th>
<th>Proportion of standardised cover in 2012</th>
<th>Contribution that each species made to the difference between 1984 and 2012 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maireana sedifolia</td>
<td>0.2</td>
<td>0.22</td>
<td>21.65</td>
</tr>
<tr>
<td>Austrostipa sp. ^</td>
<td>0.18</td>
<td>0</td>
<td>16.34</td>
</tr>
<tr>
<td>Austrodanthonia sp. ^</td>
<td>0</td>
<td>0.22</td>
<td>15.2</td>
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<td>Sclerolaena obliquicuspis</td>
<td>0.07</td>
<td>0.05</td>
<td>8.23</td>
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<td>Sclerolaena uniflora</td>
<td>0</td>
<td>0.05</td>
<td>6.94</td>
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<td>Sclerolaena diacantha</td>
<td>0.07</td>
<td>0.01</td>
<td>6.4</td>
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<td>Lycium australe</td>
<td>0.03</td>
<td>0.03</td>
<td>5.51</td>
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<td>Rhagodia spinescens</td>
<td>0.05</td>
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<td>4.99</td>
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<td>Enchylaena tomentosa var. tomentosa</td>
<td>0.04</td>
<td>0.02</td>
<td>4.29</td>
</tr>
<tr>
<td>Pittosporum angustifolium</td>
<td>0.02</td>
<td>0.01</td>
<td>3.83</td>
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</tbody>
</table>

Note: Variation in Austrostipa sp., Austrodanthonia sp., Sclerolaena uniflora, and Sclerolaena diacantha might reflect taxonomic naming issues rather than true differences in cover. Austrostipa sp., Austrodanthonia sp., can be difficult to tell apart if they do not have mature seed, and there is debate on the difference (if any) between Sclerolaena uniflora, and Sclerolaena diacantha

We expected to see a decrease in the species, which characterised the COLD/WET zone in 1984, in the COLD/WET zone in 2012. We tested this prediction by comparing the cover of plant species (Table 6, below the line) between 1984 and 2012. There was no significant difference in species cover in the COLD/WET zone between 1984 and 2012 (R = 0.002, p = 0.125).

Similarities in plant assemblages within each vegetation structural community were investigated using cluster analyses. Structural communities were divided by climate zones and analysed separately. In the HOT/DRY zone in the 2012 survey, there were six distinct groups of vegetation structural communities (Figure 13). The species that contributed the greatest difference between the groups are described in table 8.
**Figure 13** Bray-Curtis similarity dendrogram of the groups of plants in the HOT/DRY climatic zone in 2012. There are six significantly different groups based on the differences between the proportion of plants species and cover within each structural community. Each group is identified by a number (1-6) located underneath the structural community descriptions and by the black lines. On the y axis is the measure of similarity between sites ranging from 0 to 100. On the x axis are the vegetation structural communities that were compared.

**Table 8** The plant species that differentiated each group from all others in the HOT/DRY climatic zone in 2012, based on SIMPROF analyses of species and proportion of cover. The amount that each species contributed to the difference is also shown as SIMPER%.

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised cover per group</th>
<th>SIMPER %</th>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised cover per group</th>
<th>SIMPER %</th>
</tr>
</thead>
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<td>1</td>
<td><em>Acacia oswaldii</em></td>
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<td>3.8</td>
<td>4</td>
<td><em>Atriplex vesicaria</em></td>
<td>101.8</td>
<td>73.9</td>
</tr>
<tr>
<td>1</td>
<td><em>Atriplex acutibractea ssp. acutibractea</em></td>
<td>2.1</td>
<td>3.6</td>
<td>4</td>
<td><em>Austrodanthonia caespitosa</em></td>
<td>4.1</td>
<td>1.3</td>
</tr>
<tr>
<td>1</td>
<td><em>Austrodanthonia caespitosa</em></td>
<td>5.2</td>
<td>6.4</td>
<td>4</td>
<td><em>Austrostipa nitida</em></td>
<td>7.2</td>
<td>3.7</td>
</tr>
<tr>
<td>1</td>
<td><em>Austrostipa eremophila/puberula</em></td>
<td>31.3</td>
<td>66.6</td>
<td>4</td>
<td><em>Eriochiton sclerolaenoides</em></td>
<td>2.8</td>
<td>1.7</td>
</tr>
<tr>
<td>1</td>
<td><em>Enchylaena tomentosa var. tomentosa</em></td>
<td>2.1</td>
<td>2.7</td>
<td>4</td>
<td><em>Maireana sedifolia</em></td>
<td>14.5</td>
<td>11.1</td>
</tr>
<tr>
<td>1</td>
<td><em>Eremophila longifolia</em></td>
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<td><em>Maireana turbinata</em></td>
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<tr>
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<td><em>Eremophila maculata ssp. maculata</em></td>
<td>2.1</td>
<td>2.2</td>
<td>4</td>
<td><em>Sclerolaena obliquicuspis</em></td>
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<td>3.2</td>
</tr>
<tr>
<td>1</td>
<td><em>Euphorbia drummondii</em></td>
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<td>2.1</td>
<td>4</td>
<td><em>Sclerolaena patenticuspis</em></td>
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<td>1.3</td>
</tr>
<tr>
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<td><em>Lycium austrole</em></td>
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</tr>
<tr>
<td>1</td>
<td><em>Pittosporum angustifolium</em></td>
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<td>1.4</td>
<td>5</td>
<td><em>Dicrastylis beveridgei var. lanata</em></td>
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<td>33.0</td>
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<td>1</td>
<td><em>Rhogodia spinescens</em></td>
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<td>2.2</td>
<td>5</td>
<td><em>Dodonaea viscosa ssp. angustissima</em></td>
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<tr>
<td></td>
<td>total</td>
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<td>5</td>
<td><em>Eremophila willsi ssp. willsi</em></td>
<td>8.8</td>
<td>33.0</td>
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</table>

*Table 8 continues on the next page*
Table 8 continued

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised cover per group</th>
<th>SIMPER %</th>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised cover per group</th>
<th>SIMPER %</th>
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<td>6.6</td>
<td>6</td>
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<td>Aristida holathera var. holothera</td>
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<td>100.0</td>
<td></td>
<td>total</td>
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<td>6</td>
<td>Chenopodium gaudichaudianum</td>
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<td>3.1</td>
<td>6</td>
<td>Dodonaea viscosa ssp. angustissima</td>
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<td>Eriochiton sclerolaenoides</td>
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<td>0.2</td>
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<td>2.0</td>
<td>6</td>
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<td>17.3</td>
<td>9.9</td>
<td>6</td>
<td>Ptilotus obovatus</td>
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<td>3.1</td>
</tr>
<tr>
<td>3</td>
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<td>6.7</td>
<td>6</td>
<td>Sclerolaena diacantha</td>
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<td>Ptilotus obovatus</td>
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<td>1.3</td>
<td>6</td>
<td>Sclerolaena patenticuspis</td>
<td>7.9</td>
<td>4.8</td>
</tr>
<tr>
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<td>Rhagodia spinescens</td>
<td>6.0</td>
<td>3.7</td>
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<td>100.0</td>
<td></td>
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<td>100.0</td>
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</table>

Similarities in plant assemblages within each vegetation structural community indicated that in the COLD/WET zone in the 2012 survey, there were nine distinct groups of vegetation structural communities (Figure 14). The species that contributed the greatest difference between the groups are described in table 9.
**Figure 14** Bray-Curtis similarity dendrogram of plants groups in the COLD/WET climatic zone in 2012. There are nine significantly different groups based on the differences between the proportion of plant species and cover within each structural community, identified with a number below each group.

**Table 9** The plant species that differentiated each group from all others in the COLD/WET climatic zone in 2012, based on SIMPROF analyses of species and proportion of cover. The amount that each species contributed to the difference is also shown as SIMPER%.

<table>
<thead>
<tr>
<th>Group</th>
<th>Plant Species</th>
<th>Sum of standardised cover per group</th>
<th>SIMPER</th>
<th>Group</th>
<th>Plant Species</th>
<th>Sum of standardised cover per group</th>
<th>SIMPER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Atriplex acutibractea ssp. acutibractea</td>
<td>1.4</td>
<td>1.0</td>
<td>5</td>
<td>Maireana erioclada/pentatropis</td>
<td>6.6</td>
<td>0.5</td>
</tr>
<tr>
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<td>Atriplex acutibractea ssp. karaniensis</td>
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<td>0.4</td>
<td>5</td>
<td>Maireana sedifolia</td>
<td>62.9</td>
<td>9.1</td>
</tr>
<tr>
<td>1</td>
<td>Atriplex vesicaria</td>
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<td>0.2</td>
<td>5</td>
<td>Nitraria billardierei</td>
<td>18.2</td>
<td>2.6</td>
</tr>
<tr>
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<td>Sclerolaena brevifolia</td>
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<td>0.2</td>
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<tr>
<td>1</td>
<td>Austrostipa eremaphila/puberula</td>
<td>11.9</td>
<td>15.0</td>
<td>5</td>
<td>Sclerolaena obliquicus</td>
<td>12.0</td>
<td>1.7</td>
</tr>
<tr>
<td>1</td>
<td>Austrostipa nitida</td>
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<td>13.7</td>
<td>5</td>
<td>Sclerolaena patenticuspis</td>
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<td>7.6</td>
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<td>Lomandra effusa</td>
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<td>12.4</td>
<td>5</td>
<td>Sclerolaena uniflora</td>
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<td>0.4</td>
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<tr>
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<td>Maireana sedifolia</td>
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<td>Tecticornia disarticulata</td>
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<td>total</td>
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<tr>
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<td>Eremophila weldii</td>
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<td>12.9</td>
<td>6</td>
<td>Atriplex vesicaria</td>
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<td>Eucalyptus calcareaana</td>
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<td>13.1</td>
<td>6</td>
<td>Austrodanthonia sp.</td>
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</tr>
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<td>15.3</td>
<td>6</td>
<td>Geijera linearifolia</td>
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<td>7.4</td>
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<tr>
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<td>7.1</td>
<td>6</td>
<td>Lawrencea squamata</td>
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<td>11.3</td>
</tr>
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<td>Melaleuca quadrifaria</td>
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<td>26.9</td>
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<td>Lycium austral</td>
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<tr>
<td>2</td>
<td>Rhagodia crassifolia</td>
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<td>6</td>
<td>Maireana sedifolia</td>
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<td>6</td>
<td>Sclerolaena obliquicus</td>
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<td>13.5</td>
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<tr>
<td>2</td>
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<td>total</td>
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</table>

**Note:** The total for the sum of standardised cover per group is 632.4% and the total for the SIMPER% is 100.0%.
<table>
<thead>
<tr>
<th>Group</th>
<th>Plant Species</th>
<th>Sum of std cover in each group</th>
<th>SIMPER</th>
<th>Group</th>
<th>Plant Species</th>
<th>Sum of std cover in each group</th>
<th>SIMPER</th>
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<td>7</td>
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<td>7</td>
<td>Atriplex vescaria</td>
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<td>7</td>
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<td>Austrostipa nitida</td>
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<td>1.0</td>
<td>7</td>
<td>Enchyela tomentosa var. tomentosa</td>
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<td>Euphorbia tannensis ssp. eremophila</td>
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PHOTOPOINT RESULTS

Between 1985 and 2001 there were 40 sites that were surveyed using repeat photography survey methods, some of these surveys did not cover the whole period. Trends were assigned to each photopoint according to the cover, density and recruitment of plant species that were visible in the field of view. These included low shrubs, tall shrubs and trees, grasses and herbs, *Maireana sedifolia* and *Acacia aneura*.

The results of these photopoint surveys are summarised in table 10, they show a stable trend across the landscape. An explanation of the trends at each site can be found in appendix C.

| Table 10 Results of the photopoint survey. Photopoints are assessed depending on the plants that are visible, and the trend in cover, density and recruitment of these plants over time. Photopoints = pp |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| No. of pp in which these plants could be assessed | Average assessment result | No. of pp that had a decreasing trend (score of 1) | No. of pp that were stable (score of 2) | No. of pp that had an increasing trend (score of 3) |
| Overall trend of low shrub | 35 | 2.1 | 3 | 27 | 5 |
| Overall trend of tall shrubs and trees | 24 | 1.9 | 4 | 18 | 2 |
| Overall trend of grasses and herbs | 1 | 2 | 0 | 1 | 0 |
| Trend of *Maireana sedifolia* | 4 | 2 | 0 | 4 | 0 |
| Trend of Mulga trend | 1 | 1 | 1 | 0 | 0 |
BIRD SURVEY RESULTS

A total of 98 species of birds were recorded in autumn of 1984 and 2012. There were 8976 individuals observed in the 2012 survey and 3847 individuals observed in the 1984 survey. A full list of birds recorded in 2012 and 1984, including opportunistic records, are attached as appendix B, table 31 and 32. The species richness data recorded at each site in 1984 and 2012 (Table 11) were compared using a paired t-test, within the COLD/WET and HOT/DRY zones. Between 1984 and 2012 there was no difference detected in the HOT/DRY zone ($P = 0.23, F = 1.579$), but there was a significant difference in the COLD/WET zone ($P < 0.001, t = 12.727$).

Table 11 Species Richness at each site in 1984 and 2012, with HOT/DRY zone (left) separated from COLD/WET zone (right). (Only data from Autumn in 1984 and 2012 are included)

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ANOSIM was used to examine differences between bird assemblages (based on percent abundance contribution), which occurred in different climates: HOT/DRY versus COLD/WET. The bird assemblages were significantly different (1984: $R = 0.116$, $p = 0.044$. 2012: $R = 0.295$, $p = 0.002$). Tables 12 and 13 indicate the list of species that contributed the greatest difference between gradients in 2012 and 1984. The species that represent the greatest differences in 1984 form the foundation of the next analyses to test for changes in climate zones between time periods.

**Table 12** The bird species that contributed the greatest difference between HOT/DRY and COLD/WET zones in 2012 based on percent cover contribution. The species are grouped according to whether they had a higher proportion of abundance in the HOT/DRY zone (above the line) or COLD/WET zone (below the line).

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<tr>
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<td>0.65</td>
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<td>5.37</td>
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<tr>
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<td>4.76</td>
</tr>
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<td><em>Gavicalis virescens</em></td>
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<td>0.19</td>
<td>3.05</td>
</tr>
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<td><em>Cinclosoma cinnamomeum alisteri</em></td>
<td>0.24</td>
<td>0.11</td>
<td>2.53</td>
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<tr>
<td><em>Malurus splendens</em></td>
<td>0.28</td>
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<td>2.35</td>
</tr>
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<td>0.25</td>
<td>0.04</td>
<td>2.23</td>
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<td>0.16</td>
<td>0.05</td>
<td>1.58</td>
</tr>
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<td><em>Malurus lamberti</em></td>
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<td>0.01</td>
<td>1.55</td>
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<td><em>Rhipidura leucophrys</em></td>
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<td>0.04</td>
<td>1.33</td>
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<tr>
<td><em>Cinclosoma castanotum</em></td>
<td>0.14</td>
<td>0</td>
<td>1.18</td>
</tr>
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<td><em>Acanthiza chrysoorrhia</em></td>
<td>0.06</td>
<td>0.1</td>
<td>1.15</td>
</tr>
<tr>
<td><em>Melanodryas vittata</em></td>
<td>0.13</td>
<td>0</td>
<td>1.11</td>
</tr>
<tr>
<td><em>Falco berigora</em></td>
<td>0.14</td>
<td>0.03</td>
<td>1.09</td>
</tr>
<tr>
<td><em>Cracticus torquatus</em></td>
<td>0.1</td>
<td>0.04</td>
<td>1.02</td>
</tr>
<tr>
<td><em>Manorina flavigula</em></td>
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<td>3.51</td>
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<td><em>Acanthiza iredalei</em></td>
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<td>0.16</td>
<td>1.32</td>
</tr>
<tr>
<td><em>Acanthagenys rufogularis</em></td>
<td>0</td>
<td>0.13</td>
<td>1.12</td>
</tr>
<tr>
<td><em>Acanthiza apicalis</em></td>
<td>0.06</td>
<td>0.07</td>
<td>0.97</td>
</tr>
<tr>
<td><em>Sericornis frontalis</em></td>
<td>0</td>
<td>0.1</td>
<td>0.82</td>
</tr>
<tr>
<td><em>Hirundo neoxena</em></td>
<td>0</td>
<td>0.1</td>
<td>0.82</td>
</tr>
</tbody>
</table>
We expected to see an increase in the species that characterised the HOT/DRY zone in 1984, in the COLD/WET zone in 2012. We tested this prediction by comparing the abundance of bird species (Table 13, above the line) between 1984 and 2012. There was a significant change is species abundance between 1984 and 2012 in the COLD/WET zone ($R = 0.135$, $p < 0.001$). The species that were the main drivers of this difference are shown in table 13.

We expected to see a decrease in the species that characterised the COLD/WET zone in 1984, in the COLD/WET zone in 2012. We tested this prediction by comparing the abundance of bird species (Table 13, below the line) between 1984 and 2012. The overall difference in the COLD/WET zone between 1984 and 2012 was not significant ($R = 0.021$, $p = 0.144$).
Table 14 The bird species that characterised the HOT/DRY zone in 1984. The order of species is based on how much they contributed to the difference over time

<table>
<thead>
<tr>
<th>Species</th>
<th>Proportion of standardised abundance in 1984</th>
<th>Proportion of standardised abundance in 2012</th>
<th>Contribution that each species made to the difference between 1984 and 2012 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthus australis</td>
<td>0.59</td>
<td>0.18</td>
<td>22</td>
</tr>
<tr>
<td>Pomatostomus superciliosus</td>
<td>0.21</td>
<td>0.14</td>
<td>11.68</td>
</tr>
<tr>
<td>Malurus leucopterus</td>
<td>0.07</td>
<td>0.28</td>
<td>11.45</td>
</tr>
<tr>
<td>Gavicalis virescens</td>
<td>0.09</td>
<td>0.19</td>
<td>10.23</td>
</tr>
<tr>
<td>Psephotus varius</td>
<td>0.14</td>
<td>0.04</td>
<td>6.81</td>
</tr>
<tr>
<td>Artamus cinereus</td>
<td>0.12</td>
<td>0.07</td>
<td>5.96</td>
</tr>
<tr>
<td>Aphelocephala leucopsis</td>
<td>0.09</td>
<td>0.09</td>
<td>5.81</td>
</tr>
<tr>
<td>Cinclosoma cinnamomeum alisteri</td>
<td>0.01</td>
<td>0.11</td>
<td>4.35</td>
</tr>
<tr>
<td>Falco berigora</td>
<td>0.05</td>
<td>0.03</td>
<td>3.66</td>
</tr>
<tr>
<td>Corvus sp.</td>
<td>0.07</td>
<td>0</td>
<td>3.17</td>
</tr>
<tr>
<td>Colluricinclia harmonica</td>
<td>0.05</td>
<td>0.03</td>
<td>3.15</td>
</tr>
<tr>
<td>Melanodryas cucullata</td>
<td>0.03</td>
<td>0.04</td>
<td>2.58</td>
</tr>
</tbody>
</table>

Bird association with vegetation structural communities

Similarities in bird assemblages within each vegetation structural community were investigated using cluster analyses. Structural communities were divided into climate zones and analysed separately. There were 4 distinct groups of vegetation structural communities in the HOT/DRY zone in the 2012 survey (Figure 15). The species that contributed the greatest difference between the groups are described in table 15.
**Figure 15** Bray-Curtis similarity dendrogram of bird groups in the HOT/DRY climatic zone in 2012. There are four significantly different groups of vegetation structural communities based on the differences between the bird species and abundances recorded within each community. The groups are identified by a number (1-4) and by the black lines. On the y axis is the measure of similarity between sites ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.

**Table 15** The bird species that differentiated each group from all others in the HOT/DRY climatic zone in 2012, based on SIMPROF analyses of species and proportion of abundance. The proportion that each species contributed to the difference is also shown (SIMPER%).
<table>
<thead>
<tr>
<th>Group</th>
<th>Species 1</th>
<th>Species 2</th>
<th>Species 3</th>
<th>Species 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td><em>Malurus lamberti</em></td>
<td>Malurus splendens</td>
<td>Manorina flavigula</td>
<td>Melanodryas cuculata</td>
</tr>
<tr>
<td></td>
<td>1.12 3.73</td>
<td>1.37 4.54</td>
<td>1.09 3.60</td>
<td>1.69 6.43</td>
</tr>
<tr>
<td>2</td>
<td><em>Artamus cinereus</em></td>
<td><em>Calamantus campestris</em></td>
<td><em>Cinclosoma cinnamomeum alisteri</em></td>
<td><em>Cinclosoma cinnamomeum alisteri</em></td>
</tr>
<tr>
<td></td>
<td>0.85 9.64</td>
<td>1.13 11.99</td>
<td>0.70 7.66</td>
<td>0.70 7.66</td>
</tr>
<tr>
<td>2</td>
<td><em>Anthus australis</em></td>
<td><em>Artamus cinereus</em></td>
<td><em>Manorina flavigula</em></td>
<td><em>Manorina flavigula</em></td>
</tr>
<tr>
<td></td>
<td>1.38 18.58</td>
<td>0.85 9.64</td>
<td>1.09 3.60</td>
<td>1.09 3.60</td>
</tr>
<tr>
<td>2</td>
<td><em>Microeca fascinans</em></td>
<td><em>Artamus cinereus</em></td>
<td><em>Manorina flavigula</em></td>
<td><em>Manorina flavigula</em></td>
</tr>
<tr>
<td></td>
<td>0.55 2.33</td>
<td>1.09 3.60</td>
<td>1.09 3.60</td>
<td>1.09 3.60</td>
</tr>
<tr>
<td>2</td>
<td><em>Pomatostomus superciliosus</em></td>
<td><em>Melanodryas cuculata</em></td>
<td><em>Manorina flavigula</em></td>
<td><em>Manorina flavigula</em></td>
</tr>
<tr>
<td></td>
<td>5.96 22.35</td>
<td>1.69 6.43</td>
<td>1.09 3.60</td>
<td>1.09 3.60</td>
</tr>
<tr>
<td>2</td>
<td><em>Gavicalis virescens</em></td>
<td><em>Malurus leucopterus</em></td>
<td><em>Melanodryas cuculata</em></td>
<td><em>Cinclosoma cinnamomeum alisteri</em></td>
</tr>
<tr>
<td></td>
<td>0.37 3.27</td>
<td>3.72 35.09</td>
<td>1.69 6.43</td>
<td>0.70 7.66</td>
</tr>
<tr>
<td>2</td>
<td><em>Psephotus varius</em></td>
<td><em>Psephotus varius</em></td>
<td><em>Psephotus varius</em></td>
<td><em>Psephotus varius</em></td>
</tr>
<tr>
<td></td>
<td>1.45 5.98</td>
<td>1.45 5.98</td>
<td>0.80 5.95</td>
<td>0.80 5.95</td>
</tr>
</tbody>
</table>

Group 2 total 26.99 100 Group 4 total 9.62 100

Similarities in bird assemblages within each vegetation structural community indicated that in the COLD/WET zone in the 2012 survey, there were nine distinct groups of vegetation structural communities (Figure 16). The species that contributed the greatest difference between the groups are described in table 16.

Figure 16 Bray-Curtis similarity dendrogram of bird groups in the COLD/WET climatic zone in 2012. There are nine significantly different groups of vegetation structural communities based on the differences between the bird species and abundances recorded within each community. The groups are identified by a number (1-9) and by the black lines. On the y axis is the measure of similarity between sites ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.
Table 16 The bird species that differentiated each group from all others in the COLD/WET climatic zone in 2012, based on SIMPROF analyses of species and proportion of abundance. The proportion that each species contributed to the difference is also shown (SIMPER%).

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anthus australis</td>
<td>0.40</td>
<td>28.24</td>
<td>4</td>
<td>Artamus cinereus</td>
<td>0.16</td>
<td>26.00</td>
</tr>
<tr>
<td>1</td>
<td>Calamantus campestris</td>
<td>0.17</td>
<td>9.78</td>
<td>4</td>
<td>Daphoenositta chrysoperta</td>
<td>0.08</td>
<td>11.93</td>
</tr>
<tr>
<td>1</td>
<td>Falco berigora</td>
<td>0.07</td>
<td>2.93</td>
<td>4</td>
<td>Gavicalis virescens</td>
<td>0.06</td>
<td>4.28</td>
</tr>
<tr>
<td>1</td>
<td>Gavicalis virescens</td>
<td>0.27</td>
<td>16.89</td>
<td>4</td>
<td>Malurus leucotterus</td>
<td>0.22</td>
<td>23.56</td>
</tr>
<tr>
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<td>Gymnorhina tibicen</td>
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<td>26.48</td>
<td>4</td>
<td>Manorina flavigula</td>
<td>0.04</td>
<td>1.51</td>
</tr>
<tr>
<td>1</td>
<td>Hirundo neoxena</td>
<td>0.07</td>
<td>1.08</td>
<td>4</td>
<td>Melanodyras cucullata</td>
<td>0.12</td>
<td>23.28</td>
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<tr>
<td>1</td>
<td>Sericornis frontalis</td>
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<td>4.92</td>
<td>4</td>
<td>Psephotus varius</td>
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<td>9.44</td>
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<td>9.68</td>
<td>Group 4 total</td>
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<td></td>
</tr>
<tr>
<td>Group 1 total</td>
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<td>1.30</td>
<td>28.58</td>
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</tr>
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<td>2</td>
<td>Acanthagenys rufogularis</td>
<td>0.19</td>
<td>16.16</td>
<td>5</td>
<td>Calamantus campestris</td>
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<tr>
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<td>Acanthiza apicalis</td>
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<td>2.26</td>
<td>5</td>
<td>Cinclusoma cinnamomeum alisteri</td>
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<td>Corvus coronoides</td>
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<td>5</td>
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<tr>
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<td>Zosterops lateralis</td>
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<td>Acanthiza chrysothra</td>
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<tr>
<td>3</td>
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<td>3.00</td>
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<td>1.60</td>
</tr>
<tr>
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</tr>
<tr>
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<td>Colluricinclia harmonica</td>
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<td>0.89</td>
<td>8</td>
<td>Hirundo neoxena</td>
<td>0.33</td>
<td>5.72</td>
</tr>
<tr>
<td>3</td>
<td>Cracticus torquatus</td>
<td>0.11</td>
<td>1.38</td>
<td>8</td>
<td>Malurus lamberti</td>
<td>0.14</td>
<td>2.97</td>
</tr>
<tr>
<td>3</td>
<td>Daphoenositta chrysoptera</td>
<td>0.16</td>
<td>3.05</td>
<td>8</td>
<td>Malurus leucotterus</td>
<td>0.88</td>
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</tr>
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</tr>
<tr>
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<td>0.08</td>
<td>1.34</td>
<td>8</td>
<td>Petrochelidon nigricans</td>
<td>0.22</td>
<td>4.08</td>
</tr>
<tr>
<td>3</td>
<td>Malurus leucotterus</td>
<td>0.05</td>
<td>0.51</td>
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</tr>
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<td>Malurus pulcherrimus</td>
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<td>0.29</td>
<td>6.12</td>
</tr>
<tr>
<td>3</td>
<td>Malurus sp.</td>
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<td>24.86</td>
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<td>Acanthagenys rufogularis</td>
<td>0.38</td>
<td>2.96</td>
</tr>
<tr>
<td>3</td>
<td>Melanodyras cucullata</td>
<td>0.11</td>
<td>2.27</td>
<td>9</td>
<td>Acanthiza chrysothra</td>
<td>0.89</td>
<td>5.64</td>
</tr>
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<td>3</td>
<td>Petrochelidon nigricans</td>
<td>0.15</td>
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<td>Acanthiza chrysothra</td>
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<td>Anthochaera chrysoptera</td>
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<td>0.12</td>
</tr>
<tr>
<td>3</td>
<td>Psephotus varius</td>
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<td>2.43</td>
<td>9</td>
<td>Anthus australis</td>
<td>1.77</td>
<td>10.07</td>
</tr>
<tr>
<td>3</td>
<td>Ptilotula ornata</td>
<td>0.29</td>
<td>5.95</td>
<td>9</td>
<td>Aphelocephala leucopsis</td>
<td>0.70</td>
<td>5.10</td>
</tr>
<tr>
<td>3</td>
<td>Purnella albifrons</td>
<td>0.21</td>
<td>3.70</td>
<td>9</td>
<td>Artamus cinereus</td>
<td>0.45</td>
<td>2.75</td>
</tr>
<tr>
<td>3</td>
<td>Sericornis frontalis</td>
<td>0.25</td>
<td>4.18</td>
<td>9</td>
<td>Calamantus campestris</td>
<td>2.19</td>
<td>14.15</td>
</tr>
<tr>
<td>3</td>
<td>Smicrornis brevirostris</td>
<td>0.15</td>
<td>2.14</td>
<td>9</td>
<td>Cinclusoma cinnamomeum alisteri</td>
<td>1.03</td>
<td>7.33</td>
</tr>
<tr>
<td>3</td>
<td>Zosterops lateralis</td>
<td>0.07</td>
<td>0.93</td>
<td>9</td>
<td>Corvus coronoides</td>
<td>0.32</td>
<td>1.77</td>
</tr>
<tr>
<td>Group 3 total</td>
<td>5.63</td>
<td>100</td>
<td>9</td>
<td>Falco berigora</td>
<td>0.22</td>
<td>1.82</td>
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</tr>
</tbody>
</table>

Table 16 continues on next page
### Table 16 continued

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td><em>Acanthiza iredalei</em></td>
<td>0.32</td>
<td>19.10</td>
<td>9</td>
<td><em>Gavicalis virescens</em></td>
<td>0.79</td>
<td>4.95</td>
</tr>
<tr>
<td>6</td>
<td><em>Calamanthus campestris</em></td>
<td>0.43</td>
<td>25.16</td>
<td>9</td>
<td><em>Gymnorhina tibicen</em></td>
<td>0.14</td>
<td>0.24</td>
</tr>
<tr>
<td>6</td>
<td><em>Cinclosoma cinnamomeum alisteri</em></td>
<td>0.24</td>
<td>16.09</td>
<td>9</td>
<td><em>Hirundo neoxena</em></td>
<td>1.10</td>
<td>6.29</td>
</tr>
<tr>
<td>6</td>
<td><em>Malurus leucopterus</em></td>
<td>0.61</td>
<td>38.05</td>
<td>9</td>
<td><em>Malurus leucopterus</em></td>
<td>2.83</td>
<td>19.53</td>
</tr>
<tr>
<td>6</td>
<td><em>Petrochelidon nigricans</em></td>
<td>0.05</td>
<td>1.60</td>
<td>9</td>
<td><em>Manorina flavigula</em></td>
<td>0.26</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>Group 6 total</td>
<td>1.65</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><em>Acanthiza iredalei</em></td>
<td>1.00</td>
<td>41.77</td>
<td>9</td>
<td><em>Pomatostomus superciliosus</em></td>
<td>0.15</td>
<td>0.66</td>
</tr>
<tr>
<td>7</td>
<td><em>Anthus australis</em></td>
<td>0.29</td>
<td>14.78</td>
<td>9</td>
<td><em>Rhipidura leucophrys</em></td>
<td>0.31</td>
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</tr>
<tr>
<td>7</td>
<td><em>Aphelocephala leucopsis</em></td>
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<td>32.67</td>
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<td>Group 9 total</td>
<td>15.74</td>
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<tr>
<td>7</td>
<td><em>Artamus cinereus</em></td>
<td>0.43</td>
<td>35.97</td>
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<td></td>
</tr>
<tr>
<td>7</td>
<td><em>Calamanthus campestris</em></td>
<td>0.08</td>
<td>3.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><em>Corvus coronoides</em></td>
<td>0.08</td>
<td>2.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><em>Malurus leucopterus</em></td>
<td>0.20</td>
<td>5.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><em>Psephotus varius</em></td>
<td>0.10</td>
<td>3.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><em>Rhipidura leucophrys</em></td>
<td>0.08</td>
<td>2.13</td>
<td></td>
<td></td>
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<td></td>
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<td>Group 7 total</td>
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</table>
MAMMAL SURVEY RESULTS

A total of 9 mammal species were recorded in the autumn surveys of 1984 and 2012. With 1328 individuals captured in the 2012 and 161 individuals captured in 1984. A full list of mammals observed, including opportunistic records, is in appendix B, table 33 and 34. The species richness data recorded at each site in 1984 and 2012 were compared using a paired t-test, with HOT/DRY and COLD/WET data separated (Table 17). The difference between 1984 and 2012 was significant in both the HOT/DRY and COLD/WET zones (HOT/DRY: \( P = 0.02, F = 7.2 \). COLD/WET \( P = 0.01, F = 8.2 \)).

Table 17 Species Richness at each site in 1984 and 2012, with HOT/DRY zone (left) separated from COLD/WET zone (right). (Only data from Autumn in 1984 and 2012 is included)

<table>
<thead>
<tr>
<th>SITE ID</th>
<th>1984</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>MU001</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>MU002</td>
<td>1</td>
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</tr>
<tr>
<td>MU003</td>
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<td>4</td>
</tr>
<tr>
<td>MU004</td>
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<td>3</td>
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<tr>
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<td>2</td>
<td>4</td>
</tr>
<tr>
<td>HU001</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>HU002</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>HU003</td>
<td>2</td>
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</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td>HU005</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SITE ID</th>
<th>1984</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF001</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>IF002</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>IF003</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>IF004</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>IF005</td>
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</tr>
<tr>
<td>KD001</td>
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<td>1</td>
</tr>
<tr>
<td>KD002</td>
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<td>KD003</td>
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<td>ME003</td>
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<tr>
<td>CA002</td>
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<td>1</td>
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<tr>
<td>CA003</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CA004</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>CA005</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>YA001</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>YA002</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>YA003</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>YA004</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>YA005</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

| Mean    | 1.2  | 1.7  |
| Standard Deviation | 0.133 | 0.427 |
ANOSIM was used to examine differences between mammal assemblages (based on percent abundance contribution), which occurred in different climates: HOT/DRY versus COLD/WET. The mammal assemblages were significantly different (2012: $R = 0.833$, $p < 0.001$, 1984: $R = 0.210$, $p = 0.033$). Tables 18 and 19 indicate the mammal species that contributed the greatest difference between gradients in 2012 and 1984. The species that represent the greatest differences in 1984 are essential to the next analyses, to test for changes in climate zones between time periods.

**Table 18** The mammal species that contributed the greatest difference between HOT/DRY and COLD/WET zones in 2012 based on percent cover contribution. Note that all species had a higher proportion of relative abundance in the HOT/DRY zone.

<table>
<thead>
<tr>
<th>Species</th>
<th>Proportion of standardised abundance in HOT/DRY (%)</th>
<th>Proportion of standardised abundance in COLD/WET (%)</th>
<th>Contribution that each species made to the difference between climate zones in 2012 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mus musculus</em></td>
<td>7.7</td>
<td>2.96</td>
<td>65.76</td>
</tr>
<tr>
<td><em>Notomys alexis</em></td>
<td>1.15</td>
<td>0</td>
<td>15.04</td>
</tr>
<tr>
<td><em>Pseudomys hermannsburgensis</em></td>
<td>0.76</td>
<td>0.04</td>
<td>9.94</td>
</tr>
</tbody>
</table>

**Table 19** The mammal species that contributed the greatest difference between HOT/DRY and COLD/WET zones in 1984 based on percent cover contribution. The species are grouped according to whether they had a higher proportion of abundance in the HOT/DRY zone (above the line) or COLD/WET zone (below the line).

<table>
<thead>
<tr>
<th>Species</th>
<th>Proportion of standardised abundance in HOT/DRY (%)</th>
<th>Proportion of standardised abundance in COLD/WET (%)</th>
<th>Contribution that each species made to the difference between climate zones in 1984 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mus musculus</em></td>
<td>9.43</td>
<td>2.63</td>
<td>80.88</td>
</tr>
<tr>
<td><em>Sminthopsis crassicaudata</em></td>
<td>0.5</td>
<td>0.14</td>
<td>7.32</td>
</tr>
<tr>
<td><em>Notomys mitchellii</em></td>
<td>0</td>
<td>0.48</td>
<td>5.71</td>
</tr>
</tbody>
</table>

We expected to see an increase in the mammal species that characterised the HOT/DRY zone in 1984, in the COLD/WET zone in 2012. We tested this prediction by comparing the abundance of mammal species (Table 19, above the line) between 1984 and 2012. There was a significant change is species abundance between 1984 and 2012 in the COLD/WET zone ($R = 0.245$, $p < 0.001$). *Mus musculus* was the main driver of this change, contributing 92.8% of the difference between 1984 and 2012.

We expected to see a decrease in the species that characterised the COLD/WET zone in 1984, in the COLD/WET zone in 2012. We tested this prediction by comparing the
abundance of mammal species (Table 19, below the line) between 1984 and 2012. The difference in the COLD/WET zone between 1984 and 2012 was not significant (R = -0.011, p = 0.464).

**Mammal associations with vegetation structural communities**

The similarities in mammal assemblages within each vegetation structural community indicated that there were two distinct groups of vegetation structural communities detected in the HOT/DRY zone in the 2012 survey (Figure 17). The species that contributed the greatest difference between the groups are described in table 20.

![Figure 17](image_url) Bray-Curtis similarity dendrogram of mammal groups in the HOT/DRY climatic zone in 2012. There were two significantly different groups of vegetation structural communities based on the differences in the mammals recorded in each community. Groups are identified by a number (1-2) located underneath the structural community descriptions and by the black lines. On the y axis is the measure of similarity between sites ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.

**Table 20** The mammal species that differentiated each group from all others in the HOT/DRY climatic zone in 2012, based on SIMPROF analyses of species and proportion of abundance. The proportion that each species contributed to the difference is also shown (SIMPER%).

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mus musculus</td>
<td>12.39</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Notomys alexis</td>
<td>2.29</td>
<td>100</td>
</tr>
</tbody>
</table>
Similarities in mammal assemblages within each vegetation structural community were investigated using cluster analyses. Structural communities were divided into climate zones and analysed separately. There were two distinct groups of vegetation structural communities detected in the COLD/WET zone in the 2012 survey (Figure 18). The species that contributed the greatest difference between groups are described in Table 21.

**Figure 18** Bray-Curtis similarity dendrogram of mammal groups in the COLD/WET climatic zone in 2012. There were two significantly different groups of vegetation structural communities based on the differences in the mammals recorded in each community. Groups are identified by a number (1-2) located underneath the structural community descriptions and by the black lines. On the y axis is the measure of similarity between sites ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.

**Table 21** The mammal species that differentiated each group from all others in the COLD/WET climatic zone in 2012, based on SIMPROF analyses of species and proportion of abundance. The proportion that each species contributed to the difference is also shown (SIMPER%).

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Mus musculus</em></td>
<td>6.33</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td><em>Cercartetus concinnus</em></td>
<td>1.67</td>
<td>100</td>
</tr>
</tbody>
</table>
Presence of large mammals in 2012, estimated using frequency counts of scats.

The relative impacts of large herbivores were measured using counts of scats in the HOT/DRY and COLD/WET climate zones in 2012. No difference was detected in the frequency of scats between vegetation structural communities in the HOT/DRY zone (Figure 19). The species that contributed the greatest similarity within the group are rabbits and cats (Table 22).

![Bray-Curtis similarity dendrogram of large mammal groups in the HOT/DRY climatic zone in 2012. The structural communities are not significantly different, based on the difference in the frequency of scats in each community, and form 1 group. On the y axis is the measure of similarity between the frequency of scats ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.](image)

**Figure 19** Bray-Curtis similarity dendrogram of large mammal groups in the HOT/DRY climatic zone in 2012. The structural communities are not significantly different, based on the difference in the frequency of scats in each community, and form 1 group. On the y axis is the measure of similarity between the frequency of scats ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.

**Table 22** The large mammal species that contributed the greatest similarity within each group. The proportion that each species contributed to the similarity is also shown (SIMPER%).

<table>
<thead>
<tr>
<th>Group</th>
<th>Herbivore species</th>
<th>Frequency of quadrats with scats present</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>rabbit scats</td>
<td>12.4</td>
<td>83.7</td>
</tr>
<tr>
<td>1</td>
<td>cat scats</td>
<td>5.6</td>
<td>16.3</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>18.0</td>
<td>100</td>
</tr>
</tbody>
</table>
There were differences in the numbers of large mammals recorded between vegetation structural communities in the COLD/WET zone in 2012. Cluster analyses detected three significantly different groups (Figure 20): Group 1 included (tussock) grassland communities that had no records of any of the large mammals. Group 2 included tall shrubland communities and was identified by SIMPER by having a single record of fox scats. Group 3 included the remaining vegetation structural communities and identified camels, macropods and rabbits contributed the greatest difference between this group and the other (Table 23).

**Figure 20** Bray-Curtis similarity dendrogram of large mammal groups in the COLD/WET climatic zone in 2012. There are three significantly different groups of vegetation structural communities based on the differences in the frequency of scats recorded in each community. Each group is identified by a number (1 – 3) and by the black lines. On the y axis is the measure of similarity between the frequency of scats ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.

**Table 23** The large mammal species that contributed the greatest similarity within group 1. The proportion that each species contributed to the similarity is also shown (SIMPER%).

<table>
<thead>
<tr>
<th>Group</th>
<th>Herbivore species</th>
<th>Frequency of quadrats with scats present</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no scats recorded from all species</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>fox scats</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>camel scats</td>
<td>1.44</td>
<td>15.86</td>
</tr>
<tr>
<td>3</td>
<td>macropod scats</td>
<td>3.67</td>
<td>36.85</td>
</tr>
<tr>
<td>3</td>
<td>rabbit scats</td>
<td>5.55</td>
<td>47.29</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>10.66</td>
<td>100</td>
</tr>
</tbody>
</table>
REPTILE SURVEY RESULTS

There were 43 species of reptiles recorded in the surveys of 1984 and 2012. There were 366 individuals recorded in 2012, and 544 individuals recorded in 1984. A full list of reptiles recorded, including opportunistic sightings, is in appendix B, table 35 and 36. The species richness data recorded at each site in 1984 and 2012 (Table 24) were compared within the HOT/DRY and COLD/WET zones using a paired t-test. The difference between 1984 and 2012 was highly significant (p < 0.001, $F = 88.2$)

Table 24 Species Richness at each site in 1984 and 2012 (no separation from the COLD/WET & HOT/DRY zones because no difference between zones in 1984, see below) (Only data from Autumn in 1984 and 2012 is included).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MU001</td>
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<td>3</td>
<td>KD001</td>
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<td>4</td>
</tr>
<tr>
<td>MU002</td>
<td>0</td>
<td>3</td>
<td>KD002</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>MU003</td>
<td>0</td>
<td>0</td>
<td>KD003</td>
<td>2</td>
<td>4</td>
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</tr>
<tr>
<td>HU002</td>
<td>0</td>
<td>4</td>
<td>KO002</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>HU003</td>
<td>0</td>
<td>4</td>
<td>KO003</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>HU004</td>
<td>1</td>
<td>1</td>
<td>KO004</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>HU005</td>
<td>1</td>
<td>1</td>
<td>KO005</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CA001</td>
<td>1</td>
<td>5</td>
<td>ME001</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>CA002</td>
<td>1</td>
<td>7</td>
<td>ME002</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>CA003</td>
<td>3</td>
<td>5</td>
<td>ME003</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>CA004</td>
<td>2</td>
<td>4</td>
<td>ME004</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>CA005</td>
<td>0</td>
<td>3</td>
<td>ME005</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>IF001</td>
<td>1</td>
<td>6</td>
<td>YA001</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>IF002</td>
<td>3</td>
<td>3</td>
<td>YA002</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>IF003</td>
<td>0</td>
<td>1</td>
<td>YA003</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>IF004</td>
<td>2</td>
<td>3</td>
<td>YA004</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>IF005</td>
<td>1</td>
<td>3</td>
<td>YA005</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation</td>
<td>0.157</td>
<td>0.267</td>
</tr>
</tbody>
</table>

ANOSIM was used to examine differences between reptile assemblages (based on proportion of standardised abundance), which occurred in different climates: HOT/DRY versus COLD/WET. The reptile assemblages were not significantly different within 1984 ($R = 0.048$, $p = 0.249$). Because assemblages did not change respective of the climatic gradient, the hypotheses that HOT/DRY species would increase and COLD/WET species would decrease cannot be tested. Instead, we examined overall reptile assemblages between 1984 and 2012.
There was a significant change in reptile species abundance between 1984 and 2012 ($R = 0.285$, $p < 0.001$). The species identified as the main drivers of this change are listed in Table 25.

**Table 25** The reptile species that contributed 90% of the difference between 1984 and 2012. The species are ordered according to the percent that each species contributed to the overall difference. Note the change in the proportion of relative abundance over time periods.

<table>
<thead>
<tr>
<th>Species</th>
<th>Proportion of standardised abundance in 1984</th>
<th>Proportion of standardised abundance in 2012</th>
<th>Contribution that each species made to the difference between climate zones in 2012 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Nephrurus milii</em></td>
<td>2.86</td>
<td>0.37</td>
<td>16.74</td>
</tr>
<tr>
<td><em>Ctenotus schomburgkii</em></td>
<td>0.38</td>
<td>1.52</td>
<td>11.46</td>
</tr>
<tr>
<td><em>Ctenophorus pictus</em></td>
<td>0.38</td>
<td>0.42</td>
<td>6.49</td>
</tr>
<tr>
<td><em>Tympanocryptis houstoni</em></td>
<td>0.56</td>
<td>0.22</td>
<td>5.89</td>
</tr>
<tr>
<td><em>Diplodactylus calcicolus</em></td>
<td>0.19</td>
<td>0.43</td>
<td>4.59</td>
</tr>
<tr>
<td><em>Diplodactylus vittatus complex (NC)</em></td>
<td>0.50</td>
<td>0.00</td>
<td>4.50</td>
</tr>
<tr>
<td><em>Ctenophorus fordi</em></td>
<td>1.05</td>
<td>0.00</td>
<td>4.46</td>
</tr>
<tr>
<td><em>Varanus gouldii</em></td>
<td>1.05</td>
<td>0.00</td>
<td>4.46</td>
</tr>
<tr>
<td><em>Menetia greyii</em></td>
<td>0.44</td>
<td>0.08</td>
<td>4.34</td>
</tr>
<tr>
<td><em>Tiliqua rugosa</em></td>
<td>0.38</td>
<td>0.18</td>
<td>4.26</td>
</tr>
<tr>
<td><em>Ctenotus regius</em></td>
<td>0.70</td>
<td>0.25</td>
<td>4.17</td>
</tr>
<tr>
<td><em>Ctenotus euclae</em></td>
<td>0.38</td>
<td>0.10</td>
<td>4.12</td>
</tr>
<tr>
<td><em>Lucasium damaeum</em></td>
<td>0.32</td>
<td>0.16</td>
<td>4.10</td>
</tr>
<tr>
<td><em>Menetia greyii</em></td>
<td>0.13</td>
<td>0.57</td>
<td>4.09</td>
</tr>
<tr>
<td><em>Lerista labialis</em></td>
<td>0.35</td>
<td>0.16</td>
<td>2.25</td>
</tr>
<tr>
<td><em>Drysdalia mastersii</em></td>
<td>0.19</td>
<td>0.05</td>
<td>2.10</td>
</tr>
<tr>
<td><em>Ctenotus sp.</em></td>
<td>0.19</td>
<td>0.00</td>
<td>1.69</td>
</tr>
<tr>
<td><em>Lerista baynesi</em></td>
<td>0.19</td>
<td>0.00</td>
<td>1.69</td>
</tr>
</tbody>
</table>

**Reptile Association with vegetation structural communities**

Similarities in reptile assemblages within each vegetation structural community were investigated using cluster analyses. There were 2 distinct groups of vegetation structural communities in the 2012 survey (Figure 21). The species that contributed the greatest difference between the groups are described in Table 26. (Note that reptile associations are not analysed with HOT/DRY separated from COLD/WET. There was no difference according to ANOSIM analyses and, as such, the reptiles are treated as one assemblage Nullarbor-wide).
Figure 21 Bray-Curtis similarity dendrogram of reptile groups in 2012. There were two significantly different groups of vegetation structural communities based on the reptile species and abundances recorded in each community. The groups are identified by a number (1-2) located underneath the structural community descriptions. On the y axis is the measure of similarity between sites ranging from 0 to 100. On the x axis are the vegetation structural community that were compared.

Table 26 The reptile species that differentiated group 1 from group 2 in 2012, based on SIMPROF analyses of relative abundance. The amount that each species contributed to the difference is SIMPER%.

<table>
<thead>
<tr>
<th>Group</th>
<th>Species</th>
<th>Sum of std abundance per group</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cryptoblepharus australis</td>
<td>0.58</td>
<td>52.63</td>
</tr>
<tr>
<td>1</td>
<td>Delma australis</td>
<td>0.53</td>
<td>47.37</td>
</tr>
<tr>
<td></td>
<td>Group 1 total</td>
<td>1.11</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Ctenotus schomburgii</td>
<td>1.33</td>
<td>29.09</td>
</tr>
<tr>
<td>2</td>
<td>Diplodactylus calcicolus</td>
<td>0.64</td>
<td>13.07</td>
</tr>
<tr>
<td>2</td>
<td>Ctenophorus pictus</td>
<td>0.76</td>
<td>12.35</td>
</tr>
<tr>
<td>2</td>
<td>Menetia greyii</td>
<td>0.44</td>
<td>9.59</td>
</tr>
<tr>
<td>2</td>
<td>Nephrurus milii</td>
<td>0.52</td>
<td>6.88</td>
</tr>
<tr>
<td>2</td>
<td>Lucasium damaeum</td>
<td>0.29</td>
<td>4.82</td>
</tr>
<tr>
<td>2</td>
<td>Tiliqua rugosa</td>
<td>0.14</td>
<td>3.53</td>
</tr>
<tr>
<td>2</td>
<td>Ctenotus regius</td>
<td>0.14</td>
<td>3.44</td>
</tr>
<tr>
<td>2</td>
<td>Morethia obscura</td>
<td>0.15</td>
<td>3.25</td>
</tr>
<tr>
<td>2</td>
<td>Tymanocryptis houstoni</td>
<td>0.31</td>
<td>2.99</td>
</tr>
<tr>
<td>2</td>
<td>Ctenotus orientalis</td>
<td>0.24</td>
<td>2.84</td>
</tr>
<tr>
<td>2</td>
<td>Drysdalia mastersii</td>
<td>0.10</td>
<td>2.20</td>
</tr>
<tr>
<td>2</td>
<td>Ctenotus euclae</td>
<td>0.18</td>
<td>2.00</td>
</tr>
<tr>
<td>2</td>
<td>Nephrurus levis</td>
<td>0.04</td>
<td>1.99</td>
</tr>
<tr>
<td>2</td>
<td>Morethia adelaidensis</td>
<td>0.14</td>
<td>1.96</td>
</tr>
<tr>
<td></td>
<td>Group 2 total</td>
<td>5.42</td>
<td>100</td>
</tr>
</tbody>
</table>
Reptile Association with soil texture

Similarities in reptile assemblages within each soil texture class were investigated using cluster analyses. In the 2012 survey there was 1 group of soil texture classes detected (Figure 22). The species that contributed the greatest difference are described in table 27. (Note: reptile associations are not analysed with a separation of climate zones because there was no difference in assemblages based on climate, see ANOSIM analyses).

Figure 22 Bray-Curtis similarity dendrogram of reptile-soil groups in 2012. There were no significant differences between the reptile species and abundances recorded in each soil texture classes, therefore all classes formed 1 group. The measure of similarity ranging from 0 to 100 is shown on the y-axis. On the x-axis are the soil texture classes that were compared.

Table 27 The reptile species were dominant in group 1 in 2012, based on SIMPROF analyses of the species and the proportion of relative abundance. The amount that each species contributed to the difference is SIMPER%.

<table>
<thead>
<tr>
<th>Group</th>
<th>Reptile species</th>
<th>Sum of standardised abundance per group</th>
<th>SIMPER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Ctenotus schomburgki</em></td>
<td>82.0</td>
<td>39.0</td>
</tr>
<tr>
<td>1</td>
<td><em>Ctenophorus pictus</em></td>
<td>39.3</td>
<td>22.6</td>
</tr>
<tr>
<td>1</td>
<td><em>Tympanocryptis houstoni</em></td>
<td>22.0</td>
<td>9.9</td>
</tr>
<tr>
<td>1</td>
<td><em>Nephrurus milii</em></td>
<td>32.4</td>
<td>9.7</td>
</tr>
<tr>
<td>1</td>
<td><em>Diplodactylus calcicolus</em></td>
<td>29.4</td>
<td>8.2</td>
</tr>
<tr>
<td>1</td>
<td><em>Menetia greyii</em></td>
<td>31.6</td>
<td>5.9</td>
</tr>
<tr>
<td>1</td>
<td><em>Ctenotus orientalis</em></td>
<td>13.4</td>
<td>4.5</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>250.06</td>
<td>100</td>
</tr>
</tbody>
</table>

We also classified soil into three categories based on dominant texture. There were no significant reptile associations based on these classifications (R < 0.456, p > 0.125).
DISCUSSION

The key aims of this project were to detect trends in the cover of plants, and the abundance of mammals, birds and reptiles, on the basis of a comparison of an historical survey from 1984 with a current survey from 2012, and to investigate the link between temporal and spatial changes in rainfall and temperature with changes in the Nullarbor biota.

The results detected a significant relationship between the composition of plants, bird and mammals, and dominant temperature and rainfall gradients. There was a significant change between 1984 and 2012 within the COLD/WET zone in cover of plants and the abundance of birds, and small mammals that are typical in the HOT/DRY zone, but there was no change detected in the abundance and cover of species that are typical for the COLD/WET zone. Similar analyses of reptiles could not be done because the assemblage of reptile species in 1984 did not change with respect to the climate gradient. The assemblage of reptiles was not related to vegetation structural communities or soil texture either, but some changes between 1984 and 2012 were detected regardless. The results of this report demonstrate change, but cannot be used unequivocally to link changes in the ecology of a landscape with causes, such as rainfall or temperature.

Overall, some differences were observed between 1984 and 2012, but the ability to detect the causes of differences are difficult because arid lands are variable environments. Change, in itself, is not as informative as the link between change and explicit drivers. Short-term rainfall events, monitoring design, data storage, and natural fire regimes confound the interpretation of changes in the environment as being linked solely to climate change. Given the time lapse, natural fluctuations of any natural system and perceived changes due to monitoring design, the changes detected in the Nullarbor survey cannot be directly linked to climate change (Eyre, 2011) but the differences between 1984 and 2012 provide an indication of potential changes. We recommend future monitoring be undertaken long-term and focused on detecting changes that are directly associated with assets and threats in the Nullarbor, and on testing the effectiveness of management interventions applied to manage the assets of interest.

Describing trends over 18 years from two data points is difficult, particularly in landscapes with highly variable inter-year climate patterns. For example: Nullarbor rainfall in the years leading up to the 1984 survey was between 189mm and 241mm (Mean=210mm annual
rainfall), while in the years leading up to the 2012 survey rainfall ranged from 205 to 376mm (mean=272mm), with the highest rainfall being in the year immediately prior to the 2012 survey. Any increases in plant cover or animal abundance could more easily be explained by this ‘boom’ period in the boom-bust cycle of these systems (Smyth & James, 2004), rather than any consistent trending changes in the ecological measures (Pickup & Stafford-Smith, 1993). If the 2012 survey had been done in 2009 (at the end of a drought, before the break of weather) we may have detected the opposite patterns. Our results therefore reflect changes in the environment, that cannot be directly associated with long-term trends.

The 1984 and 2012 surveys had some differences in design and data collection. The comparison of vegetation in this report might have been influenced by changes to the location of sampling quadrats between 1984 and 2012. To reduce the effect of these potential biases changes to plant species and cover were compared between sites. Bird survey methods were refined in 2012 because of a lack of clarity in the 1984 survey (McKenzie & Robinson, 1987). Location of bird surveys remained the same between years but effort differed somewhat. Therefore, for birds and plants it is difficult to infer that variation in bird abundance and plant cover is a response to changing climate, because the effect of sampling design can not be separated from other effects. Furthermore, there are potential biases introduced because of data capture and storage. For example, the transformation of cover/abundance data could reduce the accuracy of some results. The differences between cover/abundance might reflect biologically meaningful patterns or resource availability or growth conditions (Gotelli & Colwell, 2001) and it is therefore important to discuss differences, but further long-term monitoring is needed to identify confidently, the causes underlying any changes observed.

Readers should note the 1984 bird data might not be an accurate reflection of what was actually recorded due to changes made to the Biological Database of South Australia between 1984 and 2012. As a result, the comparison between 1984 and 2012 bird results should be interpreted with caution.

Species richness can be a simple and effective way to describe community diversity but it is influenced by sampling biases (Gotelli & Colwell, 2001). Fundamental to species richness is the notion that as more individuals are captured, the more taxa will be recorded (Bunge & Fitzpatrick, 1993). When survey effort is not equal, as in the case of the bird surveys, it is possible to describe false differences. Cover and abundance measures that are standardised
are likely to be a stronger biodiversity metric (Albright et al., 2010). Therefore, changes in species richness are supplemented with changes in abundance or cover in this report.

The study hypothesised there would be a relative reduction of plant cover and animal abundance of those species that characterised the COLD/WET coastal fringe as the environmental conditions became less favourable, due to temporal and spatial changes to rainfall and temperature. It was expected that some plants and animals might have been on the edge of their natural ranges, and changes in the climate would decrease the range of their habitats further, but the results did not detect evidence to support this hypothesis. The results might be linked to the relatively high rainfall preceding the 2012 survey (refer to Figure 3 in the introduction). Therefore, changes (or the lack of changes) to bird and plant communities are more likely to be related to this ‘boom’ period as opposed to long term changes in rainfall and temperature. Our results did not detect significant changes to the distribution and cover/abundance of species that characterised the COLD/WET zone but this might occur as the impacts of a change in long-term rainfall and temperature are increased.

In the COLD/WET coastal zone we expected to find an increase in the cover and abundance of the plants and animals that characterised the HOT/DRY zone as the arid zone encroaches south (Bryne et al., 2008). A review of phylogeographic patterns in the Australian arid zone show that past biota demonstrate geographical movement to refuges in times of global climate change (Bryne, 2007). The coastal fringe of the Nullarbor is likely to act as a refuge due to the buffering effect of the ocean on temperature as well as the relatively high humidity and rainfall in the area (Bryne, 2007). Studies such as these demonstrate how the distribution of plants and animals can be altered because of climate change.

We detected a significant change in the bird species that characterised the HOT/DRY zone between 1984 and 2012, with *Malurus leucopterus* (white-winged fairy-wren) and *Gavicalis virescens* (singing honeyeater) both significantly increasing in abundance. Importantly, a number of species that were expected to increase were recorded as decreasing in abundance, for example *Anthus australis* (Australasian pipit). While distribution models demonstrate community-wide expectations, there are likely to be many species that do not migrate as expected for a number of complex factors, for example habitat limitations, or associations with other plants or animals.

The results also detected a significant change in the cover of plants that characterise the HOT/DRY zone that were observed in the COLD/WET zone, with some plants increasing as
expected, and others decreasing contrary to the hypothesised change. Current ecological
theories predict that many species are expected to shift their ranges to higher altitudes and
from the tropics to the poles in response to changes to global climate (Hickling et al., 2006;
Wilson et al., 2005), whereas other species will retract and potentially face extinction
(Thomas et al., 2004). These global scale, generalised predictions do not necessarily provide
a good account of what is occurring on the Nullarbor. The movement of species is probably
buffered on the Nullarbor by above average rainfall in recent decades, and possibly by the
positive effects of additional carbon dioxide in the air (Steffen et al., 2009). In contrast to
our predictions it is not surprising, therefore, to detect a decrease in some plant species that
defined the HOT/DRY zone. Our results provide a snapshot of current biodiversity, but
further monitoring is needed to determine long-term trends in cover and abundance.

Mus musculus (house mice) was the dominant species captured in the small mammal survey
and therefore dominated the analyses and results in this area. There was a significant
increase in the abundance of house mice in the COLD/WET zone. This result might support
the hypotheses that species characterising the HOT/DRY zone will move south to the coastal
refuges, but house mice are generalists and are known to retreat to more favourable areas
during dry times. Likewise, mice extend their distribution and increase in abundance in
‘boom’ periods, therefore the relative increase in mice in the COLD/WET zone might indicate
a response to short-term pulses of rainfall rather than long-term temporal and spatial
changes in rainfall and temperature.

No change was detected between 1984 and 2012 in the abundance of Notomys mitchelli,
the species that defined the COLD/WET zone. Studies in the arid zone have demonstrated
that rodents respond to pulses of precipitation by increasing abundance and extent. In
contrast, Dasyurids are not limited by water, but by other factors such as vegetation cover
and life history (Dickman et al., 1999). In Australia’s arid zone house mice are thought to
pose a mild threat to the natural biodiversity. When house mice are in plague numbers, they
support high numbers of feral cats and foxes, which then prey on native species (Norris &
Low, 2005). The vulnerable bird species, Pedionomus torquatus (plains wanderer) is likely to
be preyed on in this event (Garnett & Crowley, 2000). In contrast, house mice are recognised
as an important food source for native animals, for example the black-shouldered kite,
nankeen kestrel, kookaburras and brown snakes (Norris & Low, 2005). Studies of barn owls
in the rangelands found that house mice constitute as much as 97% of their diet (Morton &
Martin, 1979). Our study detected an increase in the number of house mice in the
COLD/WET zone in the Nullarbor, but given the low threat to biodiversity in the landscape, it is not necessary to change the region’s management of feral rodents.

We expected that assemblages of reptiles would be different between the HOT/DRY and COLD/WET sites. This was not supported by the survey results. Therefore, the hypothesis that the reptile species that characterised the HOT/DRY zone would increase in the coastal COLD/WET zone could not be analysed because no indicator species could be selected by SIMPER. Likewise, the reduction of reptiles that characterised COLD/WET between 1984 and 2012 could not be tested either.

Reptiles have low metabolic rates and low energy needs and can further reduce their need for food and water by remaining inactive and maintaining relative low body temperatures. It is therefore likely that reptiles are not subjected to population fluctuation in response to rainfall variability (Read, 1992). A similar study of herpetofauna in Kakadu National Park showed that reptile distribution and abundance is more related to the moisture substrate gradient than to vegetation structure. The study also noted a number of exceptions that were distributed landscape-wide and not related to either factor (Woinarski & Gambold, 1992). This study may offer some explanation as to why our study did not detect a relationship between reptile composition and broad climate gradients or soil texture.

The vegetation photopoint survey indicated the cover, recruitment and density of plants in the study area has been stable over time. There were 40 sites in total, where low shrubs, trees and tall shrubs, grass and herbs, Acacia aneura and Maireana sedifolia were assessed according to detect changes in density, cover and recruitment over time. On average these sites were ‘stable’, although only one assessment of A. aneura was possible, and this recorded a decreasing condition.

The warming and drying of the Nullarbor region might lead to increased frequency and intensity of fires and a reduction in patches of fire-sensitive mulga, A. aneura, in grassland communities (Myers et al., 2004). Camels and rabbits selectively feed on mulga further increasing the threats to survival and recruitment in arid Australia (Edwards et al., 2010). Additional photopoints have been installed and surveys are currently underway to measure trends in the condition of mulga stands in the Nullarbor landscape. The results from these extra photopoints will be presented in a separate report along with assessments of shrubland, grass/herb land, and woodland communities throughout the Nullarbor.
Camels have a preference for feeding on *Acacia aneura, Alectryon oleifolius ssp.*, *Amyema ssp.*, *Casuarina pauper, Eremophila longifolia, Exocarpos aphyllus, Lysiana ssp.*, *Myoporum platycarpum var.*, *Pittosporum angustifolium, Santalum acuminatum, Santalum spicatum,* and *Santalum lanceolatum* (Edwards et al. 2010; Brandle, pers. comms. 2012). These palatable plants occur across the Nullarbor landscape but are more common in tall shrubland, low open woodland, low woodland, low open shrubland and low shrubland communities within the HOT/DRY zone. In the COLD/WET zone, the plants are more common in mallee, open low mallee, open mallee, very low open woodland, very low woodland, low open woodland, and low woodland communities.

Our results showed no difference in the abundance of camels between these vegetation structural communities. Given the increase in rainfall in recent years, it is possible that increased water and resource availability meant that camels did not aggregate in any particular location. Even if camel numbers remain stable in the Nullarbor, the negative impacts are likely to be concentrated at particular points under climate change scenarios, rather than be dispersed. Remote settlements and natural water accumulation points will become important refuges and are susceptible to increases in camel visitation. Water scarcity and increased droughts will amplify water pollution, vegetation browsing and trampling, and competition caused by camels.

Strategies for conservation management should focus of the region’s priorities and assets and aim to build resilience in the system to climate change through habitat restoration, and continued management of other stressors, such as pest management and fire management (Bardsley & Wiseman, 2012). Management of feral plants and animals, including camels, has been occurring Australia-wide. The National Feral Camel Action Project (NFCAP) could be adopted for the Nullarbor region (Vertebrate Pest Committee, 2010). The NFCAP would crucially begin with the identification of assets in AW and then sets target required to protect these assets. Monitoring is essential to inform the effectiveness of management and to inform the need for adaptive management.

Biological surveys such as this one can help to identify assemblages in landscapes and provide snapshots in species abundance and cover. According to the recommendations in the report by Bardsley & Wiseman (2012) key actions for the AW region regarding conservation management should include investigation of the relationship between
biodiversity and climate and the resampling of a biological survey. This report has achieved some of the outcomes recommended for these actions for the Nullarbor region. The results of our study can be used to inform the AW of the biodiversity condition, changes in species abundance and cover relative to 1984 and provides information on the selection of environmental assets and the monitoring that is required to track the condition of these assets.

The key objective of this project was to assess the response of biodiversity to climate change. Revisiting existing biological survey sites has allowed for landscape wide changes in biodiversity to be investigated but the analysis of the results from this study has highlighted a number of limitations in the monitoring design that prevented detection of a clear links between changes in biodiversity and changes in climate over the timeframe of interest. The most fundamental limits are that there are only two samples over the time period, it was difficult to be sure that the study was repeated accurately because the methods for the oldest survey were not always clear, and the study provides a relatively small sample from a very large landscape.

Future monitoring in the Nullarbor, needs to focus on assets that are expected to be impacted by climate change. Many of these assets are current priorities for management in the AW region, for example the coastal ecosystems contributing to the Yalata Coast, Bunda Cliffs and Merdayerrah Sandpatch, the endemic biota that exist in the limestone caves across the Nullarbor landscape (AW NRM, 2011) or water points that occur throughout the rangelands (Steffen et al., 2009). It is likely that a warmer, drier environment will further impact these assets (Steffen et al., 2009). For example, our results indicated that the distribution of Maireana sedifolia, Sclerolaena obliquispis, Lycium australis, Rhagodia spinescens, Enchyilaena tomentosa var. tomentosa, Pittosporum angustifolium, Anthus australis, Pomatostomus superciliosus, Malurus leucopterus, Gavicalis virescens, Psephotus varius, Artamus cinereus, Aphelocephala leucopsis, Cinclusoma cinnamomeum alisteri, Falco berigora, Colluricinclla harmonica, and Melanodryas cucullata may have changed over the last 28 years. While our study did not link these changes to climate change, these species may be assessed as potential sentinels of climate change. These potential sentinels should not be considered the exhaustive list of the species that may change their distribution in the future.
The identification of priority species and regional assets is important to conservation planning because it assists in clearly articulating monitoring questions and allows these questions to be adequately answered. The priority species for the AW NRM should be based on: endemism, threats, abundance, potential climate change impacts, existing monitoring data, and species of high profile. An example is *Acanthiza iredalei iredalei* (slender-billed thornbill) which is common across the Nullarbor landscape and a notable priority because of its conservation status under the *EPBC Act 1999*.

Threats to the region have been identified, including: buffel grass, fire regimes and large herbivores (Biosecurity SA, 2012; Myers *et al.*, 2004; Vertebrate Pest Committee, 2010), thus monitoring the impacts these threats have on regional biodiversity assets would help to better inform management actions. This work could be linked to national and state-wide strategic plans, for example South Australia Buffel Grass Strategic Plan 2012-2017, and the National Feral Camel Action Project. Monitoring the condition and trends of assets that are likely to be impacted by climate change will increase the knowledge needed to make informed management decisions, in turn maximising the opportunities to build resilience in arid ecosystems.

An adaptive management approach should be used to improve environmental management outcomes, while at the same time increase understanding of the consequences of incomplete knowledge (Sabine *et al.*, 2004). There is extensive literature on adaptive management that can be used to design effective monitoring programs. Lindenmayer and Likens (2009) provide an accessible review that discusses the links between long-term research and monitoring in an adaptive management context.

In conclusion, the study found little support for the hypotheses that species have moved south toward coastal refuges in response to changes in rainfall and temperature, and no evidence to indicate a relative decline in species that characterised the coastal zone. Increased rainfall in the year preceding the 2012 survey, compared with the rainfall immediately preceding the 1984 survey, is a possible explanation for this. The results provide a snapshot of current levels of abundance of animals and cover of plants. Improved and enhanced monitoring can be used to inform the AW of changes in biodiversity in the Nullarbor region, and we recommend this monitoring has a stronger focus toward the long-term monitoring of assets determined by priorities set by the AW NRM.
REFERENCES


CSIRO and Bureau of Meteorology (2007) *Climate change in Australia: technical report*. Department of Climate Change, Canberra.


### APPENDIX A

**Table 28** Disturbance history of the Nullarbor Plains after European introduction in 1801

<table>
<thead>
<tr>
<th>Time period</th>
<th>People in charge</th>
<th>Location of disturbance</th>
<th>Details of disturbance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800 to 1840</td>
<td>Whalers</td>
<td>Fowlers Bay</td>
<td>Local timber clearing for Fuel for rendering pots</td>
</tr>
<tr>
<td>1841 to 1842</td>
<td>Eyre</td>
<td>Trans-Nullarbor</td>
<td>Pack horse</td>
</tr>
<tr>
<td>1858</td>
<td>Swan and Barr Smith</td>
<td>Fowlers Bay</td>
<td>Overlanding stock to the west not possible</td>
</tr>
<tr>
<td>1858 to 1859</td>
<td></td>
<td>Colona, Nundroo, Penong</td>
<td>Pastoral Settlement</td>
</tr>
<tr>
<td>1860</td>
<td>P Warburton</td>
<td>Nullarbor Plain</td>
<td>&quot;neither man nor stock could live upon (Nullarbor Plain)&quot;</td>
</tr>
<tr>
<td>1861</td>
<td></td>
<td>Fowlers Bay</td>
<td>Pastoral development begins</td>
</tr>
<tr>
<td>1863 to 1865</td>
<td>Far West Coast</td>
<td>Early Settlers</td>
<td>Severe Drought</td>
</tr>
<tr>
<td>1865</td>
<td></td>
<td>Head of Bight</td>
<td>Agricultural settlers sell out to Swan and B-Smith</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yalata Station</td>
<td>Stock being grazed; White Well Outstation established</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>White Well and soaks at Peenalubie Ilgamba are main waters</td>
</tr>
<tr>
<td>1867</td>
<td></td>
<td>Head of Bight</td>
<td>20,000 Sheep</td>
</tr>
<tr>
<td>1870 to 1871</td>
<td>J Forrest</td>
<td>Nullarbor Plain</td>
<td>5,000 driven to Adelaide due to drought</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pack horses</td>
</tr>
<tr>
<td>1871</td>
<td></td>
<td>Fowlers Bay</td>
<td>Coastal Survey Lines</td>
</tr>
<tr>
<td>1871</td>
<td></td>
<td>Mundrabilla Station</td>
<td>Stock being grazed; White Well Outstation established</td>
</tr>
<tr>
<td>1873</td>
<td>Muir Bros</td>
<td>Moopina Station</td>
<td>Station established</td>
</tr>
<tr>
<td>1875</td>
<td>E Giles</td>
<td>Nullarbor E and N Fringes</td>
<td>Exploration with Camels</td>
</tr>
<tr>
<td>1876</td>
<td></td>
<td>Madura Station</td>
<td>Station established</td>
</tr>
<tr>
<td>1876 to 1877</td>
<td></td>
<td></td>
<td>Telegraph Line constructed</td>
</tr>
<tr>
<td>1877 to 1879</td>
<td></td>
<td></td>
<td>Use of horses</td>
</tr>
<tr>
<td>1878</td>
<td>Faerie &amp; Woolley</td>
<td>Nullarbor Plain</td>
<td>Leases west of Nullarbor taken up but not stocked</td>
</tr>
<tr>
<td>1879</td>
<td>R Tate</td>
<td>Nullarbor Plain</td>
<td>Fatal Expedition; using horses</td>
</tr>
<tr>
<td>1880</td>
<td>J Jones</td>
<td>Nullarbor Plain</td>
<td>Exploration with Camels</td>
</tr>
<tr>
<td>1880</td>
<td></td>
<td>Albala-Karoo</td>
<td>First Bore</td>
</tr>
</tbody>
</table>

*Table 27 continues on the next page*
<table>
<thead>
<tr>
<th>Time period</th>
<th>People in charge</th>
<th>Location of disturbance</th>
<th>Details of disturbance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1880</td>
<td></td>
<td>Yalata Station</td>
<td>100,000 sheep</td>
</tr>
<tr>
<td>1880</td>
<td></td>
<td>Balladonia Station</td>
<td>Station established</td>
</tr>
<tr>
<td>1880 to 1889</td>
<td>W Ifould</td>
<td>Lake Ifould</td>
<td>Takes up leases around Lake Ifould</td>
</tr>
<tr>
<td>1886 to 1887</td>
<td></td>
<td>Nullarbor Station</td>
<td>Roberts Well bored</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Station established</td>
</tr>
<tr>
<td>1885?</td>
<td>HYL Brown</td>
<td></td>
<td>Camels on Geol Survey</td>
</tr>
<tr>
<td>1886 to 1889</td>
<td>Afghans</td>
<td>Nullarbor Plain</td>
<td>260 - 500 camels used as carriers across Nullarbor, to WA Goldfields</td>
</tr>
<tr>
<td>1890</td>
<td>W Ifould</td>
<td>Ooldea</td>
<td>Grazing sheep at Ooldea</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>First Well at Ooldea</td>
</tr>
<tr>
<td>1894</td>
<td>A Heath</td>
<td>Nullarbor Plain</td>
<td>Drives ~50 camels across Nullarbor to Goldfields</td>
</tr>
<tr>
<td>1894 to 1898</td>
<td></td>
<td>Nullarbor Plain</td>
<td>Rabbits cross plain from Head of Bight to Coolgardie</td>
</tr>
<tr>
<td>1896</td>
<td>Mason &amp; Yonge</td>
<td>Nullarbor Plain</td>
<td>Camel Expedition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Investigation of rabbit movements</td>
</tr>
<tr>
<td>1896 to 1897</td>
<td></td>
<td>Eucla</td>
<td>Rabbit plagues; Cat introduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sandhill drifts induced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1000 Rabbits slaughtered in a day with no evident impact</td>
</tr>
<tr>
<td>1900</td>
<td></td>
<td>Nullarbor Plain</td>
<td>500 camels driven from Marree to Kalgoorlie</td>
</tr>
<tr>
<td>1901</td>
<td>J Muir</td>
<td>Nullarbor Plain</td>
<td>Survey of WA part of Transcontinental Rail</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Uses Camels</td>
</tr>
<tr>
<td>1906</td>
<td></td>
<td>Nullarbor Plain</td>
<td>Overland track across Nullarbor recognised</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WA Goldfields developing</td>
</tr>
<tr>
<td>1912 to 1917</td>
<td></td>
<td>Nullarbor Plain</td>
<td>Construction of Transcontinental Railway</td>
</tr>
<tr>
<td>1917</td>
<td></td>
<td></td>
<td>Transcontinental Railway begins</td>
</tr>
<tr>
<td>1941</td>
<td>R&amp;C Gurney</td>
<td>Koonalda Station</td>
<td>Take up Pastoral Lease</td>
</tr>
<tr>
<td>1941 to 1942</td>
<td>Commonwealth Defence Forces</td>
<td>Nullarbor Plain Coast</td>
<td>Overland Track converted to serviceable Road</td>
</tr>
<tr>
<td>1954</td>
<td></td>
<td></td>
<td>Myxomatosis spread reduces rabbit populations</td>
</tr>
<tr>
<td>1954 to 1961</td>
<td>A&amp;C Beatty</td>
<td>Nullarbor Station</td>
<td>Run 3,000 to 5,000 sheep</td>
</tr>
<tr>
<td>1959</td>
<td></td>
<td>Nullarbor Station</td>
<td>Drought - 1700 sheep kept; water carted to them</td>
</tr>
<tr>
<td>1960 to 1969</td>
<td></td>
<td>Nullarbor Plain Coast</td>
<td>Eyre Highway becomes all-weather road</td>
</tr>
<tr>
<td>1964</td>
<td>M&amp;D Thomas</td>
<td>Nullarbor Station</td>
<td>Nullarbor Roadhouse complex established</td>
</tr>
<tr>
<td>1976</td>
<td>NPWS</td>
<td>Nullarbor Station</td>
<td>Purchase and Proclamation of Nullarbor NP</td>
</tr>
</tbody>
</table>
APPENDIX B

Survey records from 1984 and 2012:

- Plants observed in 2012, cover has been standardised by site and climate zone, table 29
- Plants observed in 1984, cover has been standardised by site and climate zone, table 30
- Birds observed in 2012 table 31
- Birds observed in 1984 table 32
- Small observed mammals in 2012 table 33
- Small observed mammals in 1984 table 34
- Reptiles observed in 2012 table 35
- Reptiles observed in 1984 table 36

Plants species tables list all plants as present (1). No number indicates absence.

Bird, mammal, and reptile tables describe the number of individuals observed at each camp, and the total number of individuals that were opportunistic observations.

NB All exotic species are identified with an asterisk, for example *Mus musculus.*
<table>
<thead>
<tr>
<th>Plant Species</th>
<th>common name</th>
<th>Life Span</th>
<th>CA</th>
<th>HU</th>
<th>IF</th>
<th>KD</th>
<th>KO</th>
<th>ME</th>
<th>MU</th>
<th>YA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abutilon leucopetalum</td>
<td>desert lantern-bush</td>
<td>perennial</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Abutilon otocalyx</td>
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<td>perennial</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Acacia aneura var.</td>
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<td>2.5</td>
<td></td>
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<td></td>
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<tr>
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<td>54.5</td>
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<td></td>
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<tr>
<td>Acacia erinacea</td>
<td>prickly wattle</td>
<td>perennial</td>
<td>3.5</td>
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<td>Acacia kempeana</td>
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<tr>
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<tr>
<td>Acacia oswaldi</td>
<td>umbrella wattle</td>
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<td>1</td>
<td>1</td>
<td>6.5</td>
<td>3</td>
<td>4.5</td>
<td>23</td>
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<td>Acacia papyrocarpa</td>
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<td>Acacia ramulosa var. linophylla</td>
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</tr>
<tr>
<td>Acacia ramulosa var. ramulosa</td>
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<td>0.5</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Acacia tetragonophylla</td>
<td>dead finish</td>
<td>perennial</td>
<td>0.5</td>
<td></td>
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<td>9</td>
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<tr>
<td>Alectryon oleifolius ssp. canescens</td>
<td>bullock bush</td>
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<tr>
<td>Amyema melaleuca</td>
<td>tea-tree mistletoe</td>
<td>perennial</td>
<td>2</td>
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<td></td>
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<tr>
<td>Amyema quandang var. quandang</td>
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<td>perennial</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
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<tr>
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<td>6.5</td>
<td>5</td>
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<td>Arabidella tricesta</td>
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<td>Aristida anthoxanthoides</td>
<td>yellow three-awn</td>
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<td>Aristida hololthera var. hololthera</td>
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<tr>
<td>Atriplex acutibacteae ssp.</td>
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<td>perennial</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Atriplex acutibacteae ssp. acutibacteae</td>
<td>pointed saltbush</td>
<td>perennial</td>
<td>2.5</td>
<td>3.5</td>
<td></td>
<td></td>
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<td>Atriplex acutibacteae ssp. karoniensis</td>
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<td>183.5</td>
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<td>32.5</td>
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<td>common wallaby-grass</td>
<td>perennial</td>
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<tr>
<td>Austroamphithoea eriantha</td>
<td>hill wallaby-grass</td>
<td>perennial</td>
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</tr>
<tr>
<td>Austroamphithoea sp.</td>
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### Table 31 2012 species list of birds, with the number of individuals recorded at each camp – incl. total opportunist records (OPP. RECORD)

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Total per camp 437 234 144 398 454 850 492 1379 743 5131
Table 33 2012 species list of mammals, with the number of individuals recorded at each camp – incl. total opportunistic records (OPP. RECORD)

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<th>IF</th>
<th>KD</th>
<th>KO</th>
<th>ME</th>
<th>MU</th>
<th>YA</th>
<th>OPP. RECORD</th>
<th>total per taxa</th>
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**total per camp** | **133** | **409** | **107** | **154** | **134** | **46** | **260** | **85** | **455** | **1783** |
Table 34 1984 species list of mammals, with the number of individuals recorded at each camp – incl. total opportunistic records (OPP. RECORD)

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<th>Mammal taxa</th>
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<th>KO</th>
<th>ME</th>
<th>MU</th>
<th>YA</th>
<th>opp. record</th>
<th>total per taxa</th>
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Table 35 2012 species list of reptiles, with the number of individuals recorded at each camp – incl. total opportunistic records (OPP. RECORD)

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<th>opp. record</th>
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| total per camp | 49 | 50 | 53 | 65 | 39 | 22 | 46 | 42 | 108 | 474 |
### Table 36: 1984 species list of reptiles, with the number of individuals recorded at each camp – incl. total opportunistic records (OPP. RECORD)

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**Total per camp**: 14 8 20 16 88 18 110 33 251 558
## APPENDIX C

Table 37 Photopoint survey results for

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<th>Site</th>
<th>Trend Period</th>
<th>Trend Summary</th>
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<td>CA00101</td>
<td>Apr 84 to Nov 01</td>
<td>Maintenance of saltbush and samphire populations with fluctuations in bush size Thinning crowns of trees at rear</td>
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<tr>
<td>CA00201</td>
<td>Apr 84 to Nov 01</td>
<td>Maintenance of Bluebush population/cover Decline of Dark green low shrub Decline of crown in trees at rear</td>
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<td>CA00301</td>
<td>Apr 84 to Nov 01</td>
<td>Maintenance of saltbush and samphire populations with fluctuations in bush size</td>
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<tr>
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<td>Apr 84 to Nov 01</td>
<td>Maintenance of saltbush and samphire populations with fluctuations in bush size</td>
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<tr>
<td>CA00501</td>
<td>Apr 84 to Nov 01</td>
<td>Increasing bladder saltbush presence on annuals dominated plain</td>
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<tr>
<td>KO00101</td>
<td>Apr 84 to Oct 87</td>
<td>Stable Myall over saltbush and samphire</td>
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<tr>
<td>KO00201</td>
<td>Apr 84 to Oct 87</td>
<td>Decreasing saltbush abundance Tree crowns stable</td>
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<tr>
<td>KO00301</td>
<td>Apr 84 to Oct 87</td>
<td>Stable Eucalypt/Cratystylis community</td>
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<tr>
<td>KO00401</td>
<td>Apr 84 to Oct 87</td>
<td>Stable Myall/Cratystylis/Saltbush Saltbush population turnover since 1984 Thinning western myall crowns</td>
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<td>KO00501</td>
<td>Apr 84 to Oct 87</td>
<td>Stable Malley/Cratystylis/Saltbush system</td>
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<td>HU00101</td>
<td>Apr 84 to May 02</td>
<td>Increased Atriplex vesicaria since Jul 1985, from a few plants only</td>
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<td>HU00201</td>
<td>Apr 84 to May 02</td>
<td>Stable saltbush low open shrubland with increase in saltbush abundance (size,cover)</td>
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<td>Apr 84 to May 02</td>
<td>Growth of Eremophila longifolia Increased abundance of ?Chenopodium nitritiaeum?</td>
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<td>Apr 84 to May 02</td>
<td>Herbland annual grassland maintained</td>
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<tr>
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<td>Apr 84 to May 02</td>
<td>Maintained Erem longifolia grove in Herbland/Annual Grassland Plain; some fluctuation in E longifolia crown density</td>
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<td>IF00101</td>
<td>Apr 84 to Nov 01</td>
<td>Stable Chenopod Shrubland Apr84 to Jul85</td>
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<td>IF00201</td>
<td>Apr 84 to Nov 01</td>
<td>Stable Bluebush shrubland Apr84 to Jul85</td>
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<tr>
<td>IF00301</td>
<td>Apr 84 to Jul 85</td>
<td>Myall/Bluebush</td>
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<td>IF00401</td>
<td>Apr 84 to Jul 85</td>
<td>Mallee: Shrub growth</td>
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<tr>
<td>IF00501</td>
<td>Apr 84 to Jul 85</td>
<td>Myall/?Declining saltbush?</td>
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<td>Apr 84 to Nov 01</td>
<td>Stable shrubland</td>
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<tr>
<td>KO00201</td>
<td>Apr 84 to Nov 01</td>
<td>Stable low mallee/Cratystylis; Craty smaller, mallee larger in 2001; rear Craty more evident in 2001</td>
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<td>KO00301</td>
<td>Apr 84 to Nov 01</td>
<td>Stable low mallee/saltbush; saltbush may be increasing in density; fluctuation in crown density</td>
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<td>Stable Chenopod Shrubland; possible abundance increase to M. pyr.</td>
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<td>Stable; some taller shrub decline</td>
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<td>Stable; some perennial groundcover increase</td>
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<td>Apr 84 to Nov 01</td>
<td>Stable? But much growth/decline of shrubs since 1985</td>
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<td>ME00401</td>
<td>Apr 84 to Nov 01</td>
<td>Stable with thickening of tall shrub and low shrub cover through size increase</td>
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<tr>
<td>ME00501</td>
<td>Apr 84 to Nov 01</td>
<td>Stable Bluebush; Tree profile at rear has altered markedly</td>
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<td>MJ00101</td>
<td>Apr 84 to May 02</td>
<td>Stable Mulga/Bluebush; Mulga crowns thinned</td>
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<td>Apr 84 to May 02</td>
<td>Mulga declining especially, crown foliage density, but marked increase in tall shrub growth (Ac ligulata?)</td>
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<td>Apr 84 to May 02</td>
<td>Stable Mulga/Ptilotus</td>
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<tr>
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<td>Apr 84 to May 02</td>
<td>Stable Mulga/Ptilotus</td>
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<tr>
<td>MJ00501</td>
<td>Apr 84 to Jul 85</td>
<td>Stable Malaleuca/Tall shrubs (Dods?) with size increase of tall shrubs</td>
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<tr>
<td>YA00101</td>
<td>Apr 84 to Jul 85</td>
<td>Stable Malaleuca/Cratystylis</td>
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<td>Apr 84 to Jul 85</td>
<td>Stable Malaleuca/Saltbush</td>
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<td>YA00301</td>
<td>Apr 84 to Jul 85</td>
<td>Stable Myoporum/Saltbush; some mid-shrub growth</td>
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<td>Stable Malaleuca/Melaleuca/Saltbush</td>
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<tr>
<td>YA00501</td>
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<td>Stable dune shrubs</td>
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