The survey

Methodology (PA Waddell)
Geomorphology (PA Waddell)
Soils (P Hennig)
Vegetation (AK Gardner)
Habitat type ecology (PA Waddell and AK Gardner)
Land systems (PA Waddell)
Resource condition (PA Waddell)
Resource management (PA Waddell)
Methodology

PA Waddell

The rangeland resource survey of the Western Australian part of the Nullarbor region was jointly undertaken by the Department of Agriculture and Food (DAFWA) and Landgate (formerly the Department of Land Information). This survey is the thirteenth of its type in a program of rangeland classification, mapping and resource evaluation in the State.

Rangeland surveys have been conducted in Western Australia since the 1950s when they were commenced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Rangeland surveys have been widely used in Western Australia by CSIRO (Speck et al. 1960; Mabbutt et al. 1963; Speck et al. 1964; Stewart et al. 1970) and in joint Department of Agriculture, Western Australia (now Department of Agriculture and Food, WA) and Department of Lands and Surveys (now Landgate) rangeland surveys which are commissioned by the Pastoral Lands Board of Western Australia (Wilcox & McKinnon 1972; Payne et al. 1979; Mitchell, McCarthy & Hacker 1979; Payne, Curry, & Spencer 1987; Payne, Mitchell & Holman 1988; Payne & Tille 1992; Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998; Van Vreeswyk et al. 2004; Cotching 2005; Hennig 2009).

The land system approach to mapping different country types has been used in all of the previous regional rangeland surveys in Western Australia. The concept of land systems was first used by Christian and Stewart in 1953. They define a land system as 'an area with a recurring pattern of topography, soils and vegetation'. These recurring patterns can be seen using aerial photography or other remotely sensed images. It is assumed areas with a similar pattern represent the same land system. The land systems are ground-truthed during field work.

Land system boundaries are mapped from 1:50 000 scale aerial photographs and can be reproduced onto topographical maps or pastoral plans at any required scale. Maps at 1:100 000 scale have been found useful for both paddock and whole station applications (Curry et al. 1994); 1:50 000 scale plans are better suited to the preparation of environmental reviews for mining and engineering projects (e.g. Pringle 1995). Land systems can also be clearly mapped at a 1:250 000 or 1:500 000 scale for regional uses.

The minimum-sized area of land considered mappable at these scales is approximately one square kilometre (1 km²) in extent. Narrower areas, for example 500 m, can be mapped provided they are 1.5 km long. This allows long sinuous features such as Ponton Creek and the clay depressions of the Woorlba land system to be mapped.

Reconnaissance field work

Black and white aerial photographs at a scale of 1:50 000 were taken between 1997 and 1998, though in some western parts for areas affected by bushfire, aerial photos from 1980 were used. Aerial photographs were used to identify land system boundaries and to plan navigation throughout the survey area.

Reconnaissance trips were initially carried out between April 2000 and September 2001. This included visiting areas mapped during the 1974 Western Australian Nullarbor Plain survey (Mitchell, McCarthy & Hacker 1979). During these trips initial descriptions of the soil and vegetation were collected from 108 inventory sites. The Nullarbor survey was delayed when higher priorities required field work. The survey recommenced in 2005, though due to staffing changes two further reconnaissance trips were required; in May the southern areas were visited and in July northern areas.

To help define land system boundaries other sources of information on the biophysical resources of the survey area were reviewed, including Lowry's geology of the Western Australian part of the Eucla Basin (1970) in conjunction with the 1:250 000 geological map series produced by Geological Survey of Western Australia and Beard’s vegetation survey of the Nullarbor (1975).

The aim of the reconnaissance trips was to familiarise survey team members with eastern land systems identified in the 1974 survey (Mitchell, McCarthy & Hacker 1979), major land types and vegetation communities, and to trial and finalise field methods to be used during the survey. Plant species not identified in the field were collected and their locations recorded. These specimens were later identified with the assistance of staff from the Western Australian Herbarium. Due to the large area to be covered in a relatively short period the team mainly...
travelled along major tracks, moving through the area relatively quickly and camping in a different location each night.

At Cocklebiddy Roadhouse in June 2005 the Nullarbor Land Conservation District held a meeting where the survey team delivered a session for pastoralists explaining the procedures and intended outcomes for the Nullarbor survey. This provided an opportunity for the team to meet with present day pastoralists and to gain some local knowledge. To assist in the preliminary mapping of land systems pastoralists provided maps of their leases with the land systems they recognised marked out on their properties. Pastoralists’ opinions were also sought on such topics as the palatability of major plant species, stocking rates of different pasture types and the susceptibility of different pasture types to fire and grazing. During the reconnaissance period former Nullarbor pastoralists and rangeland practitioners were also sought for advice and opinion.

The area was surveyed on a station by station basis. Prior to each trip traverse routes were planned for the pastoral leases to be visited. Between three and five days were spent on each lease depending on size. Pastoralists were notified when the team would be in their area and encouraged to spend at least one day with the team while they were surveying their property.

Land system identification in previous surveys involved mapping provisional land system boundaries onto aerial photography using a stereoscope prior to each field trip. Once in the field ground-truthing determined the accuracy of provisional boundaries, with amendments made as required. In the land zones other than the Nullarbor Plain proper such as the Hampton Tableland, Mardabilla Plain, Nyanga Plain and the Roe Plains this method was successfully applied, primarily in the west and south of the survey area. The 1:250 000 geological map series produced by the Geological Survey of Western Australia was also used to help determine provisional land system boundaries.

This method, however, proved impractical for the vast and featureless areas of the Nullarbor Plain. Land systems occur over a much broader scale than in previous rangeland surveys and have poorly defined boundaries, tending to transition into adjoining systems over a distance of kilometres. The land systems on the Nullarbor Plain are difficult to distinguish because of the lack of relief in the landform and the similarity in vegetation communities across the same geology. As Mitchell, McCarthy and Hacker (1979) found in the 1974 survey many land systems on the Nullarbor Plain are defined and differentiated by the arrangement of jointing patterns. Differential weathering along these jointing patterns has led to the development of drainage floors of variable form (Lowry 1970). Where jointing patterns differentiate land systems, in most cases no distinct boundary can be discerned, a transitional zone occurs where characteristics from both land systems are evident, sometimes for up to 5 km.

In determining these broad land systems traditional stereoscopic photograph interpretation was supplemented by LANDSAT satellite imagery printed onto A0 sheets at 1:50 000 to correspond with the aerial photographs. This assisted in identifying the vast land systems of

Main field work

Between September 2005 and November 2007 eleven trips lasting two to three weeks were made to the survey area. The survey team comprised two rangeland advisers and a soil surveyor from the Department of Agriculture and Food and a navigator from Landgate. The staff involved was:

- Rangeland advisers: PA Waddell, AK Gardner
- Navigator: KA Leighton
- Soil surveyor: P Hennig
the Nullarbor Plain. Land system boundaries drawn by pastoralists during the Cocklebiddy workshop also provided a valuable method for determining provisional land system boundaries. Aerial photography was still used in the field for these areas and observations regarding the landscape were marked onto the photos to assist in the final determination of a land system boundary.

Problems in navigating through this featureless terrain were largely overcome through the use of LANDSAT imagery and software linked to a Global Positioning System (GPS) unit. This was viewed on a laptop computer in real time and allowed the team to accurately determine its position on the satellite imagery in the field. During field work the navigator recorded the location of all station infrastructure both on the aerial photographs and into a geo-referenced computer program. Names of bores, dams and paddocks were checked with the pastoralist, and the positions of new watering points, tracks and fences were recorded. This ensured land resource information could later be supplied to land managers on an accurate base map.

**Traverses**

The navigator followed the predetermined traverse on the aerial photographs and LANDSAT imagery. This allowed land system boundaries to be marked, verified or amended as necessary. At 1 km intervals along the traverse the land system, land unit and habitat type were recorded. In addition, an assessment of range condition was made. The range condition was recorded as a rating of vegetation condition and the extent of accelerated erosion at the site. The 'site' was considered to be an area within a 50 m radius of the vehicle at the kilometre interval point.

The ratings of vegetation condition were subjective visual assessments. They are based on the assessor knowing what type of vegetation is supported on the particular landform/soil association being assessed and an understanding of the natural range in attributes such as species composition, density and cover and the effect unnatural and natural disturbances have on the landscape. A rating of very good, good, fair, poor or very poor was given, based on the extent of induced changes from the 'natural' state of the landscape (Table 6).

Pastoralism is the most extensive land use in the survey area, and the changes observed from the ‘natural’ state are mostly attributed to the development of artificial water points and grazing by introduced stock, native herbivores and feral animals, particularly rabbits. In conjunction with grazing, fire has a major role in extensively altering much of the Nullarbor landscape. Some vegetation communities have undergone ecological changes so dramatic the original perennial species composition has been replaced by an annual component. Some areas are now considered to be in a state of irreversible transition and therefore were assessed on their present form rather than speculating on their former state.

Table 6 **Criteria for assessment of vegetation condition**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition indicators</th>
</tr>
</thead>
</table>
| 1      | Excellent or very good  
For the land unit-vegetation type, the composition and cover of shrubs, perennial herbs and grasses is near optimal; free of obvious reductions in palatable species or increases in unpalatable species, or the habitat type supports vegetation which supports vegetation which is predominantly unattractive to herbivores and is thus largely unaltered by grazing. |
| 2      | Good  
Perennials present include all or most of the palatable species expected; some less palatable or unpalatable species may have increased, but the total perennial cover is not very different from the optimal. |
| 3      | Fair  
Moderate losses of palatable perennials and/or increases in unpalatable shrubs or grasses, but most palatable species and stability desirables still present; foliar cover is less than on comparable sites rated 1 or 2 unless unpalatable species have increased. |
| 4      | Poor  
Conspicuous losses of palatable perennials; foliar cover is either decreased through general loss of perennials or is increased by the invasion of unpalatable species. |
| 5      | Very poor  
Few palatable perennials remain; cover is either greatly reduced, with much bare ground arising from loss of stability desirables, or has become dominated by a proliferation of unpalatable species. |
In assessing range condition past surveys have rated vegetation condition alongside an assessment of accelerated erosion when present. The lack of surface drainage means the Nullarbor has not developed the large scale accelerated water-induced erosion features seen in other southern rangeland regions, particularly those with exoreic drainage now displaying widespread catchment dysfunction (Pringle, Watson & Tinley 2006). The Nullarbor land surface, especially the Nullarbor Plain with its shallow soils, has been extensively shaped through wind erosion (Lowry 1970), as well as by localised natural erosion cells driven by karst processes.

Reconnaissance trips and early traverse ratings recognised a high level of erosion across many habitat types and the dilemma faced in attributing the cause of the erosion. Whilst acknowledging pastoral activities have contributing to overgrazing leading to accelerated erosion at some locations, especially the large piospheres (zones of attenuated impact) radiating out from water points, it is increasingly difficult away from water points to differentiate natural erosion cells, a feature of the karst, against pastoral-induced erosion cells (Gillieson, Cochrane & Murray 1994). Forms of erosion away from water points were assessed on their origin, anthropogenic or karst-induced, and this was taken into account when determining a condition rating. Where erosion was attributed to pastoral activities this contributed to downgrading a site’s rating. The criteria for assessment of accelerated erosion are provided in Table 7.

To aid in assessment of each site the presence and abundance of the dominant vegetation species was recorded. As an indicator of the grazing pressure such features as the abundance of stock pads and browse lines was also recorded. If an assessment point was less than 100 m from an area of human-induced disturbance such as a quarry, road works or building then no assessment of range condition was made.

<table>
<thead>
<tr>
<th>Type – intensity combination</th>
<th>Criteria for assessment of accelerated erosion at sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>No accelerated erosion present</td>
<td><strong>No accelerated erosion present</strong></td>
</tr>
<tr>
<td>Slight erosion (&lt; 10% of site affected)</td>
<td>Slight accumulation of wind-blown soil around plant bases and other obstacles and/or</td>
</tr>
<tr>
<td></td>
<td>Removal of finer soil particles evident but soil crust is largely intact and/or</td>
</tr>
<tr>
<td></td>
<td>Occasional rills (&lt; 300 mm deep evident) and/or</td>
</tr>
<tr>
<td></td>
<td>A few scalds present, usually &lt; 2 m in diameter</td>
</tr>
<tr>
<td>Minor erosion (10–25% of site affected)</td>
<td>Accumulation of soil around plant bases with plant mounds noticeably enlarged and/or</td>
</tr>
<tr>
<td></td>
<td>Evidence of pedestalling but soil loss minor and plant bases not greatly elevated and/or</td>
</tr>
<tr>
<td></td>
<td>Breaking of surface crust with small erosion faces and some redistribution of soil and/or</td>
</tr>
<tr>
<td></td>
<td>Rilling evident but no gully development and/or</td>
</tr>
<tr>
<td></td>
<td>Scalding evident but scalds relatively small and discontinuous</td>
</tr>
<tr>
<td>Moderate erosion (25–50%) of site affected</td>
<td>Soil piling around plant bases and other obstacles is common but no plants completely covered and/or</td>
</tr>
<tr>
<td></td>
<td>Pedestalling apparent with plant bases distinctly raised and with obvious soil loss and/or</td>
</tr>
<tr>
<td></td>
<td>Rilling common or gullying present of parts of site and/or</td>
</tr>
<tr>
<td></td>
<td>Surface sheeting with erosion faces (and/or microterracing) and active redistribution of soil and/or</td>
</tr>
<tr>
<td></td>
<td>Wind scalds common</td>
</tr>
<tr>
<td>Severe erosion (50–75% of site affected)</td>
<td>Extreme hummocking around plants and other obstacles; some plants completely covered and/or</td>
</tr>
<tr>
<td></td>
<td>Severe pedestalling with plant bases greatly elevated and major soil loss and/or</td>
</tr>
<tr>
<td></td>
<td>Widespread rilling or major gullying and/or</td>
</tr>
<tr>
<td></td>
<td>Scalding extensive, smaller scalds have coalesced to form large, more or less continuous scalded areas and/or</td>
</tr>
<tr>
<td></td>
<td>Surface sheeting with extensive exposure of subsoil or parent material; erosion faces (and/or microterracing) and active redistribution of soil and/or</td>
</tr>
<tr>
<td></td>
<td>Much of surface generally unstable with ripple mark formation</td>
</tr>
<tr>
<td>Extreme erosion (75–100% of site affected)</td>
<td>General surface movement, total surface area bare with formation of shifting dunes and/or</td>
</tr>
<tr>
<td></td>
<td>Surface shifting and or scalding complete with exposure of subsoil or parent material and/or</td>
</tr>
<tr>
<td></td>
<td>Extensive gullyling</td>
</tr>
</tbody>
</table>
Ninety traverse routes, with an average length of 80 km, were completed in the survey area. These are shown in Figure 22. Some 6997 traverse points were recorded in the survey area, 6276 of which had a range condition assessment within pastoral lease boundaries. The geographical locations of the traverse points were stored using a GPS navigation unit linked to a geo-referenced computer program.

**Inventory and condition sites**

Inventory sites were selected to ensure each major land unit within each land system was adequately sampled and to assist in interpreting land system patterns as identified on aerial photos and LANDSAT imagery. Occasionally, when a different land unit/vegetation/soil association was encountered in the field additional sites were selected.

The aim of inventory sites is to collect information at the land unit scale. The site is considered to be an area within a 50 m radius of the survey vehicle. If the land unit was smaller, the assessor would only record information for the area within the selected unit.

In conjunction with inventory sites, at locations representative of major habitat type groups condition sites were sampled determined by distances from permanent water points (0.5, 1, 2, 4 or > 5 km). This allowed investigation of various site attributes which could be used to determine key variables of ecological disturbance and to characterise the patterns of condition states within major habitats.

---

*Figure 22 Traverse and reconnaissance routes in the survey area*
Condition sites provided a means of calibrating visual resource condition assessments. Sampling techniques to interpret perennial plant species density were undertaken using different size classes of quadrats depending on the vegetation type. For bindi–grassland communities the frequency of perennial grass and shrub species was assessed using 0.5 m² quadrats. For chenopod shrubland sites perennial species were counted within 100 m² quadrats.

At each site information on the landform, vegetation and soil was recorded onto a standard record sheet similar to those used by Curry et al. (1994) in the Murchison regional survey. The attributes recorded at sites were:

**General**
- site number
- land system
- land unit
- pastoral station
- GPS location
- 1:250 000 map sheet name
- aerial photograph year, run and number
- date
- compass bearing of the site photograph.

**Physical environment**
- slope (in percentage)
- unit relief
- geology (according to the 1:250 000 Geological Survey series)
- site geology—if different to the mapped geology
- surface mantle abundance, shape, size and type
- outcrop, abundance and type
- type and intensity of accelerated erosion features
- vegetation condition rating
- extent and type of surface crusting
- evidence of fire.

**Vegetation**
- habitat type
- projected foliar cover (PFC) class of perennial shrubs (Table 8, Curry, Payne & Wilcox 1983)
- the dominant species in each stratum
- the relative dominance of each stratum
- basal cover class for perennial grasses
- height class of tree stratum
- height class of tall shrub stratum
- list of perennial plant species
- list of annual species.

**Soil**
- Australian Soil Classification class (Isbell 1996)
- total soil depth
- substrate
- soil surface condition
- type and structure of pans
- soil reaction trend
- observation method
- details of soil horizon; horizon designation, depth, texture and texture group, moist colour, soil moisture status, consistence, porosity, fabric, structure, ped shape, boundary distinctness, abundance, shape, size and type of coarse fragments and segregations, effervescence with concentrated hydrochloric acid and field pH.

Notes and landscape sketches were also made on an ad hoc basis. At each site a standardised method was used to photograph the site. The photo was taken from the top of the survey vehicle with a board identifying the survey and site number placed about 10 m away.

It usually took between 30 and 60 minutes to complete the description of an inventory and/or a condition site. Over the course of the survey 392 inventory sites were sampled, though eight registered outside the survey area. Figure 23 shows the location of inventory sites, including those sampled from the 1974 survey.

Table 8 Foliar cover classes for tree and shrub strata (Curry, Payne & Wilcox 1983)

<table>
<thead>
<tr>
<th>Foliar cover class</th>
<th>Projected foliar cover (%)</th>
<th>Foliar cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0–2.5</td>
<td>Isolated</td>
</tr>
<tr>
<td>2</td>
<td>2.5–5</td>
<td>Very scattered</td>
</tr>
<tr>
<td>3</td>
<td>5–10</td>
<td>Very scattered</td>
</tr>
<tr>
<td>4</td>
<td>10–15</td>
<td>Scattered</td>
</tr>
<tr>
<td>5</td>
<td>15–20</td>
<td>Scattered</td>
</tr>
<tr>
<td>6</td>
<td>20–25</td>
<td>Moderately close</td>
</tr>
<tr>
<td>7</td>
<td>25–30</td>
<td>Moderately close</td>
</tr>
<tr>
<td>8</td>
<td>30–50</td>
<td>Close</td>
</tr>
<tr>
<td>9</td>
<td>&gt; 50</td>
<td>Closed</td>
</tr>
</tbody>
</table>
Water point sampling

Information was also gathered on all artificial watering points located adjacent to traverse routes. The water point name, map coordinates, type of water body, field pH and salinity were recorded. Whether the watering point was operational and its position in the landscape was also noted.

Analysis of data

Traverse records

Traverse assessment data was recorded in a database. As the assessment points had been recorded using GPS, the points could be referenced on the land system resource maps. This allowed traverse information recorded in the field such as the pastoral lease, paddock name and land system to be cross-referenced with the location of each traverse point on the map and amended if necessary.

Summaries of the traverse assessments were made by sorting the data on the attributes for which information was required. For example: summaries of the land units and habitat types within each land system which assisted in developing land system descriptions; and summaries of the condition of pastoral leases, land systems, land units and habitat types in the survey area. Land system area and condition statements for individual pastoral stations were also prepared.

Inventory and condition site data

The inventory and condition site data was also entered into a database, sorted and analysed to develop detailed descriptions of land systems, land units, soil, vegetation and condition trends. These are presented in the main chapters of this report. The data was then linked to the resource maps, allowing spatial interrogation. Inventory site data from the 1974 survey was also used to provide information to assist with this report.

Map production

In the southern, western and northern parts of the Nullarbor survey area land system boundaries are well defined and could be readily mapped within the confines of 1:50 000 scale aerial photography. For the Nullarbor Plain, through the central and eastern parts of the survey area, the broadscale land systems were mapped onto A0 sheets showing LANDSAT imagery at 1:50 000 to correspond with the aerial photography. Land system boundaries were finalised using the knowledge gained during field work to reinterpret and confirm boundaries drawn on aerial photographs and A0 sheets. The aerial photographs and A0 sheets were scanned and computer software was used to digitise land system boundaries.

Figure 23 The distribution of inventory sites in the survey area
First order or discernible land system boundaries were identified by solid lines. On the Nullarbor Plain land systems commonly lack obvious boundaries, tending to have a transitional zone of up to 5 km where characteristics from both land systems are likely to occur. On the map where there is no distinct land system boundary dashed lines indicate an approximate boundary occurring through the transitional zone between the land systems.

With improved aerial photography and the benefit of LANDSAT imagery the land systems identified in the eastern part of the Western Australian Nullarbor Plain during the 1974 survey (Mitchell, McCarthy & Hacker 1979) have been reassessed and in some cases boundaries have been modified. Four land systems from the 1974 survey were extensively modified resulting in one system being re-named and three systems incorporated into others.

Topographical and cultural information covering the survey area was loaded onto the computer system and updated with information collected during the field work. Land system boundaries were overlain on this background information. Maps were edited to make all features and text clear and legends were added.

Resource information has been presented on a land system map which accompanies this report. If clients require more detail, maps can be provided at a smaller scale. Special purpose maps can be produced displaying any combination of information presented on the accompanying map, as data have been captured in a multilayered geographically referenced digital format. Not all the data collected during the field work is presented in this report or on the accompanying map. More detailed information is available from the Department of Agriculture and Food on request.

Station plans at a scale of 1:100 000 have also been produced for each of the pastoral leases within the survey area. These are available to lease holders as full colour maps from the Department of Agriculture and Food.

References

Beard, JS 1975, Vegetation survey of Western Australia – Nullarbor, Sheet 4, University of Western Australia Press, Nedlands, Western Australia.


Cotching, WE 2005, An inventory of rangelands in part of the Broome Shire, Western Australia, Department of Agriculture, Western Australia, Technical Bulletin No. 93.

Curry, PJ, Payne, AL, Leighton, KA, Hennig, P & Blood, DA 1994, An inventory and condition survey of the Murchison River catchment and surrounds, Western Australia, Department of Agriculture, Western Australia, Technical Bulletin No. 84.


Geological Survey 1:250 000 scale geological map sheets and explanatory notes (various authors and dates), Balladonia, Culver, Cundeelee, Eucla–Noonaera, Forrest, Loongana, Madura–Burnabbie, Naretha, Seemore and Zanthus.


Hennig, P 2009, An inventory and condition survey of the lower Murchison River area, Western Australia, Department of Agriculture and Food, Western Australia, Technical Bulletin No. 96.


Mitchell, AA, McCarthy, RC & Hacker, RB 1979, A range inventory and condition survey of part of the Western Australian Nullarbor Plain, 1974, Western Australian Department of Agriculture, Technical Bulletin No. 47.

Munsell Color Co. 1954, Soil color charts, Munsell Color Co., Baltimore, USA.

Payne, AL, Kubicki, A, Wilcox, DG & Short, LC 1979, A report on erosion and range condition in the West Kimberley area of Western Australia, Western Australian Department of Agriculture, Technical Bulletin No. 42.

Payne, AL, Curry, PJ & Spencer, GF 1987, An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia, Western Australian Department of Agriculture, Technical Bulletin No. 73.


Payne, AL & Tille, PJ 1992, An inventory and condition survey of the Roebourne Plains and surrounds, Western Australia, Western Australian Department of Agriculture, Technical Bulletin No. 83.

Payne, AL, Van Vreeswyk, AME, Pringle, HJR, Leighton, KA & Hennig, P 1998, An inventory and condition survey of the Sandstone-Yalgoo-Paynes Find area, Western Australia, Agriculture Western Australia, Technical Bulletin No. 90.


Pringle, HJR, Van Vreeswyk, AME & Gilligan, SA 1994, An inventory and condition survey of the north-eastern Goldfields, Western Australia, Department of Agriculture, Western Australia, Technical Bulletin No. 87.

Pringle, HJR, Watson, IW & Tinley, KL 2006, ‘Landscape improvement, or ongoing degradation — reconciling apparent contradictions from the arid rangelands of Western Australia’, Landscape Ecology, 21, 1267–1279.

Speck, NH, Bradley, J, Lazarides, M, Patterson, RA, Slayter, RO, Stewart, GA & Twidale, CR 1960, The lands and pastoral resources of the North Kimberley area, Western Australia, CSIRO Land Research Series No. 4.


Van Vreeswyk, AME, Payne, AL, Leighton, KA & Hennig, P 2004, An inventory and condition survey of the Pilbara region, Western Australia. Department of Agriculture Western Australia, Technical Bulletin No. 92.

**Geomorphology**

*PA Waddell*

**Introduction**

The geomorphology of the survey area is described in terms of its morphotectonic setting at a continental and regional scale. Land surface types are described with reference to their component land systems. Landscape evolution is discussed in terms of Cainozoic alteration of the morphotectonic setting and the interactions between land use and landscape processes are considered.

**Physiographic regions of the Nullarbor Plain Province**

Physiographically most of the survey area occurs within the Nullarbor Plain Province of Jennings and Mabbutt (1977). The westernmost margin of the survey area extends into the Coonana–Ragged Plateau section of the Yilgarn Plateau Province (Figure 24). Within the Nullarbor Plain Province the survey area occupies all or parts of the following component sections of the Province – the Carlisle Plain, the Bunda Plateau, the Israelite Plain, the Roe Plains and supports a low chenopod shrub and *Austrostipa scabra* (speargrass cover over its greater part. The sections occupied by the survey area are described in Table 9.

**Table 9 Brief description of the physiographic regions in the survey area (Jennings & Mabbutt 1977)**

<table>
<thead>
<tr>
<th>Province</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nullarbor Plain</td>
<td>Carlisle Plain—sandstone plain with shallow closed depressions</td>
</tr>
<tr>
<td></td>
<td>Bunda Plateau—covered karst plain of flat-lying limestone with closed depressions and caves; continuous cliff margin on south coast</td>
</tr>
<tr>
<td></td>
<td>*Israelite Plain—narrow coastal plain with extensive dunes</td>
</tr>
<tr>
<td></td>
<td>Roe Plains—coastal plain with extensive dunes</td>
</tr>
<tr>
<td>Yilgarn Plateau</td>
<td>*Coonana–Ragged Plateau—sandplain and stripped gneissic plains with low hills of granite and metamorphic rocks; calcrite and scattered small salt lakes along shallow valleys</td>
</tr>
</tbody>
</table>

* Only very small parts of these sections fall within the survey area.

**Figure 24 Physiographic regions of the Nullarbor (after Jennings & Mabbutt 1977)**
Lowry (1970) identified five main physiographic units within the Eucla Basin: a plateau (the Bunda Plateau), a scarp (known in different places as the Hampton Range, Baxter Cliffs and Wylie Scarp), two coastal plains (Roe Plains and Israelite Plain), and a continental shelf (the Eucla Shelf).

Lowry (1970) further divided the Bunda Plateau into physiographic regions based on differences in geological history, topography, soil, vegetation and climate (Figure 25).

- **Nullarbor Plain** – restricted to the treeless part of the limestone karst in the centre of the Bunda Plateau. The landscape is generally of low relief, generally less than 4 m, and is characterised by different forms of karst depressions which form corridors of linear depressions and ‘dongas’ (locally named rounded depressions or claypans) separated by low rocky limestone ridges or rises.

- **Hampton Tableland** – in the south of the Bunda Plateau between the Nullarbor Plain to the north and bordered by the Baxter Cliffs and Hampton Range to the south. The region is characterised by undulating ridge-corridor topography with an average relief greater than elsewhere on the Bunda Plateau.

  - **Nyanga Plain** – in the west of the Bunda Plateau to the north and west of the Nullarbor Plain and the Hampton Tableland. Broad flat plains of variably thick and continuous residual clay loam and calcrete overlying Nullarbor Limestone characterise this region.
  
  - **Mardabilla Plain** – in the south-western part of the Bunda Plateau and is bordered by the Wylie Scarp to the south and the Nyanga Plain to the north-east. The surface of the plain is covered with clay and calcrete. Numerous inliers of crystalline basement rock protrude through the plateau surface.
  
  - **Carlisle Plain** – north of the Nyanga Plain. The Carlisle Plain is developed on the Colville Sandstone and consists of plains with sparsely vegetated sandy soil.

![Figure 25 Physiographic divisions of the Eucla Basin from Lowry and Jennings (1974)](image-url)
The regional geology is characterised by near-horizontal sequences of Cainozoic sediments, predominantly limestones and calcrite, overlying Cretaceous sedimentary rocks of the Eucla Basin on an irregular basement of Precambrian granite and metamorphic rocks. The survey area may be divided into two distinct geological regions within which a number of land zones have been defined. The major geological regions are the Bunda Plateau and the coastal Roe and Israelite plains. The major feature is the Bunda Plateau which also includes Quaternary sandplains on the margins of the Eucla Basin.

The survey area is situated largely within the Western Australian portion of the Eucla Basin (Jutson 1950), the margins corresponding with the limit of the present distribution of the Eucla Group. Lowry (1970), expanding on from Singleton (1954), described the Eucla Group as all sedimentary rocks deposited in the Eucla Basin between the Middle Eocene and the Lower Miocene comprising the Hampton Sandstone, Wilson Bluff Limestone, Toolinna Limestone, Abrakurrie Limestone, Nullarbor Limestone and Colville Sandstone. The upper formations of the Eucla Basin are exposed on cliffs and in caves, but the lower formations are obscured and known only from bores. The Western Australian margins of the Eucla Basin correspond with the limit of the Colville Sandstone and Plumridge Formation in the north and the Nullarbor Limestone and Toolinna Limestone in the west and south-west. The southern extremity of the basin is marked by the 200 m isobath of the continental shelf in the Great Australian Bight.

Lowry (1970) described the surface terrain as having formed as a result of a virtual absence of tectonism and an extreme regularity of karst weathering due in combination to the low rainfall, high permeability and surface solution of limestones forming the plateau surface. However Webb and James (2006) propose that climate only had a minor role in restricting karst development; it is more likely the relative lack of surface and underground karst features are due to the particular characteristics of the limestones (primary porosity, lack of jointing and inception horizons) in combination with the Nullarbor Plain's flat geomorphology and hardening of surface limestones by calcrite, which has increased resistance to solutional and erosional processes.

**Morphotectonic setting of the Eucla Basin**

By the close of the Late Precambrian the morphotectonic structures largely responsible for determining the future evolution of Western Australian geology were essentially in place (Wyrwoll & Glover 1988). The Western Australian Shield composed of the Yilgarn and Pilbara Blocks, associated orogenic belts and sedimentary basins has essentially remained the dominant morphotectonic element controlling the relative stability of large parts of present day land surfaces.

In the Palaeozoic Australia was part of the super continent Gondwanaland and the area where the Eucla Basin occurs was a stable land mass (Lowry 1970; Wyrwoll & Glover 1988). The basement rocks beneath the Eucla
Basin comprise Precambrian granite, gneiss, schist and quartzite in the south-west; with folded Proterozoic sedimentary rocks in some northern and eastern areas. When the Eucla Basin developed these Precambrian basement rocks in the south-western part had a high relief and were exposed to erosion (Lowry 1970).

By the Late Jurassic a divergence rift zone parallel to the present south coast had developed as the Gondwanaland sections of Australia and Antarctica began to separate through continental extension (Veevers, Jones & Powell 1982). Active Mesozoic drainage systems of easterly trend were precursors of modern drainage basins (Beard 1975). It is likely these drainage systems were responsible for reducing the topography of the western Precambrian rocks to the low irregular relief similar to the present day condition. Such erosion also stripped the extensive covering of tillite sediments deposited in the southern portions of the Eucla Basin during the Lower Permian (Lowry & Jennings 1974).

In the Early Cretaceous downwarping commenced in the Eucla Basin towards the southern rift (Wyrwoll & Glover 1988). Terrigenous conglomeratic sandstone (Loongana Sandstone) and siltstone and shale (the basal part of the Madura Formation) accumulated over the basins basement rocks (Lowry 1970). In the Early to Middle Cretaceous 120 to 125 million years ago (Ma) the break-up commenced between Australia and Antarctica (Hocking 1990). As subsidence continued the sea entered the Eucla Basin from the south or south-west. Marine deposition occurred across the basin and continued through to the Late Cretaceous. Marine sediments during this period continued to form the Madura Formation and the overlying Toondi Formation. In the Late Cretaceous the central area of the basin was overlain with glauconitic sandstone and sandy siltstone (Nurina Formation) (Hocking 1990). Towards the end of the Cretaceous the Officer Basin was uplifted to become land, deposition ceased in the Eucla Basin and did not recommence until the Middle Eocene (Lowry 1970).

The Australian continent began its northerly drift away from Antarctica in the Middle Eocene. Stratigraphic and palaeontologic evidence indicates Australia has become increasingly drier as it drifts northward into the arid mid-latitudes between the temperate and tropical latitudes (Jennings 1967; Lowry 1970; Beard 1975; Wasson 1982; Wyrwoll & Glover 1988; Benbow 1990a; Gillieson & Spate 1992).

During the Middle Eocene (45 Ma) downwarping of the Eucla Basin recommenced and was accompanied by marine invasion. Deposition started in the basin’s centre with lenticular sandstone (Hampton Sandstone) followed by marl (the lower part of the Wilson Bluff Limestone) until a brief pause in downwarping (Lowry 1970). In the Late Eocene downwarping resumed with the deposition of chalky, bryozoan limestone (the upper part of the Wilson Bluff Limestone) occurring across the basin in areas of calmer water and well sorted bryozoan limestone (Toolinna Limestone) in the south-west under higher energy conditions (Lowry 1970). These processes continued until the end of the Late Eocene when downwarping ceased and the sea regressed past the present shoreline, resulting in weathering and erosion across the surface of the Wilson Bluff Limestone for over 10 million years (Webb & James 2006).

In the Late Oligocene to Early Miocene (25 Ma) the sea returned resulting in the deposition of bryozoan calcarenite and calcirudite (Abrakurrie Limestone) over the centre of the basin. By the Early to Middle Miocene the marine transgression had expanded to cover the entire Eucla Basin (Lowry 1970; Hocking 1990). Widespread deposition of foraminiferal and algal calcarenite followed (Nullarbor Limestone and its basal unit, the Mullamullang Limestone Member). The Nullarbor Limestone extensively overlies most of the basin except where it laterally merges, at its northern margins, into calcareous sandstone (Colville Sandstone) (Lowry 1970) and its equivalents further east (Benbow 1990b). The Colville Sandstone grades northwards into fine-grained sandstone and siltstone with lesser claystone and conglomerate (Plumridge Formation) (Hocking 1990). The limit of the Miocene shoreline is marked by the western and northern margins of the Nullarbor Limestone and Colville Sandstone respectively, a Permian sandstone scarp in the far north and Eocene dunes of the Ooldea Range in the northeastern margin of the Bunda Plateau, in South Australia (Lowry & Jennings 1974; Benbow 1989, 1990a). Lowry (1970) stated that as there is no evidence that other areas of
southern Western Australia were submerged in the Miocene, the transgression was probably due to downwarping of the Eucla Basin.

**Evolution of landforms in the Cainozoic**

In the Middle to Late Miocene (about 15–12 Ma) the Australian continent was uplifted. Uplift of the Eucla Basin combined with global eustatic lowering of sea level resulted in the sea finally receding, exposing the Miocene sea floor. From the extent of the uplift and the vast, exposed surface of the Nullarbor Limestone, brought about by the lengthy duration of erosion, Lowry (1970) concluded the Eucla Basin had stopped subsiding. Karst features characteristic of the Bunda Plateau have since developed on and below this surface.

Since the Miocene uplift there has been extensive coastline recession of the carbonate geology where the more durable Precambrian rocks are absent, forming the Great Australian Bight. Aside from the Israelite and Roe coastal plains the land begins at the top of the limestone cliffs forming the southern edge of the Bunda Plateau, 60–100 m above sea level. West of Point Malcolm, in the Esperance District, Precambrian outcrop has reduced the effects of marine erosion along the southern coastline.

Sloping upwards from the southern sea-cliffs, to about 250 m above sea level at the northern perimeters, the majority of the Bunda Plateau’s surface is a vast and featureless limestone plain with only minimal evidence of coordinated drainage systems that became inactive during the Pleistocene. The perpetuation of the flatness of this uplifted sea floor is the result of extreme regularity in weathering and minimal tectonic activity (Lowry 1970).

On the Bunda Plateau there are primarily two kinds of surface relief. Both features can be described in terms of minor differential surface solution of limestones directed by joint patterns. Of widespread occurrence is the undulating relief of parallel, low ridges separated most often by open depressions, though closed depressions are common in some systems. The wavelength between undulations is commonly 400–1600 m, though it can be greater, with an amplitude of 1.5–3 m, though nearer the coast it can be up to 10 m. The ridges form regular limestone rises scattered with rocky outcrop whilst the open depressions have clay loam soils. These undulations are straight and parallel but the trend changes throughout the plain reflecting the systematic tectonic control through joint directions (Jennings 1967a, 1967b). In some locations where joint patterns of equal importance converge, the relief pattern develops into a lattice arrangement. Here, shortened ridges occur as compact low rises (limestone hummocks) and are surrounded by smaller depressions.

Further inland there are also circular closed karstic depressions locally termed ‘dongas’, 400–1600 m or more across and a metre or two deep, commonly clay-floored with or without gilgai micro-relief. In some areas these depressions are arranged in lines parallel with the regular wave pattern of the ridges and corridors, but elsewhere they are randomly scattered (Jennings 1967a). Dongas are considered solution dolines rather than collapsed caves, formed through water ponding in depressions in the limestone plain with solution further dissolving the limestone and deflation later exposing them (Jennings 1963; Lowry 1970).

Erosion features normally associated with limestone country, such as solution sculptured pits and rock-holes in outcrop, sinkholes, dolines, underground drainage and caverns, are scarce in proportion to the regions area (Jennings 1967a, 1967b; Lowry & Jennings 1974; Webb & James 2006). The majority of solution features occur in the south of the Plateau where rainfall has presumably always been higher than further inland. Despite having a long history this karst is considered to have remained immature and retarded, due to a lack of water available to initiate greater solution sculpturing (Jennings 1967a, 1967b). Both Jennings (1967b) and Lowry (1970) state that the climate has never been much more humid than at present for long periods since it emerged from the Miocene sea.

In the Pliocene marine erosion carved sea-cliffs into the uplifted limestones (James et al. 2006). During the Late Pliocene the underlying calcarenite geology for the two coastal plains of the Western Australian portion of the Eucla Basin was deposited (Hocking 1990; James et al. 2006). Several sea level changes associated with Pleistocene climatic fluctuations are marked today by old strand-lines on the Roe Plains. During this period the maximum high sea level stand was about 36 m above the
present sea level (Lowry 1970). The coastal
dunes overlying these plains are primarily
calcareous and on the basis of calcrete
development three significant stages of dune
building can be identified (Jennings 1968;
Lowry 1970).

From the Late Pliocene through the
Pleistocene alternating glacial and interglacial
periods influenced and controlled the develop-
ment of geomorphic features. In the Early
Pleistocene, following the onset of arid condi-
tions, erosional periods were responsible for
significant deflation of the soils of the central
Nullarbor Plain (Jessup 1961; Lowry 1970).
Lowry (1970) proposed that the combination of
low rainfall and the high permeability of the
plateau surface limestones had resulted in the
regularity of weathering across the plateau,
with up to 100 m of the surface limestone
removed. The extent of deflation that occurred
during this period exposed the subsurface relief
of the joint controlled depression and ridge
topography. However Webb and James (2006)
state that the combination of the flatness of the
plain and the hardening of the surface by
calcrete are the features most likely respon-
sible for the uniform denudation and relative
lack of surface karst features; climate having
only a minor role.

The Roe Plains are backed by the Hampton
Range and the Israelite Plain is backed by the
Wylie Scarp (Figure 25). The exposed scarp
section of the Hampton Range displays
Nullarbor Limestone over Abakurrie Limestone
and the Wylie Scarp displays calcrete over
Toolinna Limestone (Lowry & Jennings 1974).
Both scarps are only slightly degraded by
erosion. Alluvial fans have developed below
fluvial gullies along the scarp face aligned with
structurally controlled joints. The bases of the
Hampton Range and Wylie Scarp are overlain
by a concave apron of colluvium, consisting
mostly of clay with fragments of limestone and
calcrete debris washed off the tops of the
scarps (Lowry 1970).

There are two sections of presently active sea-
cliffs along the southern margin of the Bunda
Plateau: the 160 km long Baxter Cliffs in
Western Australia and the 200 km long Bunda
Cliffs in South Australia. Along the top of the
Baxter Cliffs there are sections of weathered
sand dunes. These cliff-top dunes are wind-
blown Pleistocene sand deposits formed when
substantial quantities of drift sand accumulated
against the cliffs. Sand transported up climbing
dunes formed dune ramps to the top of the
plateau. Subsequent rises in sea level eroded
the ramps re-exposing the cliff face (Jennings
1968). Whilst the wave-cut cliffs and escarp-
ments of the plateau's southern margin were
formed during past interglacial stages, wave
action today continues to erode the sea-cliffs
since the last post-glacial rise in sea level
(Davey et al. 1992; James et al. 2006).

The Bunda Plateau is Australia's largest karst
area and the world's largest arid karst region
(~250 000 km²). Arid climatic conditions, the
high permeability of the plateau surface
limestones, concretisation and the geomorphol-
ogy of the plain have been the major factors
responsible for the evolution of the present day
relief; a landscape shaped by extreme
regularity of weathering and minimal tectonic
activity. Since the emergence of the plateau
from the Miocene sea karst development has
remained restricted, most likely due to the
particular characteristics of the limestone and
the flatness of the plain. The vast, uniform land
surfaces of the Bunda Plateau, and the
associated Quaternary coastal plains, have
evolved by processes of erosion, weathering
and deposition.

Land surface types (groups of land
systems)

Eight land surface types were defined within
the survey area and grouped primarily on
geology, relief and landform, and secondly on
genesis and soil (Table 10). Land surfaces
have been further subdivided according to
vegetation and drainage patterns into 15 land
types which provide information at a more
regional level than that at the land system
scale (refer to land systems chapter).

(i) Calcrete plains

These surfaces are level to gently undulating
plains of very low relief formed of cemented
calcium carbonate developed as part of the
subsoil of an original soil profile. These
surfaces are generally underlain by various
limestones of the Eucla Group, except in rare
instances in the south-west where granite
outcrop protrudes through the surface. Pre-
dominantly consisting as relict land surfaces
with deposits of uncertain origin, some land
systems represent stages of transition with
<table>
<thead>
<tr>
<th>Land surface type</th>
<th>Land system</th>
<th>Predominant surface geology</th>
<th>Characteristic landform(s)</th>
<th>Dominant vegetation type</th>
<th>Survey location and distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Calcrete plains</td>
<td>Caiguna</td>
<td>Calcrete</td>
<td>Gently undulating plains with residual calcareous low rises</td>
<td>Low eucalypt woodland</td>
<td>South-west, common</td>
</tr>
<tr>
<td></td>
<td>Carlisle</td>
<td>Calcrete</td>
<td>Gently undulating partially deflated stony plains</td>
<td>Bindi grassland with sparse myall</td>
<td>North-east, uncommon</td>
</tr>
<tr>
<td></td>
<td>Colville</td>
<td>Calcrete</td>
<td>Very gently undulating plains overlain by sandy loam</td>
<td>Myall woodland over bindi grassland</td>
<td>North-east, rare</td>
</tr>
<tr>
<td></td>
<td>Culver</td>
<td>Calcrete</td>
<td>Gently undulating stony plains</td>
<td>Low mallee woodland overlain by sedges and hummock grasses</td>
<td>South, common</td>
</tr>
<tr>
<td></td>
<td>Gumbelt</td>
<td>Calcrete</td>
<td>Very gently undulating plains overlain by sandy loam</td>
<td>Eucalypt woodland with mixed scrub understorey</td>
<td>West, common</td>
</tr>
<tr>
<td></td>
<td>Haig</td>
<td>Calcrete</td>
<td>Level loamy plains</td>
<td>Chenopod shrubland or bindi grassland</td>
<td>Central, rare</td>
</tr>
<tr>
<td></td>
<td>Jubilee</td>
<td>Calcrete</td>
<td>Undulating and dissected plains</td>
<td>Bindi grassland with very scattered myall</td>
<td>North-east, uncommon</td>
</tr>
<tr>
<td></td>
<td>Kyarra</td>
<td>Calcrete</td>
<td>Level loamy plains</td>
<td>Bindi grassland with sparse myall</td>
<td>Central and north, common</td>
</tr>
<tr>
<td></td>
<td>Moodini</td>
<td>Calcrete</td>
<td>Level to gently undulating sandy loam plains</td>
<td>Eucalypt or myall woodland</td>
<td>South-east, rare</td>
</tr>
<tr>
<td></td>
<td>Moopina</td>
<td>Calcrete</td>
<td>Level sandy clay plains</td>
<td>Eucalypt and melaleuca woodland; false bluebush shrubland in drainage foci</td>
<td>South-east, rare</td>
</tr>
<tr>
<td></td>
<td>Nyanga</td>
<td>Calcrete</td>
<td>Level loamy plains</td>
<td>Myall or casuarina woodland over chenopod understorey</td>
<td>West and north, very common</td>
</tr>
<tr>
<td></td>
<td>Rabbit</td>
<td>Calcrete</td>
<td>Level loamy plains</td>
<td>Bindi grassland</td>
<td>North-east, rare</td>
</tr>
<tr>
<td></td>
<td>Zanthus</td>
<td>Calcrete</td>
<td>Level sandy loam plains</td>
<td>Mallee woodland overlain by spinifex</td>
<td>West, rare</td>
</tr>
<tr>
<td>(ii) Depressions within calcrete plains</td>
<td>Koonjarra</td>
<td>Calcrete</td>
<td>Low breakaways and depressions</td>
<td>Chenopod shrubland or grassland</td>
<td>West, uncommon</td>
</tr>
<tr>
<td></td>
<td>Woortba</td>
<td>Calcrete</td>
<td>Closed depressions</td>
<td>Chenopod shrubland or grassland</td>
<td>South-west, uncommon</td>
</tr>
<tr>
<td>(iii) Granite outcrop in calcrete plains</td>
<td>Balladonia</td>
<td>Granite</td>
<td>Low granite outcrop</td>
<td>Bare granite outcrop with fringing acacia–dodonaea–eremophila shrubland</td>
<td>South-west, rare</td>
</tr>
<tr>
<td>(iv) Limestone plains [with deeper soil than (v)]</td>
<td>Kanandah</td>
<td>Recrystallised Limestone</td>
<td>Gently undulating plains</td>
<td>Myall woodland over pearl bluebush shrubland or bindi grassland</td>
<td>North-west, common</td>
</tr>
<tr>
<td></td>
<td>Lowry</td>
<td>Recrystallised Limestone</td>
<td>Undulating rise overlain by sandy loam</td>
<td>Pearl bluebush shrubland</td>
<td>Central, rare</td>
</tr>
<tr>
<td></td>
<td>Thampanna</td>
<td>Abrakurrie Limestone, Murrumullang Member Limestone, Nullarbor Limestone</td>
<td>Undulating joint controlled stony ridges and rises</td>
<td>Eucalypt and myall woodland on ridges; chenopod shrubland and grassland mosaics on drainage floors</td>
<td>South-east, common</td>
</tr>
<tr>
<td></td>
<td>Toolinna</td>
<td>Toolinna Limestone, Abrakurrie Limestone</td>
<td>Undulating stony plains</td>
<td>Low mallee woodland, coastal heath and scrub</td>
<td>South, common</td>
</tr>
<tr>
<td></td>
<td>Virginia</td>
<td>Recrystallised Limestone</td>
<td>Gently undulating plains</td>
<td>Myall woodland on low ridges; halophytic shrubland on saline drainage floors</td>
<td>West, common</td>
</tr>
<tr>
<td></td>
<td>Weebubbie</td>
<td>Nullarbor Limestone</td>
<td>Gently undulating stony plains</td>
<td>Eucalypt and melaleuca woodland on rises; grassland on drainage floors and claypans</td>
<td>South-east, uncommon</td>
</tr>
<tr>
<td>Land surface type</td>
<td>Land system</td>
<td>Predominant surface geology</td>
<td>Characteristic landform(s)</td>
<td>Dominant vegetation type</td>
<td>Survey location and distribution</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------</td>
<td>-----------------------------</td>
<td>---------------------------</td>
<td>-------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>(v) Deflated limestone plains</td>
<td>Arubiddy Nullarbor Limestone</td>
<td>Gently undulating stony plains with irregular joint patterns</td>
<td>Pearl bluebush shrubland; halophytic shrubland on drainage floors</td>
<td>South-central, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Balgair Nullarbor Limestone</td>
<td>Gently undulating stony plains with irregular joint patterns</td>
<td>Pearl bluebush shrubland on broad ridges; bladder saltbush shrubland and grassland mosaics on drainage floors</td>
<td>Central, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bullseye Nullarbor Limestone</td>
<td>Very gently undulating stony plains, dongas common</td>
<td>Bindi grassland; donga groves</td>
<td>Central north, very common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chowilla Nullarbor Limestone</td>
<td>Gently undulating stony plains with irregular joint patterns</td>
<td>Myall woodland and pearl bluebush shrubland; grassland and halophytic shrubland mosaics on drainage floors</td>
<td>South-east, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gafa Nullarbor Limestone</td>
<td>Very gently undulating stony plains with irregular joint patterns</td>
<td>Pearl bluebush shrubland or bindi grassland; bladder saltbush and grassland shrubland mosaics on drainage floors</td>
<td>Central, very common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kinclaven Nullarbor Limestone</td>
<td>Level stony plains, dongas common</td>
<td>Mixed shrubs and bindi grassland; donga groves</td>
<td>Central north, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kitchener Nullarbor Limestone</td>
<td>Gently undulating stony plains</td>
<td>Mixed acacia shrubs and bindi grassland with sparse black oak</td>
<td>North-west, uncommon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kybo Nullarbor Limestone</td>
<td>Undulating stony plains</td>
<td>Pearl bluebush shrubland; grassland and herbland on drainage floors</td>
<td>Central, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moonera Nullarbor Limestone</td>
<td>Very gently undulating stony plains defined by north-east to south-west trending joint patterns</td>
<td>Pearl bluebush shrubland; bladder saltbush shrubland on drainage floors</td>
<td>Central, very common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morris Nullarbor Limestone</td>
<td>Level to very gently undulating stony plains with irregular joint patterns</td>
<td>Pearl bluebush shrubland; bladder saltbush shrubland and grassland on drainage floors</td>
<td>South-east, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nanambinia Nullarbor Limestone</td>
<td>Level to gently undulating stony plains</td>
<td>Sugarwood over chenopod shrubland or grassland</td>
<td>South-west, uncommon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Naretha Nullarbor Limestone</td>
<td>Gently undulating stony plains</td>
<td>Mixed acacia and pearl bluebush shrubland; bindi grassland</td>
<td>Central west, uncommon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nightshade Nullarbor Limestone</td>
<td>Gently undulating stony plains</td>
<td>Tussock grassland; halophytic shrubs in drainage foci</td>
<td>South, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nurina Nullarbor Limestone</td>
<td>Stony plains commonly with gilgai patches</td>
<td>Grassland or bladder saltbush shrubland</td>
<td>Central, uncommon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oasis Nullarbor Limestone</td>
<td>Level stony plains, dongas common</td>
<td>Bindi grassland; donga groves</td>
<td>North-east, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pondana Nullarbor Limestone</td>
<td>Gently undulating stony plains with large rounded claypan depressions</td>
<td>Pearl bluebush shrubland; bladder saltbush shrubland or annual herbland in claypan depressions</td>
<td>Central west, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reid Nullarbor Limestone</td>
<td>Level to very gently undulating stony plains defined by north-west to south-east trending joint patterns</td>
<td>Pearl bluebush shrubland; bladder saltbush shrubland on drainage floors</td>
<td>East, common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seemore Nullarbor Limestone</td>
<td>Level stony plains</td>
<td>Pearl bluebush shrubland with sparse myall and black oak</td>
<td>North-east, uncommon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shakehole Nullarbor Limestone</td>
<td>Gently undulating stony plains along regular joint patterns trending north-east to south-west</td>
<td>Pearl bluebush shrubland with sparse myall; grassland and bladder saltbush shrubland mosaics on drainage floors</td>
<td>South-east, common</td>
<td></td>
</tr>
</tbody>
</table>
erosional processes dominant as indurated calcrete surfaces become exposed through denudation. This surface type occupies the second largest part of the survey area, occupying almost 29 per cent. The land systems of this surface type are:

**Caiguna**—Level to gently undulating plains of residual and aeolian loam containing sheet and nodular calcrete, with occasional residual calcareous rises, supporting low eucalypt woodland.

**Carlisle**—Gently undulating plains of residual clay loam containing sheet and nodular calcrete dissected to expose Nullarbor Limestone supporting bindii grassland with sparse myall; differential surface weathering has formed dongas and drainage floors.

**Colville**—Very gently undulating plains of residual sandy loam containing sheet and nodular calcrete at or near the surface supporting myall woodland over bindii grassland; dongas and claypans exhibit centripetal drainage.

**Culver**—Level to gently undulating stony plains of residual and aeolian loam containing sheet and nodular calcrete, irregularly dissected by differential weathering along joint patterns to form closed drainage foci and low rises. Supports low mallee woodland over sedges and hummock grasses.

**Gumbelt**—Level to very gently undulating plains of shallow aeolian sand over residual loam containing sheet and nodular calcrete supporting eucalypt woodland with mixed scrub understorey.

**Haig**—Level to gently undulating plains of residual clay loam containing sheet and nodular calcrete supporting chenopod shrubland or bindii grassland; weakly dissected by relic ancient river courses.

---

### Table 10 continued

<table>
<thead>
<tr>
<th>Land surface type</th>
<th>Land system</th>
<th>Predominant surface geology</th>
<th>Characteristic landform(s)</th>
<th>Dominant vegetation type</th>
<th>Survey location and distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skink</td>
<td>Nullarbor Limestone</td>
<td>Level to very gently undulating stony plains defined by north-east to south-west trending joint patterns</td>
<td>Pearl bluebush shrubland; bladder saltbush shrubland on drainage floors</td>
<td>Central south-east, common</td>
<td></td>
</tr>
<tr>
<td>Vanesk</td>
<td>Nullarbor Limestone</td>
<td>Gently undulating stony plains defined by north-south trending joint patterns</td>
<td>Pearl bluebush shrubland and scattered myall woodland on low ridges; halophytic shrubland on drainage floors</td>
<td>Central west, uncommon</td>
<td></td>
</tr>
<tr>
<td>Mundrabilla</td>
<td>Colluvium, Roe Calcarenite</td>
<td>Level loamy plains</td>
<td>Myall woodland over false bluebush; open chenopod shrubland and nitré bush</td>
<td>South, Uncommon</td>
<td></td>
</tr>
<tr>
<td>Roe</td>
<td>Colluvium, Roe Calcarenite</td>
<td>Level plains overlain by sandy loam</td>
<td>Eucalyptus and melaleuca woodland</td>
<td>South, Uncommon</td>
<td></td>
</tr>
<tr>
<td>Baxter</td>
<td>Sand, calcrite</td>
<td>Clifftop dunes</td>
<td>Banksia coastal heath and scrubland</td>
<td>South-west, rare</td>
<td></td>
</tr>
<tr>
<td>Bilbunya</td>
<td>Sand</td>
<td>Coastal dunes, beach foredunes, dunefields</td>
<td>Coastal shrubland</td>
<td>South-west, rare</td>
<td></td>
</tr>
<tr>
<td>Delisser</td>
<td>Sand</td>
<td>Coastal dunes, beach foredunes</td>
<td>Coastal shrubland</td>
<td>South, rare</td>
<td></td>
</tr>
<tr>
<td>Wurunggooya</td>
<td>Sand, calcrite</td>
<td>Coastal dunes</td>
<td>Eucalyptus coastal heath woodland</td>
<td>South, rare</td>
<td></td>
</tr>
<tr>
<td>Wylie</td>
<td>Sand, calcrite</td>
<td>Coastal dunes</td>
<td>Banksia coastal heath and scrubland</td>
<td>South-west, rare</td>
<td></td>
</tr>
<tr>
<td>Boonderoo</td>
<td>Alluvium, sand, gypsum</td>
<td>Lake bed, saline alluvial plains, sandy banks</td>
<td>Halophytic and non-halophytic shrubland</td>
<td>North-west, rare</td>
<td></td>
</tr>
<tr>
<td>Damper</td>
<td>Alluvium, clay, gypsum</td>
<td>Lagoonal saline clay flats</td>
<td>Halophytic shrubland</td>
<td>South, rare</td>
<td></td>
</tr>
<tr>
<td>Lefroy</td>
<td>Alluvium, sand, gypsum</td>
<td>Lake beds, saline alluvial plains, sandy plains</td>
<td>Halophytic shrubland</td>
<td>South-west, rare</td>
<td></td>
</tr>
<tr>
<td>Ponton</td>
<td>Alluvium, silt, sand</td>
<td>Concentrated drainage channels</td>
<td>Halophytic and non-halophytic shrubland</td>
<td>North-west, rare</td>
<td></td>
</tr>
</tbody>
</table>
Jubilee—Undulating plains of residual clay loam containing sheet and nodular calcrete, dissected by differential weathering along joints and relic ancient river courses to expose Nullarbor Limestone. Supports bindii grassland with very scattered myall. This system is intermediate in form between intact residual loamy calcrete plains of the Nyanga and Rabbit land systems and the completely deflated stony limestone plains of the Bullseye and Oasis land systems.

Kyarra—Level plains of residual clay loam containing sheet and nodular calcrete partially dissected to expose Nullarbor Limestone, supporting bindii grassland with sparse myall. This system is intermediate in form between intact residual loamy calcrete plains of the Kyarra and Nyanga land systems and the completely deflated stony limestone plains of the Bullseye and Oasis land systems.

Moodini—Level to gently undulating plains of undissected residual sandy loam and calcrete, derived from weathered residual aeolian deposits. Supports eucalypt or myall woodland.

Moopina—Level plains of undissected residual sandy clay and calcrete, derived from weathered residual aeolian deposits, supporting dense eucalypt and melaleuca woodland.

Nyanga—Level plains of residual clay loam containing sheet and nodular calcrete, supporting myall or casuarina woodland over chenopod understorey.

Rabbit—Level plains of residual clay loam containing sheet and nodular calcrete, with infrequent small, shallow claypans. Dominated by bindii grassland.

Zanthus—Level plains of residual sandy loam containing nodular calcrete near the surface, overlain by shallow deposits of aeolian sand. Supports mallee woodland over spinifex hummock grassland.

Depression floors are almost level with drainage foci in the lowest positions with various limestones of the Eucla Group exposed at the surface either through deflation or gilgai processes. Solution of the underlying limestone and deflation of clay is believed to be the process responsible for depression formation (Lowry 1970). This surface occupies almost 1.4 per cent of the survey area. The land systems of this surface type are:

Koonjarra—Low breakaways form plateau edges to calcrete plains enclosing large, depressions, supporting chenopod shrubland or grassland, with centripetal drainage patterns to drainage foci with gilgai micro-relief.

Woorlba—Level to gently inclined depressions, supporting chenopod shrubland or grassland, forming drainage foci for surrounding plains.

(iii) Granite outcrop in calcrete plains

In the south-west part of the Bunda Plateau inliers of Proterozoic granite protrude through the calcrete plains of the Mardabilla Plain. Fringing surfaces are characterised by gritty-sandy surfaces or moat-like depressions where water run-off is concentrated leading to dissolution of calcareous surroundings. This surface type is a rare occurrence occupying about 0.1 per cent of the survey area. The land system of this surface type is:

Balladonia—Granite low rises and domes protruding through calcrete plains, fringed by gritty, sandy surfaces supporting acacia–dodonaea–eremophila shrubland.

(iv) Limestone plains [with deeper soils than (v)]

These limestone plains differ from the deflated limestone plains primarily by the amount of soil development brought about by weathering. These surfaces are capable of supporting woodland and occupy about 9.3 per cent of the survey area. This surface type can be further subdivided into two groups based on post-depositional limestone weathering processes. Along the south of the Bunda Plateau surface weathering has created greater land unit relief in the Hampton Tableland than in land units of the Nullarbor Plain. This is considered largely a factor of higher rainfall in southern areas.
causing greater solution of the limestones along joint patterns. The plains of the Hampton Tableland consist of undulating stony rises and ridges separated by karstic depressions of various form and length. The land systems of this surface type are:

**Thampanna**—Undulating irregular low stony rises (limestone hummocks) and ridges supporting eucalypt and myall low open woodland separated by open depressions formed by differential weathering of limestones along predominantly north-east to south-west trending joint patterns which support a mosaic of chenopod shrubland and grassland.

**Toolinna**—Undulating stony plains with irregular low rises (limestone hummocks) separated by stony marginal slopes and irregular drainage foci in-filled with colluvium. Supports low mallee woodland grading seaward into coastal heath and scrub along cliff tops.

**Weebubbie**—Gently undulating low ridges and stony plains enclosing small drainage foci. Supports eucalypt and melaleuca woodland on rises and grassland on the lower slopes, closed drainage floors and claypans.

Along the west of the Nullarbor Plain weathering of Nullarbor Limestone has resulted in recrystallisation from a hard (indurated) limestone to a soft, porous, rubbly limestone. The land systems of this surface type are:

**Kanandah**—Gently undulating plains of partially deflated residual loam over recrystallised Nullarbor Limestone, supporting myall woodland over pearl bluebush shrubland or bindii grassland; differential weathering of the surface has formed small dongas and gilgaied depressions.

**Lowry**—Undulating low rise composed of recrystallised Nullarbor Limestone supporting pearl bluebush shrubland.

**Virginia**—Gently undulating plains formed through differential weathering of recrystallised Nullarbor Limestone along north-south trending joint patterns have formed parallel, low stony ridges, supporting myall woodland, separated by narrow, saline drainage floors up to 10 km long, dominated by halophytic shrubland.

**(v) Deflated stony limestone plains**

These surfaces form the Nullarbor Plain and occur in the centre of the Bunda Plateau. This erosional surface is the largest in the survey area occupying approximately 53.2 per cent of the area. Wind erosion in combination with weathering dissolution is the process most responsible for the regularity of weathering across the plain. Extensive deflation over the plateau surface has exposed a level to gently undulating surface with thin soil on the rises and clay to clay loam in the depressions. Deflated stony limestone plains can be further subdivided into two groups based on the genesis of karst landforms.

In the south of the Nullarbor Plain the surface has a gently undulating relief of parallel, low rocky ridges and rises separated by depressions controlled by structural joints in the underlying limestones. The land systems of this surface type are:

**Arubiddy**—Gently undulating stony plains supporting pearl bluebush shrubland, differentially weathered along irregular joint patterns to form closed drainage depressions, supporting halophytic shrubland.

**Balgair**—Gently undulating low stony rises with broad stony marginal slopes, supporting pearl bluebush shrubland, separated by drainage floors, containing a mosaic of bladder saltbush shrubland and grassland, along irregular joint patterns with infrequent large claypans and dongas; occasional relic ancient river courses form sinuous, narrow drainage tracts terminating indistinctly into the surrounding plains.

**Chowilla**—Gently undulating stony plains, supporting scattered myall woodland and pearl bluebush shrubland, separated by drainage floors, forming a mosaic of bladder saltbush shrubland and grassland, along irregular joint patterns forming narrow drainage floors often terminating in oval claypans or as small closed drainage foci randomly distributed throughout the stony plains.

**Gafa**—Very gently undulating stony plains, supporting pearl bluebush shrubland or bindii grassland, with large claypans, infrequent dongas, lignum swamps and wide drainage floors, supporting a mosaic of grassland and bladder saltbush shrubland; drainage patterns restricted to the ancient river tracts.
Kitchener—Gently undulating stony plains of residual calcareous loam and sheet calcrite dissected to expose Nullarbor Limestone; differential weathering of the surface has formed infrequent dongas. Plains support mixed shrubs and bindi grassland. This system is intermediate in form between the intact residual loamy calcrite plains of the Nyanga land system, the weathered limestone plains of the Kanandah land system and the deflated stony limestone plains of the Naretha land system.

Kybo—A deflated fault scarp, supporting pearl bluebush shrubland, trending north-south for nearly 40 km characterises this system. Elongated clay drainage floors lie to the west of the low scarp, elsewhere superficial weathering of the limestone plain along north-east to south-west trending joint patterns has formed undulating stony ridges separated by broad, level drainage floors, up to 8 km long and < 1 km wide, with infrequent claypans and dongas forming large drainage foci in the lower-lying areas. Drainage floors support grassland and herbland.

Moonera—Very gently undulating stony plains. Defined by north-east to south-west trending joint patterns, which have formed wide drainage floors supporting bladder saltbush shrubland, separated by very gently undulating broad, stony low rises and ridges, supporting pearl bluebush shrubland; large infrequent irregular claypans, < 1 km in extent.

Morris—Level to very gently undulating stony plains, supporting pearl bluebush shrubland, separated by sinuous drainage floors along irregular joint patterns, up to 3 km long, and large, irregular claypans in drainage foci, up to 1.5 km in extent. Drainage floors support bladder saltbush shrubland and grassland.

Nanambinia—Level to gently undulating stony plains and gently inclined depressions subject to very diffuse sheet flow. Supports scattered sugarwood over chenopod shrubland or grassland.

Naretha—Gently undulating stony plains partially overlain by shallow sandy loams, support mixed acacia and pearl bluebush shrubland over bindi grassland. Differential weathering of the surface has formed long, narrow drainage tracts, occasional dongas and very shallow clay depressions.

Infrequent relic ancient river courses form sinuous, narrow drainage tracts terminating indistinctly into the surrounding plains.

Nightshade—Gently undulating stony plains differentially weathered along irregular joint patterns to form closed drainage depressions or open drainage floors; saline drainage foci supporting halophytic shrubs occur irregularly throughout the plains. Plains are dominated by tussock grassland.

Pondana—Gently undulating stony plains differentially weathered to form large, closed depressions with level claypan floors characterise this system. Elsewhere the plains are superficially weathered to form dongas or drainage floors along north-south trending joint patterns. Drainage is restricted to relic ancient river courses. Plains support pearl bluebush shrubland; depressions support bladder saltbush shrubland or annual herbland.

Seemore—Level plains of partially deflated residual loam exposing Nullarbor Limestone support pearl bluebush shrubland with sparse myall and black oak. Differential weathering of the surface has formed small dongas and gilgaied depressions. This system is intermediate in form between the intact residual loamy calcrite plains of the Nyanga land system, the recrystallised limestone plains of the Kanandah land system and the deflated stony limestone plains of the Kinclaven land system.

Shakehole—Gently undulating stony plains differentially weathered along north-east to south-west trending joint patterns form a series of long, narrow drainage floors, up to 10 km long. Large drainage foci within drainage floors consist of closed, round claypans < 1 km in diameter or open, irregular clay plains up to 3 km in extent. Stony plains support pearl bluebush shrubland with sparse myall on rises and a mosaic of grassland and bladder saltbush shrubland in drainage floors.
Skink—Level to very gently undulating stony plains differentially weathered along predominantly north-east to south-west trending joint patterns to form long, narrow drainage floors, generally up to 10 km long, and large oval claypans in drainage foci, < 1 km in extent. Stony plains support pearl bluebush shrubland; drainage floors support bladder saltbush shrubland.

Vanesk—Gently undulating stony plains defined by north-south trending joint patterns forming marginal slopes to drainage floors, with saline drainage foci. Stony plains and low ridges support pearl bluebush shrubland and scattered myall woodland; saline drainage floors support halophytic shrubland.

In the north of the Nullarbor Plain the surface of the level plain is interrupted by many, rounded shallow, closed karstic depressions locally called ‘dongas’. Dongas can be either randomly scattered or aligned parallel with joint patterns in the underlying limestone. The land systems of this surface type are:

Bullseye—Very gently undulating stony limestone plains supporting bindii grassland and drainage floors with frequent large dongas, occasional swamps and small claypans.

Kinclaven—Level stony plains, supporting mixed shrubs and bindii grassland, with frequent dongas, occasional swamps and small gilgai patches randomly distributed through stony plains.

Nurina—Stony plains dissected by broad drainage floors, occasional dongas and infrequent relic ancient river courses. Gilgai patches characterise this system. Plains support grassland or bladder saltbush shrubland.

Oasis—Level stony plains supporting bindii grassland, with numerous small dongas; drainage is restricted to relic ancient river courses.

(vi) Calcarenite plains

These surfaces occur on the Roe Plains below the Bunda Plateau. The coastal plain is underlain by calcarenite deposited after Late Pliocene marine erosion removed the earlier limestones of the Eucla Group and formed the escarpment and cliffs of the Bunda Plateau. They are predominantly level, depositional land surfaces subject to pedogenesis; clay loams and calcrite dominate the soil profile. This surface occupies almost 4 per cent of the survey area. The land systems of this surface type are:

Mundrabilla—Landward section of coastal plain, backed by marine eroded scarp, covered by shallow clay loam containing sheet and nodular calcrite; supporting myall woodland over false bluebush and open shrubland dominated by chenopods and nitre bush.

Roe—Coastal plain, in sections backed by marine eroded scarp, covered by shallow clay loam, with superficial sands, containing calcrite nodules; supporting eucalyptus and melaleuca woodland.

(vii) Coastal plains and dunes

These depositional surfaces form the coastal areas in the south of the survey area. They consist of beaches, foredunes, interdunal swales and saline depressions, partially consolidated to unconsolidated dunefields and colluvial sand ramps against the escarpment of the Bunda Plateau. These coastal surface types occupy about 2.5 per cent of the survey area. The land systems of this surface type are:

Baxter—Clifftop transverse sand dunes trending west-north-west separated by interdunal corridors of indurated calcrite; supporting banksia coastal heath and scrubland.

Bilbunya—Beaches, foredunes, interdunal swales and coastal dunefields with largely unconsolidated parabolic dunes trending approximately north-south, frequently becoming reticulate, occasionally forming star dunes; dune relief up to 90 m. Sparsely vegetated by coastal shrubland.

Delisser—Beaches, unconsolidated to partially consolidated foredunes, dunefields of unconsolidated parabolic dunes trending approximately north-south, swales and interdunal saline depressions. Sparsely vegetated by coastal shrubland.

Wurrengodyea—Coastal parabolic sand dunes and swales supporting eucalypt coastal heath woodland. Sand dunes partially consolidated by a thin layer of sheet or nodular calcrite close to the surface.
Wylie—Interdunal saline depressions between partially consolidated coastal dunes backed to the escarpment by colluvial sand ramps supporting banksia coastal heath woodland.

(viii) Salt lakes
Salt lakes and their fringing tributary plains have developed as a result of past drainage systems becoming infilled by alluvial deposition and choked by aeolian sediments. They are capable of holding water for extended periods after heavy rainfall. These surface types are the lowest depositional surfaces and occupy about 0.5 per cent of the survey area. The land systems of this surface type are:

Boonderoo—Lake beds and fringing plains on saline alluvium surrounded by sandy banks, gypsiferous and kopi dunes, supporting halophytic and non-halophytic shrubland.

Damper—Lagoonal surfaces of saline, gypsiferous calcareous clay with aeolian deposits forming minor low dunes; supporting halophytic shrubland.

Lefroy—Lake beds and fringing plains on saline alluvium with drainage foci and claypans surrounded by sandy banks, low sand dunes and kopi dunes, supporting halophytic shrubland; only occurs in the far south-west of the survey area.

Ponton—Channels with narrow flanking alluvial plains and sandy banks supporting halophytic and non-halophytic shrubland; only occurs in the far north-west of the survey area.

Erosional landforms and processes
Erosional land surfaces dominate the survey area, occurring extensively across the Nullarbor Plain and where the calcrete plains of the Nyanga Plain are solution weathered, dissected and deflated exposing the underlying Nullarbor Limestone.

The surface of the Nullarbor Plain has been formed through solution, concretisation and deflation by wind erosion resulting in uniform regularity across the plateau. The karst features characteristic of the Bunda Plateau have since developed on and below this surface. The limestone plains can be subdivided into two surface types distinguished by the amount of soil development. Limestone plains with calcareous soils of variable depth occur on the margins of the Nullarbor Plain, whilst the majority of the plain is dominated by deflated surfaces. The extent of deflation has exposed the subsurface relief of the joint controlled depression and ridge topography. Stony limestone plains and infrequent low rises are the predominant features across the Nullarbor Plain’s surface, separated by open or closed drainage floors, claypans and dongas. Less common are traditional karst features such as caves, dolines and sinkholes. The limestone plains generally have an abundant mantle of limestone and calcrite fragments, with outcrop more common on the tops of rises and undulations.

Some areas of the Nyanga Plain also exhibit erosional surfaces. Calcrete plains on the margins of the Nullarbor Plain are commonly dissected and the soil surface is shallow with extensive limestone outcrop. These surfaces are considered intermediate in form between intact residual loamy calcrete plains of the Nyanga Plain and the deflated stony limestone Nullarbor Plain. Erosion is the dominant process rather than the formation of soil and calcrete. Similarly some calcrete surfaces within the Hampton Tableland are also dominated by erosional processes. Within the Nyanga Plain the large karstic depressions forming the Koonjarra land system are also considered erosional land surfaces.

The southern edge of the Bunda Plateau represents a major erosional surface. The sea-cliffs and escarpments carved by marine erosion into the uplifted limestones are active zones of erosion with cliff retreat a prominent feature of the present day coastline. Scree and colluvial development against the escarpment on the coastal plains is less dramatic but still an active process.

Of rare occurrence in the south-west of the survey area are the protrusions of granite outcrop through the calcareous plains. The exfoliation observed on low granite domes and rises, as well as the surrounding gritty surface margins, indicate erosional processes. Depressions, 3–10 m deep and 50–150 m wide, characteristically ring most granite outcrop. These moat-like depressions are caused by water run-off from the granite concentrating solutional processes on the surrounding calcareous sediments (Lowry & Jennings 1974).
Relict land surfaces and processes

Relict land surfaces are the second most common surfaces in the survey area. Negligible soil development is the predominant process. The term 'relict' as defined by Hocking et al. (2007) refers to landforms where deposits are of uncertain origin, being either transported or weathered in situ. On such relict land surfaces the processes of denudation operate with minimum intensity and the rate of weathering is often equal to or exceeds the pace of surface erosion (Thomas 1974). The majority of these surface types occur on the Nyanga Plain to the west and north of the Nullarbor Plain. Small isolated areas also exist on the southern edge of the Bunda Plateau on the top of the Hampton Range.

The level to gently undulating surface of the Nyanga Plain is underlain by about 4.5 m of clay loam and calcrete, developed as part of the subsoil of an original soil profile. In most locations the plains support open myall woodland. The calcrete has formed as part of the soil profile through the cementation of calcium carbonate. The thick surfaces of clay loam have developed over an extensive time period with calcrete formation possibly commencing as early as the Pliocene (Lowry 1970).

Residual Late Pleistocene dunes are situated on the top of the Hampton Range. Formerly highly calcareous these have been reduced to sandy clay loams. Calcrete exists at or near the surface as a well developed horizon.

Depositional landforms and processes

Depositional landforms are less common in the Nullarbor region than in other Western Australian physiographic regions. They are the least common surface types in the survey area, largely due to the areic, self-draining nature of the Bunda Plateau. The lack of surface drainage, particularly across the Nullarbor Plain, means the volume of sediment dispersed by alluvial processes is greatly reduced. Aside from deposition processes associated with coastal environments, on the Bunda Plateau areas of deposition are largely restricted to depressions evolved through karst solution processes.

On the Nullarbor Plain karstic depressions within the limestone plains are controlled by structural joints in the underlying limestones. Depression evolution can be described in terms of differential surface solution of limestones. Though their genesis is solutional, depression landforms such as drainage floors and dongas are locally depositional settings accumulating colluvium from the surrounding stony plains and aeolian sediments from further afield. Within depressions soil depth is variable, determined by the degree of limestone solution. However, surfaces can display stony fragments exposed through deflation or brought to the surface through gilgai processes. Within the land system hierarchy they are part of the greater erosional process active on the limestone plains.

Within the Nyanga and Mardabilla plains clay floored depressions form drainage foci for surrounding systems. These depressions form the base unit of the Woorlba land system and are enclosed by gentle slopes draining down from neighbouring land systems. Fine colluvial sediments eroded via sheet flow from surrounding plains accumulate in the depressions.

On the Roe Plains colluvial deposits grade into distal sheetwash deposits in areas proximally associated to the Hampton Range. The majority of the Roe Plains, not overlain by coastal dunes, consist of clay loam underlain by Roe Calcarenite. These surfaces support either open myall woodland and open shrubland or melaleuca and eucalyptus mallee woodland.

Elsewhere coastal dunes have developed on land surfaces adjacent to the coast. Dunes fringe the Roe and Israelite coastal plains as well as locations on top of the Baxter Cliffs. On the coastal plains dune deposition is an ongoing process forming the present day beaches, foredunes and interdunal swales bordering the Southern Ocean. These recent deposits are backed by large dunefields of unconsolidated, mobile dunes forming the Bilbunya Dunes on the Israelite Plain and the Wurrongoodyea Hills and Delisser Sandhills on the Roe Plains. Older, consolidated dunes exist on the landward side of the younger dunes and on top of the Baxter Cliffs. Considered to be of Late Pleistocene age these older dunes have calcrete development close to the surface and are vegetated. At specific locations sand ramps link the Bunda Plateau and the coastal plains. These wind-built ramps formed at the base of the escarpment when the sea exposed coastal areas during a past sea regression.
Along the coast on the Roe and Israelite plains small lagoons have developed in interdunal depressions containing sand, silt, clay and occasionally gypsiferous sediments. On the Roe Plains two larger areas of lagoonal deposits represent Pleistocene lagoons barred from the sea by advancing dunes.

Salt lakes are rare in the survey area occurring in the west at the end of Ponton Creek forming Lake Boonderoo and in the far south-west. Lake sediments consist of recent aeolian and lacustrine deposits of quartz sand, silt and clay, sometimes with halite and gypsum. Lake Boonderoo is intermittently filled by infrequent cyclonic summer rains when Ponton Creek flows after being fed by salt lakes to the west of the Eucla Basin. Due to saline headwaters Lake Boonderoo can be highly saline.

In summary, the majority of the present landforms in the survey area occur on the Bunda Plateau comprising extensive level to gently undulating limestone plains, distinguished by soil development and karst landforms, bordered in the north and west by calcrete plains. In the south the Western Australian portion of the Bunda Plateau is bordered by sea-cliffs and the Roe and Israelite coastal plains fringed by beach and coastal dunes. Relief is greatly subdued and surface drainage is generally absent except in the west where there are rare salt lakes. The areic drainage surface above the Eucla Group limestones results in surface waters permeating through karst landforms into underground drainage systems. Landform patterns are best appreciated in terms of the morphotectonic setting with uplift of the Eucla Basin leading to the exposure of the Miocene sea floor. Minimal tectonic activity since uplift, in combination with the onset of arid conditions, the highly permeable nature of the surface limestones, hardening through concretisation and plain geomorphology has resulted in the regularity of weathering across the plateau surface. Karst features have since developed on and below this surface.

Land use impacts on landscape processes

Until recently there had been little research on the impacts of land use on landscape processes in Western Australian rangelands. Similar surveys to this one (Wilcox & McKinnon 1972; Payne, Curry & Spencer 1987; Payne et al. 1998; Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994) document lands on which natural erosion processes have been accelerated by inappropriate land uses. More recently participatory research and extension projects in the southern rangelands of Western Australia have begun to look at rangeland landscapes across a variety of scales and in doing so are identifying geomorphic determinants responsible for landscape change (Pringle & Tinley 2001, 2003; Pringle, Watson & Tinley 2006).

Calcrete plains

These surfaces are level to gently undulating plains of very low relief generally with clay loam soils of variable depth (e.g. Nyanga land system). When in good condition the moderate covering of vegetation in combination with the flat topography means these surfaces are generally resistant to erosion. However the friable nature of the soil surface makes these plains susceptible to degradation and erosion following disturbance, particularly after preferential grazing fragments vegetation communities or fire completely exposes the ground surface.

Where calcrete plains border the Nullarbor Plain the surfaces are even more susceptible to erosion (e.g. Jubilee and Kyarra land system). Due to landform dissection and slight gradient differences between the calcrete plains over the underlying limestone, soil depth becomes shallower in these intermediate surface types as they merge onto the Nullarbor Plain. The decrease in soil depth reduces the capacity for vegetation formations to offer significant soil surface protection as their coverage is generally scattered. When vegetation is further reduced through disturbance, such as by overgrazing, storm damage and fire, soil loss is further exacerbated.

Depressions within calcrete plains

Low breakaway scarps in the calcrete plain occupy a very small area of the survey (e.g. Koonjarra land system). These land units are inherently unstable and have tributary rills, guttering, gullies and exhibit soil loss downslope. They exhibit some of the most active natural erosion within the survey area as they represent erosional fronts between the topographically higher calcrete plains and the
underlying limestones. Naturally eroding through solution of the underlying limestone and deflation of clay; the degradation of the breakaway scarps is accelerated through loss of perennial shrubs by overgrazing and vehicle tracks. To reduce the track impact on breakaway slopes and to protect associated fragile vegetation communities bunds should be constructed to reduce the volume and erosive potential of water flow channelled by the tracks.

Granite outcrop in calcrete plains
The nature of this surface type results in very little infiltration and run-off is concentrated to the margins of the protruding rock outcrop. Erosion of these surfaces is generally not a concern as the surfaces are commonly bare, exposed granite outcrop fringed by gritty-sandy surfaces.

Limestone plains [with deeper soils]
These limestone plains are level to gently undulating and are capable of supporting open woodland primarily due to the amount of soil development improving infiltration. These plains are generally covered by a variable soil layer with a stony mantle. They are generally not susceptible to erosion except when plant cover is reduced and cryptogamic crusts become fragmented through disturbance.

On the Hampton Tableland in the south, where surface weathering has resulted in greater land unit relief, undulating stony rises and ridges are active sites of erosion as sediments are transported to surrounding depressions (e.g. Thampanna land system). Vegetation loss through overgrazing or fire can result in erosion leaving rises (limestone hummocks) completely bare and exposed. In such landforms, particularly when affected by fire, total grazing pressure should be restricted for a period of time set by seasonal conditions which will determine the effectiveness of recovery. Continuous grazing pressure immediately after fire and/or through extended dry periods can result in continual erosion stripping these surfaces to such as extent they become incapable of supporting perennial vegetation communities.

Deflated stony limestone plains
Deflated limestone plains are dominated by level to gently undulating stony surfaces with regular outcrop. Soils on the stony surfaces are shallow and vegetation cover is commonly low and scattered (usually less than 15 per cent projected foliar cover). The stony mantle offers some protection but where loss of perennial shrubs has occurred wind erosion is accelerated.

The lack of surface drainage on the Nullarbor Plain results in water sheet flow having only a restricted and localised role in transporting sediment from the stony plains to surrounding karstic depressions. Wind is also responsible for supplying depression deposits. Deposits form level surfaces in the depressions except where gilgai cause irregular, hummocky patches. The fine clay soil crust of depression floors is readily erodible and any form of disturbance will inevitably lead to accelerated deflation through wind erosion. Installing water points on such fragile landforms has resulted in the extensive piospheres scarring the landscape through the Nullarbor pastoral areas. The reduction in perennial vegetation to trap wind-blown material exacerbates the extent of piospheres, zones of attenuated impact. Through deflation such areas are losing their ability to provide suitable conditions for germination and establishment of perennial plants. Dust storms on the Nullarbor are a common occurrence, especially during prolonged dry periods.

A piosphere caused by overgrazing at a water point located on the fragile soils of a drainage floor between stony plains.
Calcarenite plains

These surfaces occur on the Roe Plains below the Bunda Plateau (e.g. Mundrabilla and Roe land systems). Underlain by calcarenite these surfaces form level plains subject to pedogenesis with clay loams and calcrete through the soil profile. The flat topography and moderately dense surface cover of vegetation comprising either open myall woodland and open shrubland or melaleuca and eucalyptus mallee woodland means the plains are generally resistant to erosion. Disturbance through overgrazing and fire can expose surfaces making them susceptible to erosion. The colluvial footslopes of the Hampton Range are naturally erodible due to steep gradients. Grazing activity should be minimised on these slopes. Regularly spaced bunds and spoon drains should be constructed on scarp tracks to reduce the volume and erosive potential of water flow channelled by tracks.

Coastal plains and dunes

Unconsolidated coastal beach dunes (e.g. Bilbunya and Delisser land systems) and partially consolidated coastal sand dunes (e.g. Baxter, Wurrengoodyea and Wylie land systems) are subject to strong sea breezes and are susceptible to wind erosion if vegetation is lost. Aside from beach dunes and mobile dune-fields, most coastal dunes are stabilised with coastal scrubland and partially consolidated with thin calcrete horizons near or at the surface. Fire and vehicle traffic are the most likely causes of disturbance responsible for reducing vegetation cover and initiating erosion.

Salt lakes and lagoonal flats

Level to very gently inclined saline alluvial plains are found adjacent to salt lakes (e.g. Boonderoo and Lefroy land systems). Soils are duplex types with a sandy surface horizon commonly over gypsiferous sediments. Water infiltration is often enhanced and there are widespread cryptogamic crusts. On the coastal plains lagoonal clay flats occur in interdunal swales or as Pleistocene lagoons (e.g. Damper land system). Generally, lack of slope renders these systems not susceptible to water erosion, though they are subject to inundation. If vegetation cover is reduced and cryptogamic crusts are disturbed (e.g. by overgrazing and trampling) wind erosion can result in scalding.

In summary, the Western Australian part of the Nullarbor region has a number of natural characteristics which help protect the landscape from the impacts of inappropriate land use. The factor most responsible for offering protection to the Nullarbor landscape is its flat topography and calcrete capping of surface limestones in conjunction with prolonged arid to semi-arid climatic conditions, resulting in the nearly level, areic terrain. The lack of distinct coordinated surface drainage means the Nullarbor has not developed the large scale accelerated water-induced erosion features initiated by overgrazing, as seen in other
southern rangeland regions, particularly those with exoreic drainage. Other protective characteristics include the stony surfaces and cryptogamic soil crusts. On the calcrite and coastal plains moderately dense vegetation communities comprising species which are largely unaffected by grazing have also contributed to protecting the landscape.

Fire is a natural feature of the Nullarbor environment spontaneously occurring as a result of lightning strikes during summer thunderstorms. Good seasonal conditions promote an abundance of annual growth and expansion of *Austrostipa scabra* (speargrass). Following dry conditions the potential fuel load from this growth will readily carry fire. Since European settlement the frequency of fires in the Nullarbor region has increased particularly during the period when steam trains used the Trans-Australian Railway and sparks ignited fires adjacent to the railway line.

The areas in which the landscape is most susceptible to inappropriate land use are the Bunda Plateau escarpment footslopes and low breakaway scarps of the calcrite plains which are subject to sheet flow; various forms of karstic depressions (e.g. drainage floors, claypans and dongas) where disturbance accelerates deflation; sand dunes along coastal areas; and sites supporting vegetation which is highly preferred by herbivores. The impact of land use in these areas has not been quantified in terms of soil loss rates, sediment yields, vegetation cover thresholds and other such variables inherently reflective of landscape processes and ecosystem health.

References

Beard, JS 1975, *Vegetation survey of Western Australia: Nullarbor, 1:1 000 000 Vegetation Series, Explanatory notes to sheet 4*, University of Western Australia Press, Perth.


Curry, PJ, Payne, AL, Leighton, KA, Hennig, P & Blood, DA 1994, *An inventory and condition survey of the Murchison River catchment and surrounds, Western Australia*, Department of Agriculture, Western Australia, Technical Bulletin No. 84.


Payne, AL, Curry, PJ & Spencer, GF 1987, *An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia*, Western Australian Department of Agriculture, Technical Bulletin No. 73.


Soils

P Hennig

Summary

The soils of the study area are dominated by reddish shallow calcareous loams and sands derived from calcareous parent materials. White, grey and brown deep sands, predominantly calcareous, are associated with coastal margins of the survey area. Red/brown clayey soils occur sporadically throughout in clay plains and clay, gilgai or donga depressions. Red sands and red sandy earths are associated with sand banks near Lake Boonderoo in the north-west. Small areas of saline and gypsiferous soils occur around Lake Boonderoo and variable stony soils, gritty shallow red sands and bare rock are associated with occasional granite outcrop in the south-west.

Previous surveys

The Nullarbor Plain soils were broadly described and mapped at a scale of 1:2 000 000 by Northcote et al. (1960–68) as part of The Atlas of Australian Soils, providing a general overview of soil distribution. Laut et al. (1977), Mitchell et al. (1979) and McKenzie et al. (1987) provided more detailed soils information.

Soil classification and description

The Australian Soil Classification (Isbell 2002) is the national system for classifying soils. It replaces previous systems by Stace et al. (1968) and Northcote (1979). The Australian Soil Classification system uses scientific, soil-based nomenclature similar to other classification systems in the world.

In Western Australia a simple system for describing the main soil types—the Soil groups of Western Australia is also used (Schoknecht 2002). Soil groups are a simple method of describing and naming the soils in Western Australia using easily recognisable soil morphological features. In this chapter, the soil types of the Nullarbor are categorised by WA Soil groups with reference to typical Australian Soil Classifications provided within each category.

Field sampling methods

Three hundred and twenty soils were described using the criteria of the Australian Soil and Land Survey Field Handbook (McDonald et al. 1990). Sampling was via shallow soil pits and a 50 mm diameter soil auger, to retrieve soil to a depth of 1 m or to the level of the impermeable underlying rock. Samples were laid out on groundsheets to determine different soil layers. Soil textures were determined for the sieved fine earth fraction (< 2 mm) through moistening the sample and noting the behaviour of the kneaded soil. Field textures provided an indication of the proportions of sand, silt and clay. Soil textures range from sand (< 5 per cent clay) to heavy clay (> 50 per cent clay).

Textures were determined down the profile to separate the major soil layers into A, B, C or K horizons where, the ‘A’ horizon is the topsoil, the ‘B’ horizon is the subsoil, the ‘C’ horizon is weathered rock and the ‘K’ horizon is limestone or calcrete.

Soil colour was determined in the field using a moistened fresh soil aggregate and compared to standard soil colour charts (Munsell 1954). Consistence (a measure of soil particle bonding) was determined by compressing a 20 mm unit of undisturbed soil. Soil structure and fabric were determined using a hand lens.
The presence or absence, size and shape of soil aggregates (particle clusters held together by forces of inter-particle bonds) were recorded.

The parent material, substrate or underlying rock was determined either from examination of material retrieved via soil auger or from geological maps. Soil pH was measured using a portable pH meter or less commonly a paste calorimetric method described by Raupach and Tucker (1959). Carbonates were detected via drops of hydrochloric acid, effervescence indicating presence of calcium carbonate.

The electrical conductivity (EC) of soil horizons was obtained in the field using a portable EC meter using 10 g of soil in 50 mL of distilled water. This was used to indicate the total soluble salts expressed in milliSiemens per metre (1 mS/m equates to about 5 parts per million). The soil salinity classes are:

**Topsoil**
- Low (non-saline) 1–40 mS/m
- Moderate (saline) 41–80 mS/m
- High (highly saline) > 80 mS/m

**Subsoil**
- Low (non-saline) 0–120 mS/m
- High (saline) > 120 mS/m

Other recordings were the shape, size and abundance of coarse fragments, soft segregations or crystals within a profile plus surface features such as mantle, outcrop and cryptogam crusting.

Cryptogams (microbiotic assemblages of mosses, fungi, lichen and liverworts) form thin surface crusts covering many soil surfaces.

The soils were classified using the Australian Soil Classification system in which the soil depth classes are:
- < 25 cm very shallow
- 25–50 cm shallow
- 50–100 cm moderately deep
- > 100 cm deep

Describing a soil profile at an inventory site.
Soil groups

Eighteen soil groups (Schoknecht 2002) were identified in the survey area and are summarised in Table 11. The soil group concept seeks to summarise and standardise the naming of soils across Western Australia based on easily recognisable soil morphological features. A summary table lists the dominant features of each soil group. Soil types occupying greater than 25 per cent of a land system are listed as major soils. Soils occupying 10–25 per cent of a land system are listed as minor soils.

Table 11 Soil groups in the survey area

<table>
<thead>
<tr>
<th>Soil group (code)</th>
<th>Description</th>
<th>Landscape location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt lake soil (102)</td>
<td>Gypsiferous deposits</td>
<td>Lake Boonderoo, lacustrine plains</td>
</tr>
<tr>
<td>Bare rock (201)</td>
<td>Rock outcrop with very shallow skeletal soils</td>
<td>Granitic outcrop</td>
</tr>
<tr>
<td>Stony soil (203)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red deep sandy duplex soils (405)</td>
<td>Red deep sandy surfaced soils overlying clay subsoils</td>
<td>Floors of depressions with calcrite plain</td>
</tr>
<tr>
<td>Calcareous shallow sands (421)</td>
<td>Shallow sands overlying limestone</td>
<td>Hampton and Wylie scarps</td>
</tr>
<tr>
<td>Pale shallow sands (422)</td>
<td>Pale shallow sands overlying calcrite</td>
<td>Interdunal swale</td>
</tr>
<tr>
<td>Red shallow sands (423)</td>
<td>Red shallow red sands overlying granule or occasionally calcrite</td>
<td>In the west of the survey area near granitic outcrop</td>
</tr>
<tr>
<td>Deep sands (440)</td>
<td>Grey and brown deep sands</td>
<td>Beach foredunes and swales</td>
</tr>
<tr>
<td>Calcareous deep sands (442)</td>
<td>Calcareous sands over 1 m deep</td>
<td>Beach and foredunes; coastal dunefields and dune ramps</td>
</tr>
<tr>
<td>Red deep sands (445)</td>
<td>Red sands over 1 m deep</td>
<td>Sandy banks around Lake Boonderoo</td>
</tr>
<tr>
<td>Red sandy earths (463)</td>
<td>Red soils with a sandy surface grading to loam or clay by 80 cm</td>
<td>Sandy banks around Lake Boonderoo; Nyanga Plain</td>
</tr>
<tr>
<td>Calcareous shallow loams (521) incorporating Calcareous stony soil (202)</td>
<td>Shallow calcareous loam overlying calcereous rock types</td>
<td>Limestone, calcrite and calcarenite plains</td>
</tr>
<tr>
<td>Red shallow loams (522)</td>
<td>Shallow red loam overlying calcrite</td>
<td>Calcrete plains</td>
</tr>
<tr>
<td>Calcareous loamy earths (542)</td>
<td>Loamy surfaced soils grading to clay loam subsoils; calcareous throughout</td>
<td>Limestone, calcrite and calcarenite plains</td>
</tr>
<tr>
<td>Red loamy earths (544)</td>
<td>Deep red loamy surfaced soils often grading to clay loam</td>
<td>Calcrete plains</td>
</tr>
<tr>
<td>Cracking clays (600)</td>
<td>Cracking clays exhibiting surfaces cracks or gilgai mounding</td>
<td>Dongas, swamps and drainage foci</td>
</tr>
<tr>
<td>Red/brown non-cracking clays (622)</td>
<td>Red to brown clays (mostly deep) sometimes with cracking clays</td>
<td>Dongas, drainage foci and lacustrine depressions; calcrite plains</td>
</tr>
</tbody>
</table>
Soil group 102—Salt lake soils
(Gypsiferous deposits)

This soil type is uncommon and was recorded around the lake bed and saline plains of Lake Boonderoo. These soils also occur on the saline plains, gypsiferous plains and lagoonal low dunes of the Damper land system, or kopi dunes of the Lefroy land system. Gypsum (calcium sulphate) deposits form from saline groundwater or lacustrine accumulations. When dry these deposits are redistributed by wind erosion, often forming dunes on lake or saline plain margins. An accumulation of pure gypsum deposits is in one sense, not a true soil, but rather a growth medium for very specific plants. Gypsum deposits are highly saline and alkaline, providing a harsh growing environment, and as such, support little or no vegetation. When masked by thin layers of sand or clay, gypsum deposits support samphire and other highly salt tolerant plant species. Surface exposures of gypsum are protected from erosion via a thin firm surface crust.

Gypsum deposits forming around margins of Lake Boonderoo.

Gypsiferous deposits summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Gypsic Hypersalic Hydrosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Fine crystals of gypsum throughout the profile or occasionally overlain by thin layers of fine sand or light clay</td>
</tr>
<tr>
<td>Land systems</td>
<td>Major soil of the Boonderoo land system, minor with the Damper and Lefroy systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Lake bed, saline plain, gypsiferous plain or lagoonal low dunes</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Greyish brown (2.5Y 5/2) topsoil to brownish yellow (10YR 6/8) subsoil</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>No rock outcrop or mantle</td>
</tr>
<tr>
<td>Topsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Subsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil pH range</td>
<td>Alkaline (9.5) topsoil and subsoil</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Highly saline (&gt; 1500 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Highly saline (&gt; 200 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>High</td>
</tr>
<tr>
<td>Wind/water erosion hazard</td>
<td>High</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>High</td>
</tr>
</tbody>
</table>
Soil group 201—Bare rock and Soil group 203—Stony soil  
(Rocky granite soils)

These soil groups are uncommon and occur in the south-west of the survey area on exposed domes of granite. In terms of development, these soils are little more than roughly sorted coarse gritty sands lying on or at the base of granite rock. Granite rock is mainly composed of feldspar, mica and quartz. Feldspar and mica decompose relatively quickly during weathering leaving mainly coarse quartz. In displaying little or no true soil development these soils are classified as Rudosols. Soil depths range from just a few millimetres to about 30–40 cm in localised accumulation zones. As the soil consists of very coarse quartz grains, nutrients and organic matter are leached from the profile relatively quickly resulting in soil with excellent drainage, but with few nutrients and a low water-holding capacity. These soils display an acidic soil reaction trend. These soils have linkages to the red shallow sands (soil group 423). The soil is reddish brown and the surface may have an infrequent to common mantle of granite with abundant rock outcrop.

Rocky granite soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Paralithic, Lithic, Leptic or Arenic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil texture</td>
<td>Very coarse sand</td>
</tr>
<tr>
<td>Land system</td>
<td>Balladonia land system</td>
</tr>
<tr>
<td>Land unit</td>
<td>Low granite rise</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Dark reddish brown (2.5YR 3/4 to 5YR 3/4)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow (&lt; 25 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy and single grain</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Loose with a common (10–50%) stony mantle of granite and abundant rock outcrop (&gt; 50%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Granite</td>
</tr>
<tr>
<td>Topsoil/subsoil pH range</td>
<td>Acidic (5.5–6.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Negligible</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Negligible</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Very low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Low</td>
</tr>
<tr>
<td>Wind/water erosion hazard</td>
<td>Minor</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 405—Red deep sandy duplex soils

This soil type was only recorded once as a minor occurrence on the marginal slopes to depression floors in the Koonjarra land system. The soil profile comprised thin fine sandy topsoil overlying a deep subsoil of silty clay loam grading to light clay. The topsoil was non-saline, with a neutral soil reaction, and non-dispersive, but did slake. The subsoil was saline with an alkaline soil reaction. The soil surface was stone-free and displayed abundant cryptogams. Soil colour ranged from dark red in the topsoil to red in the subsoil.

Red deep sandy duplex soil summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Red Chromosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Fine sand overlying silty clay grading to light clay</td>
</tr>
<tr>
<td>Land system</td>
<td>Minor soil within the Koonjarra land system</td>
</tr>
<tr>
<td>Land units</td>
<td>Marginal slope to drainage floor</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Dark red (2.5YR 3/6) topsoil to red (2.5YR 5/6) subsoil</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>No rock outcrop or mantle; abundant (70%) cryptogam crusting</td>
</tr>
<tr>
<td>Substrate</td>
<td>Calcrete</td>
</tr>
<tr>
<td>Topsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil pH range</td>
<td>Neutral (7.0) topsoil and alkaline (9.5) subsoil</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Saline (200 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Moderately permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Moderate</td>
</tr>
<tr>
<td>Wind/water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 421—Calcareous shallow sands

Calcareous shallow sands are restricted to the scarp face land unit of the Wurrengoodyea land system. These sands are very shallow and overlie limestone. Biological surface crusts are infrequent, but limestone mantles and outcrop are abundant. The soil textures are fine sand with a topsoil colour of light brownish grey overlying dark greyish brown subsurface sand. These soils are highly calcareous, non-saline and have an alkaline soil reaction trend. This soil type is uncommon.

Calcareous shallow sand summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Hypercalcic Calcarosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Fine sand over sand</td>
</tr>
<tr>
<td>Land system</td>
<td>Minor soil within Wurrengoodyea land system</td>
</tr>
<tr>
<td>Land unit</td>
<td>Scarp face</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Topsoil of light brownish grey (10YR 6/2) over subsoil of dark greyish brown (10YR 4/2)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow (&lt; 25 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy and single grained</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Infrequent (&lt; 10%) biological surface crusting with an abundant (&gt; 50%) limestone mantle and outcrop</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Very low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Low</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Moderate (due to landscape position)</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 422—Pale shallow sands

These soils are uniform textured fine sands overlying calcrete or calcarenite at very shallow depth. Soil surfaces are soft with no biological surface crusts and have no mantle. The soil is non-calcareous and non-saline with a neutral soil reaction trend. Soil colour ranges from light grey at the surface to dark yellowish brown in the subsoil. This soil type is uncommon and was recorded only once on the interdunal swale land unit of the Wurrengoodyea land system.

Pale shallow sand summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Leptic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil texture</td>
<td>Fine sand</td>
</tr>
<tr>
<td>Land system</td>
<td>Minor soil within the Wurrengoodyea land system</td>
</tr>
<tr>
<td>Land unit</td>
<td>Interdunal swale</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Topsoils of light grey (10YR 7/1) and subsoils of dark yellowish brown (10YR 4/4)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow (&lt; 25 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal sandy and single grained</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Soft surface with infrequent (&lt; 10%) cryptogam crusting and no mantle</td>
</tr>
<tr>
<td>Substrate</td>
<td>Calcarenite</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Neutral (6.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Neutral (7.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Very low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Low</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low to moderate dependant</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Nil</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 423—Red shallow sands

These soils are very shallow to shallow, uniform textured loamy sands overlying calcrete. The soils are dark red in colour, non-calcareous and have a neutral to weakly alkaline soil reaction trend. This soil type is uncommon in the survey area and was found in the Balladonia and Zanthus land systems.

Within the gritty-surfaced plains of the Balladonia land system the shallow substrate is granite with an occasional veneer of calcrete. Biological surface crusts are common and a mantle of calcrete/limestone fragments is frequent. The loamy sands associated with granitic land systems tend to be marginally coarse in texture, as the sands are generally developed in situ and are not transported long distances though wind or water erosion.

Within the Zanthus land system red shallow sands occur on the calcareous plains. The sands are also shallow and overlie calcrete and some of these sands contain calcrete nodules. Soil textures tend to be marginally finer than those of the granitic (Balladonia) land system as the Zanthus sands tend to be of aeolian origin. These sands generally lack surface crusting or a mantle.

Red shallow sand summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Arenic or Leptic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Medium grained loamy sand (occasionally medium to coarse) in the Balladonia land system and medium to fine-grained loamy sand in the Zanthus land system</td>
</tr>
<tr>
<td>Land systems</td>
<td>Major soil Balladonia and Zanthus land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Gritty-surfaced plains (Balladonia land system) and calcareous plains (Zanthus land system)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Dark red (2.5YR 3/6)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow to shallow (&lt; 25–50 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy and single grained or aperal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Common (10–50%) cryptogam crusts with frequent (10–50%) limestone mantle or infrequent mantle and crusting</td>
</tr>
<tr>
<td>Substrate</td>
<td>Granite (with or without a calcrete veneer or calcrete)</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Neutral (7.5) to alkaline (8.2)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Mostly alkaline (8.0–8.5)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Very low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Low</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low for granitic areas, otherwise nil</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 440—Deep (grey and brown) sands

These sands occur inland from the calcareous deep sands (soil group 442) associated with the beaches. They are more developed than the beach sands and occur as sand dunes and sand sheet swales. Soil textures comprise fine sand and the soils are non-saline. Soil reaction is neutral to alkaline and these soils contain little or no carbonates. These soils trend from grey near the coast progressively showing brown and yellow colours further inland. Sand dune soils have colour ranges from grey-brown in the topsoils to yellowish brown in the deep subsoil. In the swales soil colour ranges from grey to dark yellowish brown.

Deep (brown) sand soil summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Arenic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Fine sand sometimes grading to weak clayey sand</td>
</tr>
<tr>
<td>Land system</td>
<td>Major soil of the Wurrengoodyea land system</td>
</tr>
<tr>
<td>Land units</td>
<td>Dunes and swales</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Grey (10YR 5/1) to greyish brown (10YR 4/2, 10YR 5/2) grading to dark yellowish brown (10YR 4/6) or yellowish brown (10YR 5/4, 10YR 6/4)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy and single grained</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Soft with common (30–40%) cryptogam crusting</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Neutral (7.5) to alkaline (8.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0–9.5)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Non-saline (&lt; 5 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Very low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>High</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Moderate</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 442—Calcareous deep sands

This soil group comprises deep white, grey and brown calcareous sands of the sandy coastal margins of the survey area. The sands tend to be white to light grey on the beach and foredune zones, trending to brown inland. Soil textures are fine sand and soil colour depends on the vegetative cover. As such, beach sands with little or no vegetation are mostly white or grey. Inland from the beaches, shrubs and stunted trees contribute organic matter to the soil, resulting in different coloured and more stable soils. Calcareous deep sands occur within four land systems: Baxter, Bilbunya, Delisser and Wurrengoodyea. The Bilbunya and Delisser systems front the ocean and consists of beaches, foredunes and inland dunes. The beach sands show no organisation in a soil development sense. They are fine sands continually rearranged by the forces of wind and the ocean. As such they are structureless and support little or no vegetation because of the harsh environment in which they occur. Although faced with regular erosion (and reformation), occasional inundation and influenced by strong salt laden sea breezes, these soils contain very low levels of salt due to their highly porous nature. The colour of the beach sands is white to light grey. Adjoining the beach sands are the beach foredunes, somewhat mobile dunes due to the influence of wind erosion. These foredunes are similar in texture to the beach sands, but are commonly stabilised with pioneer plant species.

Calcareous deep sand soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Shelly, Arenic or Hypersalic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil texture</td>
<td>Fine sand</td>
</tr>
<tr>
<td>Land systems</td>
<td>Major soil of the Bilbunya, Delisser and Wurrengoodyea land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Beach, inter-dune swale, sand dune</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Beaches of white or light grey (10YR 7/1), dunes of light grey to very pale brown (10YR 8/3) to brown (10YR 5/3) or brown (10YR 5/3) to white (10YR 8/2)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy and single grained</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Loose (on the beach and dunes), otherwise soft to firm with infrequent to common (&lt; 50%) cryptogam crusting</td>
</tr>
<tr>
<td>Substrate</td>
<td>Occasionally coastal limestone</td>
</tr>
<tr>
<td>Topsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Subsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (&gt; 8.9)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (&gt; 8.5)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (1–25 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Mostly non-saline (1–18 mS/m), some weakly saline (60–135 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Very low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>High</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>High</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low (beach and dune land units high)</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low (tidal beach land unit high)</td>
</tr>
</tbody>
</table>
Soil group 445—Red deep sands

This soil type is uncommon and occurs on the sandy banks of the Boonderoo land system. These soils are deep and have thin to medium topsoil textures of loamy sand overlying thick subsoils of clayey sand. The soils are red in colour and have an alkaline soil reaction trend due to the association with gypsic elements from Lake Boonderoo. The profiles are free of coarse fragments and the soil surfaces are soft.

These soils may occur adjacent to and among red sandy earths (soil group 463). There may be some intergrading of these soil groups. In many instances the red deep sands and the red sandy earths share similar types of topsoils. Red sandy earths are more clayey with depth.

The red deep sands are very common in the desert areas north of the Bunda Plateau, but have neutral to weakly acidic soil reaction trends.

Red deep sand soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Arenic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Loamy sand to clayey sand</td>
</tr>
<tr>
<td>Land system</td>
<td>Minor soil of the Boonderoo land system</td>
</tr>
<tr>
<td>Land unit</td>
<td>Sand bank</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Red (7.5YR 4/6) to reddish brown (5YR 4/4) and yellowish red (5YR 5/6) subsoils</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy, single grained</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Soft with infrequent (&lt; 10%) cryptogam crusts</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (8.5)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (&lt; 2 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Non-saline (&lt; 2 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>High</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Soil group 463—Red sandy earths

These soils exhibit thin to medium topsoils of loamy sand to sandy loam graduating to medium to thick subsoils of loam or sandy clay loam or clay loam. They are deep soils and may contain calcareous nodules in the lower subsoil or be weakly saline at depth. Soil reaction is alkaline and colour is red throughout. Red sandy earths are uncommon and occur with red deep sands (soil group 445) on the sand bank land unit of the Boonderoo land system. Within the Nyanga land system this soil was recorded infrequently in areas where shallow aeolian sands overlay the calcareous loams.

Red sandy earth soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Red Kandosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Loamy sand to sandy loam overlying sandy loam or sandy clay loam; calcareous nodules occasionally present</td>
</tr>
<tr>
<td>Land systems</td>
<td>Major soil of the Colville and Zanthus land systems; minor soil of the Nyanga, Ponton and Boonderoo land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Calcareous loamy plain overlain with shallow aeolian sands or sandy banks</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Dark reddish brown (2.5YR 3/3) or dark red (2.5YR 4/6) grading to yellowish red (5YR 4/6 and 5/6) to reddish yellow (5YR 6/6)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 1 m)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, sandy or earthy (with intergrades); single grain to massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Soft to firm</td>
</tr>
<tr>
<td>Substrate</td>
<td>Occasional calcareous nodules in lower subsoil</td>
</tr>
<tr>
<td>Topsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Subsoil slaking</td>
<td>Complete</td>
</tr>
<tr>
<td>Topsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Subsoil dispersion</td>
<td>Partial</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (8.5)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0–9.5)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Non-saline (1–5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Non-saline to weakly saline (5–90 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Moderate</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Moderate</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation risk/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
Soil group 521—Calcareous shallow loams (incorporating soil group 202—Calcareous stony soil)

Calcareous shallow loams are common on all but coastal and sub-coastal land systems. These soils are divided into three subgroups: sandy loams, loams, and clay loams all over calcareous rock types (i.e. limestone, calcrete, calcarenite). Profiles with more than 50 per cent of rock fragments or calcrete are classified as Calcareous stony soil.

Sandy loams are uncommon and have either uniform textures of fine sandy loam overlying calcrete at very shallow depth or weak gradational textures of sandy loam grading to loam at shallow depth. The fine sandy loam type has only one major horizon whereas the gradational soil type has two primary layers. Soil colour is principally red for the fine sandy loams and reddish brown to brown for the gradational loams. The fine sandy loams are non-saline while the gradational loams may be either non-saline or weakly saline. All of these soils are non-dispersive and do not slake.

Calcareous shallow (sandy) loam soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Lithocalcic Calcarosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Fine sandy loam to sandy loam</td>
</tr>
<tr>
<td>Land systems</td>
<td>Minor soils of the Lowry, Naretha, Nyanga, Roe and Virginia land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Calcrete plain overlain by loam (KPL), Limestone hummock (low rise) (LHR), Calcareous plain with shallow sands (PKE), Stony limestone plain (SLP)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly dark red (2.5YR 3/6) for fine sand loams and reddish brown (5YR 4/4) to yellowish red (5YR 4/6) or brown (7.5YR 3/4) to strong brown (10YR 5/4) for gradational types</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow (&lt; 25 cm) for fine sandy loams and shallow (25–50 cm) for deeper gradational sandy loam to loam soils</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Mostly to abundant (50–90%) stony mantle of calcareous geology or where below 50% abundant biological (cryptogam) crusting (50–60%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone, calcrete, calcarenite</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–5 mS/m) for fine sandy loams, weakly saline (30 mS/m) for some gradational loams</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (1–10 mS/m) for fine sandy loams, weakly saline (60 mS/m) for some gradational loams</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Shallow</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
The loam soil subgroup is very common and consists of mainly one or two loam-textured horizons overlying limestone at very shallow or shallow depth. Soil colour is mainly reddish brown to yellowish red with occasional stronger hues of brown for the more shallow types. The slightly deeper soils have reddish brown top-soils overlying strong brown or dark yellowish brown subsoils. The deeper soils tend to show slightly more saline subsoils than the more shallow types. Soil reaction is alkaline.

**Calcareous shallow loam soils summary**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Lithocalcic Calcarosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil texture</td>
<td>Loam</td>
</tr>
<tr>
<td>Land systems</td>
<td>Soils of the Balgair, Caiguna, Culver, Haig, Nanambinia, Narethla, Nightshade, Nurina, Nyanga, Thampanna, Roe, Shakehole and Weebubble land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Calcrete plain overlain by loam (KPL), Calcrete stony plain (KSP), Limestone hummock (low rise) (LHR), Calcareous plain with shallow sands (PKE), Stony limestone plain (SLP)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly dark red (2.5YR 3/6) or brown (7.5YR 3/4) to strong brown (10YR 5/4)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow (&lt; 25 cm) to shallow (25–50 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Mostly an abundant (50–90%) stony mantle of calcareous geology, abundant biological (cryptogam) crusting (50–60%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone, calcrete, calcarenite</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–30 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (1–30 mS/m), weakly saline (60 mS/m) for some gradational loams</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Shallow</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>

A calcareous shallow loam with only 15–20 cm of soil overlying limestone. Soils like this are common throughout much of the Nullarbor Plain proper.

This shallow soil supports speargrass (Austrostipa scabra) and wallaby grass (Austrodanthonia caespitosa), some shrubs and a few trees. The shrub and tree roots follow fissures in the limestone in search of soil moisture. This is from an area west of Rawlinna Station homestead.
Calcareous shallow clay loams are very common and have textures ranging from heavy loams at the surface grading into clay loams above the calcareous substrate. The soils may have one to three, mostly thin, horizons. Soil colour ranges from yellowish red in the topsoil to yellowish red and dark brown in the subsoil. Salinity is very low in the topsoil and may range from non-saline to highly saline in the deeper subsoils. These soils are non-dispersive and do not slake. Mantles of calcareous rock types are mostly abundant and surface biological crusting is conversely abundant (i.e. where the mantle is highly abundant, crust abundance is low). Soil reaction is alkaline.

### Calcareous shallow clay loam soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Calcarosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Heavy loam throughout or grading to clay loam where soil depth is over 30 cm</td>
</tr>
<tr>
<td>Land systems</td>
<td>Major soils of the Balladonia, Caiguna, Culver, Damper, Gafa, Gumbelt, Kybo, Mundrabilla, Nanambinia, Nightshade, Nurina, Nyanga, Roe, Thampanna, Toolinna and Zanthus land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Calcrete plain overlain by loam (KPL), Calcrete stony plain (KSP), Low granite rise (LGR), Limestone hummock (low rise) (LHR), Stony limestone plain (SLP)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly yellowish red (5YR 4/6) or brown (7.5YR 4/4) to dark brown (10YR 3/3) for gradational types</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Shallow (25–50 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Mostly abundant (50–90%) stony mantles of limestone or where below 50%, common to abundant biological (cryptogam) crusting (30–50%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (8.5–9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–30 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (1–30 mS/m) to high (50–200 mS/m) for deeper clay loams</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Shallow</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
Soil group 522—Red shallow loams

Red shallow loams are uncommon in the survey area. They mostly consist of sandy loams, rarely grading to sandy clay loams and overlie limestone, nodules of limestone or occasionally calcrete. Some soils have a thin veneer of sand on the surface. When overlying granite, soil textures are sandy clay loams.

Generally soil reactions are neutral to weakly alkaline and no coarse or soft calcareous fragments occur through the profile. Soil colour is dark reddish brown to red or dark brown. Soils with sandy veneers have stone-free surfaces. Elsewhere the surfaces have infrequent to common mantles of calcareous fragments commonly with biological crusts.

Red shallow loam soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Petrocalcic, Lithic or Leptic Rudosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Sandy loam occasionally grading to sandy clay loam; sandy clay loams when over granite</td>
</tr>
<tr>
<td>Land systems</td>
<td>Soils within the Balladonia, Gumbelt, Naretha, Nyanga, and Zanthus land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Drainage floor (DFL), calcrete plain overlain by calcareous loam (KPL), low granite rise (LGR), plain calcareous loam with aeolian sand covering (PKE), stony limestone plain (SLP)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly dark reddish brown (2.5YR 3/4) and red (2.5YR 4/6) to red or dark brown (7.5YR 3/3)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Very shallow (&lt; 25 cm) to shallow (25–50 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>No stony mantle for soils with a thin sand veneer, otherwise few to common (2–50%) stony mantles of limestone and common to abundant biological (cryptogam) crusting (40–80%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone or limestone nodules, occasionally calcrete or granite</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Weakly alkaline to alkaline (7.9–8.6), except where it is neutral (6.5–7.0) in granite areas</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (8.5–9.0), except in granite areas where it is neutral to weakly alkaline (7.0–8.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (1–10 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Low</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Shallow</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
Soil group 542—Calcareous loamy earths

This group is comprised of soils with textures of loam throughout the profile. It is a complex of various soil types.

The lightest expression of this Soil group displays topsoils of fine sandy loam or sandy loam overlying subsoils of loam. This soil phase is relatively uncommon, occurring mainly in the Nyanga land system. Most soils within the calcareous loamy earth soil group consist of loam to heavy loam topsoils overlying subsoils of heavy loam to clay loam. This soil phase occurs on almost every land system. A less common soil phase is the heavier textured loam soils being clay loam topsoils grading to light clay subsoils.

Most of the soils within this soil group have thin to medium topsoils overlying moderate to deep subsoils. Limestone or calcrite often underlie these moderate depth soils. Limestone gravels occur within 30 cm of the soil surface and generally increase in abundance and size with depth. Saline subsoils mostly occur in low-lying areas supporting salt tolerant vegetation or where gypsum occurs within the soil. Similarly soils with clayey subsoils are almost always weakly to strongly saline. In lighter textured soils salinity is variable. Soil reaction is alkaline.

Soil colour is generally dark reddish brown to reddish brown near the surface to yellowish red in the subsoil. Within the Thampanna land system the loamy soils tend to be browner in colour. The soil surfaces are generally covered with an abundant mantle of limestone or calcrite with infrequent to common cryptogam crusting.

Calcareous loamy earth summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Calcarosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Fine sandy loam to sandy loam over loam; loam grading to clay loam or clay loam grading to light clay</td>
</tr>
<tr>
<td>Land systems</td>
<td>Major soils of the Arubiddy, Caiguna, Damper, Kyarra, Kybo, Mundrabilla, Moonera, Nanambinia, Nightshade, Nyanga, Thampanna, Shakehole and Roe land systems. Minor soils of the Lowry, Naretha, Virginia and Zanthus land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Calcrete plain overlain by loam (KPL), calcrete stony plain (KSP), calcrete rise overlain by calcareous loam (KRL), stony limestone plain (SLP), plain calcareous loam (PKL), Limestone hummock (low rise) (LHR)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly dark red (2.5YR 3/6) and reddish brown (5YR 4/4) to yellowish red (5YR 4/6) or brown (7.5YR 3/4) to strong brown (10YR 5/4)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Moderate to deep (&gt; 80 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Mostly to abundant (50–90%) stony mantles of limestone, common to abundant biological (cryptogam) crusting (10–50%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–10 mS/m) for sandy loams and some loams</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (1–10 mS/m) for sandy loam and some loams, moderately to highly saline (100–400 mS/m) clay loam or light clay subsoils</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Loamy soils—highly permeable, loams grading to clays moderately permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Moderate to deep</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
Soil group 544—Red loamy earths

Red loamy earths are infrequent. They occur as deep soils with sandy clay loam or clay loam topsoils graduating to clay loam or light clay subsoils. The soil surfaces may have a thin sandy veneer or occasionally support a light mantle of stone. The soils are non-saline and only rarely have calcareous deep subsoils. Soil reaction is neutral or occasionally alkaline and the topsoils do not slake or disperse. The soil colour ranges from dark reddish brown to dark brown.

Red loamy earth soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Red Kandosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Sandy clay loam to clay loam overlying light clay loam</td>
</tr>
<tr>
<td>Land systems</td>
<td>Minor soils of the Gumbelt and Naretha land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Clay depression (CLD) and plain with calcareous loam and thin sand veneer (PKS)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly dark reddish brown (2.5YR 3/6) to dark red (2.5YR 4/6)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm) or moderately deep (&gt; 80 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Apedal, earthy and massive</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Thin sandy veneer on surface or infrequent to common biological (cryptogam) crusting (0–40%)</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil for topsoil, nil to partial for subsoil</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil for topsoil, nil to complete for subsoil</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Neutral (7.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Neutral to alkaline (7.0–8.5)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–5 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (5–20 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>Moderate</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Deep</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
Soil group 600—cracking clays

Cracking clay soils are deep with thin to medium light clay (occasionally medium clay) topsoils. Occasionally the topsoils may include a thin layer of clay loam. The thick to very thick subsoils have textures of light or medium to heavy clay. The uppermost layers display large surface cracks or have crumbly (self-mulching) surfaces when dry and often show rough mounded (gilgai) surfaces. Large areas of cracking clays tend to show zonations of varying amounts of surface cracking. Soil colour is mainly dark reddish brown to red, soil reaction is alkaline and many soils contain some carbonates within at least part of the profile. The soil surfaces are generally non-saline with deep subsoils being either non-saline or partially saline. These soils occur in dongas, swamps or areas of surface water accumulation. Cracking clay soils often occur with or adjacent to, red/brown non-cracking clay soils (Soil group 622).

Cracking clay soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Red Vertosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Light clay grading to medium or heavy clay</td>
</tr>
<tr>
<td>Land systems</td>
<td>Soils of the Haig, Koonjarra, Nurina and Nyanga land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Clay plain (CLP), Gilgai depression (GIL), Calcrete plain overlain by loam (KPL)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly yellowish red (5YR 4/6) or strong brown (7.5YR 4/6 to 7.5YR 5/6)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm)</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Pedal, moderate to strong polyhedral ped structure</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Occasional infrequent to common (10–30%) limestone with some soil surface cracks or mounded gilgais</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil, sometimes partial</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Nil, sometimes partial or complete</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low (1–20 mS/m) occasionally high (90 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low (10–20 mS/m) occasionally high (390 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Moderately permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>High</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Moderate to deep</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low</td>
</tr>
</tbody>
</table>
Soil group 622—Red/brown non-cracking clays

Red/brown non-cracking clays are mostly deep soils. Shallow clays occur sporadically throughout the area but rarely dominate.

The deep clays are generally composed of light clay, occasionally grading to medium or heavy clay. Deep clays are mostly non-saline, but saline types tend to occur in areas accumulating overland water flow like clay plains, clay depressions, saline plains, and areas with gypsum in the subsoil. Shallow clays overlie limestone.

Deep red/brown non-cracking clays often occur with cracking clay soils and some soils show juvenile features of cracking clays such as weakly developed self-mulching surfaces or minor soil surface cracking. Soil colour is mainly dark reddish brown to dark red or strong brown. The soils are alkaline throughout and may contain calcareous segregations of weathered limestone fragments in the lower subsoils. The topsoils generally do not slake or disperse (unless highly saline) but subsoils commonly partially or completely slake and disperse. The soil surfaces generally have an infrequent mantle of limestone, but display abundant biological cryptogam crusting.

Red/brown non-cracking clay soils summary

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Red Kandosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil textures</td>
<td>Light clay grading to light medium or sometimes heavy clay</td>
</tr>
<tr>
<td>Land systems</td>
<td>Commonly found on the Damper, Lefroy, Koonjarra, Kybo, Pondana, Thampanna, Shakehole and Vanesk land systems. Minor soils of the Caiguna, Gafa, Haig, Jubilee, Kanandah, Kitchener, Moonera, Nurina, Skink and Woorbla land systems</td>
</tr>
<tr>
<td>Land units</td>
<td>Clay depression (CLA), clay plain (CLP), donga depression (DON), Gilgai depression (GIL), Calcrete plain overlain by loam (KPL)</td>
</tr>
<tr>
<td>Soil colour</td>
<td>Mainly dark reddish brown (2.5YR 4/6) to yellowish red (5YR 4/6) or strong brown (7.5YR 5/6)</td>
</tr>
<tr>
<td>Soil depth</td>
<td>Deep (&gt; 100 cm), minor shallow soils (50 cm) over limestone</td>
</tr>
<tr>
<td>Pedality/Fabric/Structure</td>
<td>Mostly apedal, earthy and massive, or moderately structured with polyhedral ped when occurring among cracking clay soils</td>
</tr>
<tr>
<td>Soil surface condition</td>
<td>Hardsetting with mostly abundant biological (cryptogam) crusting (50–90%) and infrequent (&lt; 10%) mantles of limestone</td>
</tr>
<tr>
<td>Substrate</td>
<td>Limestone for shallow soils</td>
</tr>
<tr>
<td>Topsoil/subsoil slaking</td>
<td>Nil unless saline, then partial</td>
</tr>
<tr>
<td>Topsoil/subsoil dispersion</td>
<td>Mostly partial to complete</td>
</tr>
<tr>
<td>Topsoil pH range</td>
<td>Alkaline (8.5–9.0)</td>
</tr>
<tr>
<td>Subsoil pH range</td>
<td>Alkaline (9.0)</td>
</tr>
<tr>
<td>Topsoil EC range</td>
<td>Low for non-saline soils (1–30 mS/m), high for saline soils (100–160 mS/m)</td>
</tr>
<tr>
<td>Subsoil EC range</td>
<td>Low for non-saline soils (30–50 mS/m), high for saline soils (200–600 mS/m)</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>Highly permeable</td>
</tr>
<tr>
<td>Available water storage</td>
<td>High for deep soils, low for shallow soils</td>
</tr>
<tr>
<td>Unrestricted rooting depth</td>
<td>Deep, low for shallow soils</td>
</tr>
<tr>
<td>Wind erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Water erosion hazard</td>
<td>Low</td>
</tr>
<tr>
<td>Inundation/flooding risk</td>
<td>Low, but high in clay or gilgai depressions</td>
</tr>
</tbody>
</table>
Biological soil crusts

Most soil surfaces of the Nullarbor have some form of protection from wind and water erosion. This can be in the form of stone, plant or leaf litter cover. Where there is none of this cover, soil crusting mostly exists. Biological soil crusts make up a vital component of the arid or semi-arid ecosystem. Collectively known as cryptogams (from two Greek words ‘kryptos’ meaning hidden and ‘gamos’ meaning marriage), they are made up of various lichens, mosses, liverworts, fungi and blue-green algae. The lichen and larger mosses are visible while the microflora of the algae and fungi are difficult to distinguish without the aid of magnification. The lack of soil crusts around some permanent livestock watering points in the Nullarbor pastoral area is notable. Soil surface crusting falls into four scenarios:

- **Stone (mantle) free, open low plains** surrounded by low rises. The low plains act as micro-sumps collecting some run-off water from the surrounding rises. These low plains primarily have deep clay-based soils and water percolation through the soil is not rapid, taking days rather than hours. The primary vegetation is bladder saltbush (*Atriplex vesicaria*) and may make up to 20 per cent of the soil cover. Plants provide protection to the soil through intercepting rainfall and creating protection from wind erosion. As such biological soil crusting does not grow under the plant canopies. The remaining soil cover is mostly soil crusting.

- **Stony open low rises or level to gently undulating plains** with isolated or scattered eucalyptus trees also support low to tall shrubs. Tree and shrub canopies protect the soil surface. Under many trees leaf litter also provides soil protection. Vegetation canopies may cover up to 40 per cent of the soil surface and stone cover may be infrequent to common. The soils are generally free draining with light textured topsoils. Generally cryptogam crust cover ranges from 10 to 20 per cent in these environments.

- **Undulating plains with isolated or scattered eucalyptus trees** also support low to tall shrubs. Tree and shrub canopies protect the soil surface. Under many trees leaf litter also provides soil protection. Vegetation canopies may cover up to 40 per cent of the soil surface and stone cover may be infrequent to common. The soils are generally free draining with light textured topsoils. Generally cryptogam crust cover ranges from 10 to 20 per cent in these environments.

- **Drainage foci on open plains** act as local drainage termination zones. Water percolation through the soil profile is slow (weeks rather than days). These foci are mostly stone-free and may support either (non-saline) gilgai soils with grasses or claypans with salt-tolerant vegetation. Soil salinity influences the amount of crusting (in a downward trend) and the surface crust rarely exceeds 70 per cent.

Biological soil crusts often appear somewhat brittle and hard in the dry state, but with the slightest amount of rainfall become soft, pliable and spongy. Soil crusts have not evolved to withstand continuous trampling by hard-hoofed animals and regular vehicle impact. Once broken the crusts re-establish relatively quickly provided they are no longer disturbed. Constant trampling or traffic will destroy the crusts and re-establishment may take many years.

---

A section of healthy biological soil crust. Note the different colours and types of cryptogams. During dry times much of the crust will appear black and lifeless. Some cryptogams, especially certain mosses, ‘green-up’ almost immediately after wetting.
Biological soil crusts not only protect the underlying soil surface from forces above the ground, but also provide a mulch-effect reducing soil desiccation rates through solar evaporation. There is also anecdotal evidence soil crusts influence surface salinity. In some random tests, salinity levels were measured on the surface of the ruts of vehicle station tracks and healthy intact soil surfaces less than one metre away from the tracks. Soil salinity levels just below the surface of healthy crusted surfaces were so low the salinity could not be measured with a field electrical conductivity (EC) meter. However the salinity of the soil surface (and just below) in the active vehicle tracks was high because there were no binding crusts.

References


**Vegetation**

*AK Gardner*

This chapter describes aspects of the vegetation. The first part provides a review of the regional vegetation within the survey area based on the Interim Biogeographical Regionalisation of Australia (Environment Australia 2000) and Beard’s (1975) vegetation survey of the Nullarbor. The remainder presents the findings of the current survey. A summary of the major taxa recorded during the survey is presented in the second section. Following this the vegetation of the survey area is discussed firstly in terms of plant form and secondly as vegetation formations. Regional patterns of distribution at a plant community and species level are then presented to provide a broader biogeographic perspective. Finally flora conservation is addressed.

This chapter focuses on plants and the communities they comprise. The habitat type ecology chapter looks in more detail at the ecology of vegetation communities.

**Regional overview**

Most of the survey area lies in the Nullarbor Biogeographic Region of the Interim Biogeographic Regionalisation of Australia. In the south-east is the Hampton Biogeographic Region, and in the south-west some of the survey area is classified within the Coolgardie and Mallee Biogeographic Regions. A small portion in the north-west includes the Great Victoria Desert Biogeographic Region. All of these biogeographic regions are within the Eremaean Botanical Province apart from the Mallee Biogeographic region which is within the South-west Botanical Province (Figure 26).

![Figure 26 Biogeographic regions in the survey area (after Environment Australia 2000)]
Beard (1975) mapped the major vegetation communities within Western Australia at a scale of 1:1 000 000. The survey area occurs within Beard’s (1975) Nullarbor map sheet 4. Most is located within the Eucla Botanical District of the Eremaean Botanical Province, with smaller areas within the Nanambinia System of the South-Western Interzone and the Culver System of the South-west Botanical Province. Generalised vegetation formations modified from Beard (1975) are displayed in Figure 27.

Eremaean Botanical Province

Nullarbor Biogeographic Region

Broad plains of gently undulating limestone dominate this region. The plains consist of low rises, marginal run-off areas, drainage tracts and claypans. The low rises predominantly support a low shrubland of *Maireana sedifolia*, the marginal slopes support *Atriplex vesicaria* and the drainage tracts and claypans support either a low shrubland of *Atriplex vesicaria* and/or grassland of *Austrostipa scabra* and *Austrodanthonia caespitosa*.

To the north, large circular depressions or dongas become prominent. The dongas support open grassy groves dominated by *Acacia tetragonophylla*, *Eremophila longifolia*, *Grevillea nematophylla* and/or *Pittosporum angustifolium*.

Further to the north and west calcrete plains support open woodlands of *Acacia papyrocarpa* (myall) with an understorey of chenopod shrubs (Chapman 2005). The calcrete plains become progressively more wooded towards the northern and western periphery of the Nullarbor province, with myall replaced by *Acacia aneura*, *Casuarina pauper*, *Myoporum platycarpum* and eucalypts (Beard 1975). Eucalypts and spinifex become increasingly dominant at the perimeter of the north and west of the region, indicative of the transition into the Coolgardie and Great Victoria Biogeographic Regions.

Figure 27 Generalised vegetation formations within the survey area (modified from Beard 1975)
Hampton Biogeographic Region
The Hampton tableland supports tall shrubland of eucalypts and melaleucas, with an understorey of sclerophyll and succulent shrubs. The scree slopes of the Hampton Scarp are dominated by open mallee woodland (Chapman 2005).

Below the Hampton Scarp the extensive calcarenite Roe Plains overlies marine limestone. The northern portion of the Roe Plains supports open myall woodland with Melaleuca lanceolata and Myoporum platycarpum with an understorey of Atriplex species, Cratystylis conocephala and Nitraria billardierei. This vegetation association alternates with open saltbush plains and occasional patches of mallee. The vegetation grades eastwards into mallee woodland with an understorey of Cratystylis conocephala (Beard 1975). Soils are calcareous shallow loams and calcareous loamy earths.

The southern portion of the Roe Plains supports stony plains covered with mallee woodland with an understorey of heath and sedge species including Beaufortia, Callitris, Spyridium, Dianella, Lepidosperma and Schoenus. Along the coast is a belt of partially consolidated dunes, poorly vegetated with open mallee woodland with an understorey of Cratystylis conocephala (Beard 1975). Soils are calcareous shallow loams and calcareous loamy earths.

Coolgardie Biogeographic Region
Unique to this biogeographic region is scattered granite outcrop. The outcrop is often sparsely vegetated and surrounded by dense stands of Dodonaea lobulata and Eremophila alternifolia. This region predominantly supports mallee woodland on calcrite plains of Eocene and Oligocene marine limestone of the Eucla Basin. The understorey is composed of a variety of mixed shrubs including Atriplex, Cratystylis, Dodonaea, Eremophila, Maireana and Senna (Beard 1975). Soils are calcareous shallow loams, calcareous loamy earths and occasionally red loamy earths.

South-west Botanical Province
Mallee Biogeographic Region
Most of this region comprises mallee woodland with an understorey of scattered mixed shrubs, including Melaleuca, Eremophila and Senna. A sparse layer of low shrubs including Atriplex vesicaria, Cratystylis conocephala and Maireana sedifolia is also present. The understorey becomes increasingly dominated by heath species including Adenanthes, Beaufortia, Callitris and Grevillea towards the coast and the vegetation becomes progressively wind-pruned (Beard 1975). Soils are primarily calcareous loams and sands overlying Eocene and Oligocene marine limestone.

Where sand dunes occur at Point Culver, Toolinna, and Twilight Cove the vegetation is similar to that of the sandplains of Esperance due to the siliceous nature of the sands. Banksias, grevilleas and casuarinas dominate the understorey of sparse mallee woodland (Beard 1975).

Taxonomic summary
The plant taxonomy adopted in this survey is based on the Census of Western Australia Plants but also adopts changes on the advice of the Western Australian Herbarium. Scientific names are used with colloquial names of common species provided in the appendices.

Four-hundred-and-twenty-six species of vascular plants representing 198 genera in 61 families were collected during the survey, including 328 perennials and 98 annual species (Appendix 2i). A small number of botanical families contain a large proportion of the species (Table 12).

The largest family is the Chenopodiaceae; the species in this family dominate the survey area, particularly the limestone plains of the treeless portion of the Nullarbor land zone. The Asteraceae family contained the second greatest number of species; species within this family are found in many different landscapes. The Myrtaceae family is predominantly growing at the perimeters of the Nullarbor land zone to the north, south and west, with melaleucas preferring the coastal areas. The grasses of the Poaceae family are found in a wide variety of environments.
Table 12 Major families and dominant genera in the survey area

<table>
<thead>
<tr>
<th>Family</th>
<th>No. of species</th>
<th>Dominant genera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asteraceae</td>
<td>49</td>
<td>Cratystylis, Olearia, Rhodanthe, Senecio</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>47</td>
<td>Atriplex, Chenopodium, Maireana, Raphodia, Sclerolaena</td>
</tr>
<tr>
<td>Poaceae</td>
<td>37</td>
<td>Austrodonanthia, Austrostipa, Enneapogon, Eragrostis</td>
</tr>
<tr>
<td>Myrtaceae</td>
<td>35</td>
<td>Eucalyptus, Melaleuca</td>
</tr>
<tr>
<td>Mimosaceae</td>
<td>25</td>
<td>Acacia</td>
</tr>
<tr>
<td>Myoporaceae</td>
<td>23</td>
<td>Eremophila, Myoporum</td>
</tr>
<tr>
<td>Proteaceae</td>
<td>15</td>
<td>Adenanthis, Banksia, Grevillea, Hakea</td>
</tr>
<tr>
<td>Brassicaceae</td>
<td>13</td>
<td>Carrichtera, Lepidium, Sisymbrium</td>
</tr>
<tr>
<td>Papilionaceae</td>
<td>13</td>
<td>Pultenaea, Swainsona, Templetokia</td>
</tr>
<tr>
<td>Solanaceae</td>
<td>12</td>
<td>Lycium, Nicotiana, Solanum</td>
</tr>
</tbody>
</table>

Plant forms

The major plant forms observed within the survey area were trees, mallees, tall shrubs (> 2 m), mid shrubs (1–2 m), low shrubs (< 1 m), subshrubs or perennial herbs (< 0.5 m), perennial grasses, annual herbs and grasses, creepers, sedges, fern and soil cryptogams. These are briefly described below.

Trees

Trees are very scattered throughout the survey area, becoming increasingly abundant away from the Nullarbor land zone. The most common species are Acacia papyrocarpa, Myoporum platycarpum and Pittosporum angustifolium. Also common are Alectryon oleifolius, Casuarina pauper and Eremophila longifolia. Other trees which occur occasionally include Acacia aneura and Grevillea nematophylla. Most common eucalypts recorded in tree form were in the west and north-west of the survey area. Eucalyptus concinna, E. eremophila, E. fraseri subsp. fraseri, E. fraseri subsp. melanobasis, E. gracilis, E. melanoxylon, E. salubris and E. urna occur in tree form, though some species also occur in mallee form.

Mallees

Mallees are common towards the west and south of the survey area. Mallees are usually found as open multi-stemmed plants rarely exceeding 6 m high. The most common mallees recorded were the Eucalyptus oleosa (group) and E. yalatensis. Other mallees recorded include Eucalyptus brachycalyx, E. conglobata, E. cooperiana, E. discreta, E. diversifolia, E. sp. Fraser Range, E. incrassata, E. melanoxylon, E. rigida, E. socialis and E. surgens.

Tall shrubs

Acacias and melaleucas dominate the tall shrubs (> 2 m) throughout the survey area. The most common acacias are Acacia burkittii, A. oswaldii and A. tetragononphylla and the most common melaleucas are Melaleuca lanceolata and M. quadrifaria. Other tall shrubs common within the survey area include Dodonaea lobulata, Eremophila dempsteri, Exocarpos aphyllus, Geijera linearifolia and Myoporum platycarpum.

Mid shrubs

The most common mid shrub (1–2 m) within the survey area is Atriplex nummularia. Eremophila and Senna are also commonly represented within this group. Common Eremophila include E. alternifolia, E. decipiens, E. dempsteri, E. deserti and E. scoparia. Common Senna includes S. artemisioides subsp. x artemisioides and S. artemisioides subsp. x coriacea. Other common mid shrubs include Dodonaea lobulata, D. stenzyga, Exocarpos aphyllus and Nitraria billardierei.

Low shrubs

The most common growth form is low shrubs (< 1 m). Most are succulent low shrubs belonging to the Chenopodiaceae family. The most common members of this family are Atriplex vesicarica and Maireana sedifolia. Other common low shrubs from this family include Chenopodium curvispicatum, Enchylaena
tomentosa, Maireana erioclada, M. trichoptera, M. turbinata, Rhagodia grassifolia and Tecticornia spp.

Common low shrubs not in the Chenopodiaceae family include Cratystylis conocephala, Lawrecnia squamata, Lycium australre, Olearia calcar, Ptilotus obovatus, Solanum nummularium and Westringia rigida.

Subshrubs or perennial herbs

Subshrubs are seasonally dependent, weakly facultative perennial, generally less than 0.5 m (50 cm) in height. Common subshrubs are Atriplex acutibractea, Euphorbia drummondii, Sclerolaena diacantha, S. obliquicuspis, S. patenticuspis and Sida spodochroma.

Perennial grasses

The most common perennial grasses are the tussock grasses Austrodanthonia caespitosa and Austrostipa scabra. Tussock grasses vary from dense, well developed plants to open almost herbaceous forms. Other common tussock grasses include Austrostipa platychaeta, Enneapogon caerulescens, E. cylindricus, Eragrostis dielsii and E. setifolia.

Hummock grasses are a uniquely Australian form of grass in which rigid, pungent involute leaves form large rounded ‘hummocks’. Only one species of hummock grass, Triodia scariosa (spinifex) is found in the survey area and is restricted to the woodland in the north-western, west and south-western extent where aeolian sand begins to accumulate over calcrete.

Annual herbs and grasses

The survey was conducted in dry seasonal conditions, however, following localised heavy rains that fell predominantly on Kybo Station in the south-east the presence of annuals recorded increased within that localised rainfall zone. The most commonly recorded annuals were Aristida sp., Eriochiton sclerolaenoides, Salsola tragus and the introduced weed Carrichtera annua. Other common annuals include Atriplex acutibractea, Rhodanthe floribunda and Zygophyllum iodocarpum.

Creepers

Five creepers were recorded within the survey area. The most common was Marsdenia australis that produces edible fruits. Others included Billardiera fusiformis, Cassytha melantha, Comesperma volubile, Glycine rubiginosa and Mariantus bicolor var. bicolor.

Sedges

Seven species of the sedge family Cyperaceae occur. The most common of these was Gahnia lanigera and Tetraria capillaris. Other sedges included Ficinia nodosa, Isolepis congrua, Lepidosperma sp. A2 Island Flat, Mesomelaena stygia, M. stygia subsp. stygia, Schoenus caespititius, S. lanatus and S. subflavus subsp. hispid culms. Sedges are predominantly found along the south coast.

Ferns

Four species of fern were recorded. Cheilanthes austrotenufolia and C. lasiophylla were found in the crevices of granite outcrop. Marsilea hirsuta and Pleurosorus rutifolius were also recorded.

Soil cryptogams

Soil cryptogams consist of unicellular algae, liverworts, and foliose and crustose lichens. They have an important role in soil ecology in arid zones as they fix nitrogen and stabilise naturally dispersive soils. Particularly in the Nullarbor land zone cryptogams have an especially important role in protecting the soil from wind erosion. Where cryptogams are absent or scarce, generally due to soil disturbance, wind erosion is severe leading to the prominent piospheres seen in satellite imagery around water points. Cryptogams also provide forage for microscopic herbivores, contributing both directly and indirectly to biological activity at the soil surface.

Vegetation formations and their floristic components

The vegetation formations described below have been developed from inventory site data. The dominant stratum at each habitat type was recorded. The vegetation formations are defined as:
**Woodland**

dominant stratum is trees or mallees (trees have a single stem to 1.3 m high above ground level and mallees are multi-stemmed plants to 6 m)

**Tall shrubland**

dominant stratum is shrubs over 2 m tall

**Mid shrubland**

dominant stratum is shrubs 1 to 2 m tall

**Low shrubland**

dominant stratum is shrubs less than 1 m tall

**Tussock grassland**

dominant stratum is tussock grasses

**Hummock grassland**

dominant stratum is hummock grasses

**Herbland**

dominant stratum is herbs or subshrubs less than 0.5 m tall (herbs may be annual or perennial plants).

These vegetation formations are a simplification of traditional methods of describing vegetation. Muir’s (1977) method of classification is referred to in each of the formations described below.

Vegetation was described at 392 inventory sites. Twenty-five had co-dominant strata and one site had no vegetation. The dominant stratum at the remaining 366 sites is shown in Table 13.

Low shrubs were the dominant stratum at the majority of inventory sites, followed by trees, tussock grasses, mid shrubs, tall shrubs, herbs and lastly hummock grasses.

### Table 13 The floristic variability of dominant strata

<table>
<thead>
<tr>
<th>Dominant stratum</th>
<th>No. of sites</th>
<th>No. of dominant species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree</td>
<td>73</td>
<td>24</td>
</tr>
<tr>
<td>Tall shrub</td>
<td>31</td>
<td>21</td>
</tr>
<tr>
<td>Mid shrub</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Low shrub</td>
<td>160</td>
<td>26</td>
</tr>
<tr>
<td>Tussock grass</td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td>Hummock grass</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Herb/subshrub</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>366</strong></td>
<td><strong>108</strong></td>
</tr>
</tbody>
</table>

Low shrubland had the least floristic variability in the dominant strata, considering the large number of sites sampled. In comparison, sites that had a dominant stratum of tall shrubs, mid shrubs and herbs had greater floristic variability.
Acacias and melaleucas were the dominant species at over two-thirds of the 31 tall shrubland sites. Both *Melaleuca lanceolata* and *M. quadrifaria* were the dominant species at six sites, predominantly located along the south coast. *Acacia burkittii* was the most common acacia to dominate tall shrub sites (three sites); these sites were located in the central west of the survey area. However, *Acacia tetragonophylla* and *Acacia oswaldii* were the most common tall shrubs, occurring as very scattered to isolated shrubs, featuring in 30 and 34 inventory sites respectively, especially in the Nullarbor land zone.

Tall shrubland sites on plains overlain by shallow aeolian sands and land units associated with granite outcrops were dominated by *Dodonaea* and *Eremophila*.

Nearly half (49 per cent) of tall shrubland sites were in good condition, 30 per cent in very good condition, 8 per cent in fair condition and 13 per cent in poor condition.

Low shrubland

The PFC for low shrubland sites varied from 5 to 50 per cent. They are categorised as 'Low Heath C' where the PFC is between 30 and 50 per cent, 'Dwarf scrub C' where the PFC is between 10 and 30 per cent and 'Open Dwarf Scrub C' where the PFC is lower than 10 per cent (Muir 1977).

Of the 160 low shrubland sites, 19 were co-dominated by two species of low shrubs and one site by three species. Of the 140 sites dominated by a single species of low shrub, over 75 per cent were dominated by species of the Chenopodiaceae family. *Atriplex vesicaria* dominated 48 of these sites and *Maireana sedifolia* 39 of these sites. Eight other species of Chenopodiaceae dominated the 14 other sites.

Sixteen species of low shrubs not within the Chenopodiaceae family dominated the remaining 32 sites. *Cratystylis conocephala* dominated nine of these sites, *Lawrencia squamata* five sites and *Lycium australe* four sites. Sites dominated by *Lawrencia squamata* commonly occurred on the breakaway slope to drainage floor within the Koonjarra land system. *Ptilotus obovatus* and *Westringia rigida* each occurred at three sites. An overstorey of scattered trees and mallees is often associated with low shrubland dominated by non-chenopodiaceous species. These sites are commonly found towards the northern and western perimeters of the survey area.

Over half (57 per cent) of the sites were in good condition, 21 per cent were in very good condition, 17 per cent in fair condition, 4 per cent in poor condition and 1 per cent in very poor condition.

Mid shrubland

The majority of mid shrubland sampled had a PFC of 5 to 20 per cent, which according to Muir’s (1977) system of classification are ‘Low Scrub A or B’ where the PFC is between 10 and 30 per cent and ‘Open Low Scrub A or B’ where the PFC is less than 10 per cent. *Cratystylis conocephala* and *Maireana sedifolia* which dominated the most sites, reach a maximum height of 1.5 m and fall within group B, whilst species such as *Atriplex nummularia* and *Geijera linearifolia* grow to 2 m and are in group A. Where the PFC was greater than 30 per cent such sites were classified as heathland.

Nine of the 30 mid shrubland sites were dominated by *Maireana sedifolia*. These sites were located throughout the survey area, excluding the coastal region to the south. *Cratystylis conocephala* was the dominant shrub at three sites, a scattered overstorey of *Acacia papyrocarpa* or eucalypts was present at these sites. *Geijera linearifolia* and *Nitraria billardierei* each dominated two sites in the south of the survey area and *Atriplex nummularia* dominated two sites in the west.

The majority (64 per cent) of mid shrubland sites were in good condition, 18 per cent were in very good condition and 18 per cent were in fair condition.

Tussock grassland

The basal cover of tussock grasses is most commonly 5 to 10 per cent. The PFC was estimated to be between 30 to 70 per cent. The height of grasses that dominate this stratum is predominantly less than 0.5 m. Tussock grassland is classified as ‘Low Grasslands’ (Muir 1977).

Eight dominant species were recorded at the 42 tussock grassland sites. *Austrostipa scabra* was the dominant species at most grassland sites. *Austrodanthonia caespitosa*, *Eragrostis dielsii* and *Eragrostis setifolia* were each dominant at three sites.
Grassland sites dominated by Austrostipa scabra and Austrodanthonia caespitosa often represented a transition from degraded shrubland sites. It is likely the shrubs were lost or reduced by fire and overgrazing by rabbits, and secondarily through overgrazing by domestic stock. These sites predominantly occur on limestone plains, with Austrostipa scabra dominating sites across the survey area and Austrodanthonia caespitosa sites in the north-east. Grassland dominated by Eragrostis dielsii and Eragrostis setifolia is found in areas where surface drainage accumulates, commonly claypans, dongas and gilgai.

Tussock grassland is difficult to rate as it often dominated an altered vegetation community. As it is assumed that the altered transition is permanent, vegetation communities were rated as found rather than as was perceived to have been once. Over half (56 per cent) of the grassland sites were considered to be in good condition, with 15 per cent in very good condition, 27 per cent in fair condition and 2 per cent in poor condition.

Hummock grasslands

Three hummock grassland sites were recorded; the sites had a PFC of 10 to 40 per cent. According to Muir (1977), a site with a PFC of less than 30 per cent is classified as ‘Hummock Grass’ and a site with a PFC of greater than 30 per cent, ‘Mid Dense Hummock Grass’. Only one species of hummock grass, Triodia scariosa was found. Hummock grassland occurs in the north-west, west and south-west of the survey area on calcareous aeolian sandplains.

All sites were rated as being in good condition.

Herbland

The PFC for herbland sites was mostly between 2 and 15 per cent. Herbland sites are therefore classified as ‘Very Open Herbs’ where the PFC is less than 10 per cent and ‘Open Herbs’ where the PFC is greater than 10 per cent (Muir 1977).

Thirteen species of herb were recorded at 27 herbland sites. Sclerolaena obliquicuspis dominated four sites and Sclerolaena patenticuspis dominated seven sites. These sites were commonly located on limestone plains in the north-east of the survey area. Salsola tragus was the dominant species at three sites located within areas of drainage focus in the north-east. Herb species that dominated two sites included Carrichtera annua, Cullen cinereum and Zygophyllum iodocarpum. These species commonly dominate sites in dongas in the north.

Nearly half (52 per cent) of herbland sites were considered to be in fair condition, 15 per cent were very good, 26 per cent were good and 7 per cent were poor.

Regional distribution of plant communities

There is a noticeable geographic variation in the dominant strata at sampling sites across the survey area. Low shrubland is the most common vegetation formation on all 1:250 000 scale map sheets except Burnabbie where woodland dominates. The Cundeelee, Forrest and Noonaera map sheets had too few sites recorded to allow any analysis.

Low shrubland is most common on the Eucla, Madura and Naretha map sheets that fall predominantly within the Nullarbor Plain proper. Woodland is more common on the Balladonia and Burnabbie map sheets that border the survey area in the south-west and south. The majority of woodland on these map sheets is mallee woodland. Tussock grassland grading southwards into tall shrubland is most common on the Culver map sheet. On the Zanthus map sheet mallee woodland and mid shrubland is most common. Herbland is common through the Loongana map sheet, though myall woodland is common along the western border. Similarly herbland is common in the south-east of the Seemore map sheet with woodland in the north-western portion.

Atriplex vesicaria was the most commonly recorded species on the Balladonia, Eucla, Madura and Zanthus map sheets recorded at nearly 90 per cent of the sites on these map sheets, except the Zanthus map sheet where it occurred at 77 per cent of the sites. In the north on the Loongana, Naretha and Seemore map sheets, Austrostipa scabra was the most common species recorded at over 70 per cent of the sites.

In the south of the survey area on the Burnabbie and Culver map sheets vegetation associations have more defined boundaries and are confined to smaller areas than further north. This is due to the close coastal proximity and its effect on
the geophysical development of landforms and local weather conditions. As a result, no one species was recorded at more than 55 per cent of the sites on these two map sheets. *Maireana erioclada* (54 per cent) and *Melaleuca lanceolata* (50 per cent) were the most commonly recorded plants on the Burnabbie map sheet and *Austrostipa scabra* (48 per cent) on the Culver map sheet.

The most noticeable geographic variation in individual species is the distribution of trees. The distribution is largely dependent on geomorphology, geology, soils and rainfall gradients across the landscape. The distribution across map sheets of five tree species common on the Nullarbor is shown in Table 15.

*Acacia papyrocarpa* (myall) is found on all map sheets within the survey area, though is most common on the Eucla, Seemore and Zanthus map sheets. The understorey of myall woodland is primarily composed of *Cratystylis conocephala* and Chenopodiaceae. In the north, dense population recruitment of juvenile myall is occurring. In dry periods myall trees are browsed, whilst sheep and rabbits favour myall seedlings. It is likely the germination is most noticeable in these northern areas as these areas are not stocked with sheep and rabbit numbers have been substantially reduced by rabbit calicivirus. The reduction in the total grazing pressure is providing the opportunity for myall seedlings to survive beyond germination.

*Casuarina pauper* (black oak) is most common in the south-west, on the Naretha and Zanthus map sheets. It is commonly found on calcrete plains or residual calcrete rises and is often associated with an understorey of *Acacia, Eremophila* and Chenopodiaceae.
Myoporum platycarpum (sugarwood) is mostly found on the Balladonia, Seemore and Zanthus map sheets. Sugarwood often dominates the stony calccrete plains of the Nanambinia land system and the clay depressions of the Woobla land system. Dense recruitment of sugarwood is often found in these areas, which is considered to be in response to the reduction in rabbit numbers due to rabbit calicivirus.

A variety of eucalypt species is found in the western and southern perimeters of the survey area coinciding with greatest rainfall. Eucalyptus gracilis, E. oleosa and E. yalatensis were the most common eucalypts recorded. Eucalyptus gracilis and E. oleosa can survive with less water than Eucalyptus yalatensis (Parsons 1970) and therefore have a greater range, being most common on the Balladonia, Zanthus and southern portion of the Eucla map sheets. Eucalyptus yalatensis is restricted to the narrow strip along the coast from Balladonia into South Australia. Within the survey area Eucalyptus yalatensis is most common on the Balladonia and southern portion of the Eucla map sheets.

Flora conservation

Flora conservation involves maintaining biological diversity at a variety of scales, from genetic diversity within single populations to continental and global species richness. In this section the threats to plant species and communities, and threatened species are discussed.

Threats to native flora

Pastoralism

Pastoralism has extensively modified native plant communities in the rangelands. Where grazing has been excessive, plant species that are palatable to domestic stock, feral animals and kangaroos have been substantially reduced or removed. The vacated niches are then replaced by suites of less palatable plants, with the resulting species richness, density and cover rarely equal to that of the previous vegetation community (Payne et al. 1998). No plants are known to have become extinct in the survey area since pastoralism was introduced, though palatable plant species such as Maireana georgei are likely to have been reduced. The prolific germination of Acacia papyrocarpa (myall) in areas absent of sheep, coinciding with reduced rabbit numbers, is evidence of the impact sheep have had on suppressing myall populations.

Two key factors affect the susceptibility of plant communities to grazing: first the distance from water and second the palatability of plant species. Cridland and Stafford Smith (1993) demonstrated that the impact of grazing increases as the distance from water decreases. Closer to watering points the concentration of stock is greatest, as all stock from within a paddock congregate in the small area surrounding watering points to drink. This results in increased grazing and trampling of the vegetation and paddling of the soil in close proximity to watering points.

The intensity of the piosphere effect surrounding water points depends on the volume of water stock need; this varies depending on the salt content of feed and water, temperature and seasonal conditions. When stock are grazing on saline feed and drinking saline water, as is often the case on the Nullarbor, the volume of water required per day is greatly increased. High temperatures also increase the volume that stock must drink to replace that lost through evaporative cooling mechanisms (Macfarlane & Howard 1974). The greater the volume of water required, the longer stock will spend near watering points and the less distance they will be able to travel away from watering points before needing to return. This increases the level of deterioration of the soil and vegetation surrounding watering points.

Following periods of rainfall, stock are able to graze further from water points due to the increased volume of water ingested as a component of newly germinated herbage. During these times sheep can often fulfil their daily requirements from the water within feed, cattle however will always need access to sources of ‘free’ water (Burnside, Williams & Curry 1990).

Vegetation communities that are highly palatable and accessible to stock are at the greatest risk from overgrazing. Livestock are known to actively seek more desirable plants from pasture, and will range, if necessary, beyond their expected grazing radius to select these plants even when there is abundant feed along the way (Eckersley 1988). Within the Nullarbor, the most palatable feed is often the grasses and herbage that grow between the perennial shrubs. In dry seasons when grasses and
herbage are scarce, the preferred vegetation is often chenopod shrubs, particularly *Atriplex vesicaria*, and browse from *Acacia papyrocarpa*, *Alectryon oleifolius*, *Cratystylis conoecephala*, *Eremophila longifolia* and *Pittosporum angustifolium*. These perennial shrubs and trees may be killed by overgrazing, leading to loss of plant cover and increased exposure of soil which increases the susceptibility to all forms of erosion.

A more even distribution of grazing can be achieved if paddocks enclose similar land types (Pringle 1994). All areas within a paddock will be similarly preferred by stock, and so stock will not selectively graze out the most palatable areas. Small areas such as dongas and drainage foci often contain vegetation of high palatability, but also support unique vegetation communities which are important contributors to the heterogeneity of the Nullarbor ecosystem. Excluding dongas and drainage foci from grazing systems is unfeasible, however such areas would benefit from not having water points located directly in them to reduce the degradation that such positioning inevitably causes. This would also encourage more even grazing of the surrounding dominant vegetation types.

**Introduced flora species**

Forty-three introduced flora species were recorded within the survey area (Table 16). Of the 6997 traverse ratings where range condition was assessed, introduced flora was recorded at 3.3 per cent of traverse points. The most common species was *Carrichtera annua* (Ward's weed) recorded at 3 per cent of traverse points.

Many introduced flora species were commonly recorded in degraded dongas and along the Trans-Australian Railway line and Eyre Highway. Whilst many of the introduced flora species tend to remain restricted to depressions some species have the potential to cause significant ecological problems to Nullarbor communities. *Asphodelus fistulosus* (onion weed) has become established in a number of locations through its ability to dominate disturbed or degraded areas. Another species with the potential to spread on the Nullarbor is *Cenchrus ciliaris* (buffel grass). At the time of the survey buffel grass was observed in the vicinity of the Trans-Australian Railway line, occurring in small but established populations. Other introduced flora increasing in specific localised areas included *Salvia verbenaca* (wild sage), *Schinus molle var. areira* (pepper tree) and *Tamarix aphylla* (tamarisk).

**Feral herbivores**

Historically, rabbits have had a large impact on the Nullarbor. During the 1940s their number was so great it enabled a substantial commercial trade, with 20 000 rabbits a week trapped in the Cocklebiddy area alone (Parsons 1970). Rabbit plagues have had a devastating effect on the landscape. They have reduced the recruitment of trees such as *Acacia papyrocarpa* by grazing on seedlings and juveniles, and ringbarking older trees. Rabbit densities must remain very low in some arid areas to enable plant regeneration. The regeneration of *Acacia papyrocarpa* was found to be affected by rabbit grazing at densities of less than 0.5 rabbits per kilometre (Lange & Graham 1983). Rabbits have also overgrazed palatable herbs and grasses, leading to a reduction in ground cover so that the rate of erosion is increased (Gilfillan 1999). The reduction in perennial plants as well as the soil disturbance caused by burrowing has also led to an increase in populations of unpalatable, short-lived annuals. The release of the viruses (myxomatosis in 1954 and 1966, rabbit calicivirus in 1995) has greatly reduced rabbit numbers across the Nullarbor (Gilfillan 1999).

Feral camels occur in medium to high numbers throughout the pastoral areas, with larger numbers in the Unallocated Crown Land in the north and east of the survey area (Woolnough et al. 2005), feral horses are also present though in lower numbers. Horses and camels graze on the fruits, leaves and stems of trees. They are able to browse higher trees than other animals within the area. The repeated browsing of foliage and bark, breaking of branches and eventually the central trunk can lead to the death of trees. The mustering of feral horses and the shooting of both feral camels and horses is considered the most practical form of control for these animals. Control programs are carried out by pastoralists.
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Common name</th>
<th>Growth form</th>
<th>No. of inventory sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anagallis arvensis</td>
<td>Pimpernel</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Arctotheca populifolia</td>
<td>Dune arctotheca</td>
<td>Perennial herb</td>
<td>-</td>
</tr>
<tr>
<td>Asphodelus fistulosus</td>
<td>Onion weed</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Brassica tournefortii</td>
<td>Wild turnip</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Cakile maritima</td>
<td>Sea rocket</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Carduus nutans</td>
<td>Nodding thistle</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Carrichtera annua</td>
<td>Ward’s weed</td>
<td>Annual herb</td>
<td>111</td>
</tr>
<tr>
<td>Carthamus lanatus</td>
<td>Saffron thistle</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Centchris ciliaris</td>
<td>Buffel grass</td>
<td>Perennial grass</td>
<td>-</td>
</tr>
<tr>
<td>Centaurea melitensis</td>
<td>Maltese cockspur</td>
<td>Annual herb</td>
<td>2</td>
</tr>
<tr>
<td>Centaurea erythraea</td>
<td>Common centaury</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Chenopodium murale</td>
<td>Nettle-leaf goosefoot</td>
<td>Annual herb</td>
<td>2</td>
</tr>
<tr>
<td>Chlorsis gayana</td>
<td>Rhodes grass</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Citrullus lanatus</td>
<td>Pim elon</td>
<td>Perennial herb</td>
<td>6</td>
</tr>
<tr>
<td>Cucumis myriocarpus</td>
<td>Prickly paddy melon</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Emex australis</td>
<td>Doublegee</td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Erodium aureum</td>
<td></td>
<td>Annual herb</td>
<td>21</td>
</tr>
<tr>
<td>Erodium cicutarium</td>
<td>Common storks bill</td>
<td>Annual herb</td>
<td>4</td>
</tr>
<tr>
<td>Euphorbia paralias</td>
<td>Sea spurge</td>
<td>Perennial herb</td>
<td>2</td>
</tr>
<tr>
<td>Heliotropium europaeum</td>
<td>Common heliotrope</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Gomphocarpus fruticosus</td>
<td>Narrowleaf cottonbush</td>
<td>Perennial herb</td>
<td>-</td>
</tr>
<tr>
<td>Hordeum glaucum</td>
<td>Northern barley grass</td>
<td>Annual grass</td>
<td>-</td>
</tr>
<tr>
<td>Lepidium africanum</td>
<td>Rubble peppercress</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Lythrum hyssopifolia</td>
<td>Lesser loosestrife</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Malva parviflora</td>
<td>Marshmallow</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Malvastrum americanum</td>
<td>Spiked malvastrum</td>
<td>Perennial herb</td>
<td>6</td>
</tr>
<tr>
<td>Marrubium vulgare</td>
<td>Horehound</td>
<td>Perennial herb</td>
<td>-</td>
</tr>
<tr>
<td>Mesembryanthemum cristallinum</td>
<td>Iceplant</td>
<td>Annual herb</td>
<td>35</td>
</tr>
<tr>
<td>Mesembryanthemum nodiflorum</td>
<td>Slender iceplant</td>
<td>Annual herb</td>
<td>3</td>
</tr>
<tr>
<td>Nicotiana glauca</td>
<td>Tree tobacco</td>
<td>Tree</td>
<td>-</td>
</tr>
<tr>
<td>Oncosiphon suffruticosum</td>
<td></td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Oxalis corniculata</td>
<td>Yellow wood sorrel</td>
<td>Annual herb</td>
<td>5</td>
</tr>
<tr>
<td>Pentaschistis airoides</td>
<td>False hairgrass</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Rostraria pumila</td>
<td></td>
<td>Annual herb</td>
<td>1</td>
</tr>
<tr>
<td>Salvia verbenaca</td>
<td>Wild sage</td>
<td>Perennial herb</td>
<td>4</td>
</tr>
<tr>
<td>Schinus molle var. areira</td>
<td>Pepper tree</td>
<td>Tree</td>
<td>-</td>
</tr>
<tr>
<td>Schismus barbatus</td>
<td>Kelch grass</td>
<td>Annual grass</td>
<td>-</td>
</tr>
<tr>
<td>Sisymbrium erysimumoides</td>
<td>Smooth mustard</td>
<td>Perennial herb</td>
<td>10</td>
</tr>
<tr>
<td>Sisymbrium  trio</td>
<td>London rocket</td>
<td>Annual herb</td>
<td>-</td>
</tr>
<tr>
<td>Solanum nigrum</td>
<td>Blackberry nightshade</td>
<td>Perennial herb</td>
<td>2</td>
</tr>
<tr>
<td>Sonchus oleraceus</td>
<td>Common sowthistle</td>
<td>Annual herb</td>
<td>17</td>
</tr>
<tr>
<td>Tamarix aphylla</td>
<td>Tamarisk</td>
<td>Tree</td>
<td>1</td>
</tr>
<tr>
<td>Xanthium spinosum</td>
<td>Bathurst burr</td>
<td>Annual herb</td>
<td>7</td>
</tr>
</tbody>
</table>
Kangaroos

Kangaroo numbers are unnaturally high in pastoral country due to permanent water at artificial watering points (Oliver 1986; Norbury 1992). This results in additional grazing pressure on native plants. Kangaroo grazing is largely uncontrolled due to the ineffectiveness of conventional stock fences in prohibiting kangaroo movement. It has been demonstrated that kangaroos hinder regeneration programs in areas where stock have been excluded to encourage the recovery of native plants (Gardiner 1986a, 1986b; Norbury & Norbury 1991). Commercial shooting is the main method of control of kangaroos.

Fire

Bushfires are a natural feature of the Nullarbor. In years following prolific annual growth the abundant dry matter has the potential to readily catch fire as a result of lightening strikes during thunderstorms. Since European settlement the frequency of fires has increased in the Nullarbor district. Sparks from steam trains on the Trans-Australian Railway are considered responsible for many fires on land adjacent to the railway (Mitchell, McCarthy & Hacker 1979).

The Chenopodiaceae are the most dominant flora type in the survey area. Chenopod shrubland is not adapted to a regular fire regime (Graetz & Wilson 1984). Maireana sedifolia (pearl bluebush) can tolerate moderate intensity fires though may be substantially thinned out, whilst Atriplex vesicaria (bladder saltbush) may be completely eliminated. Hodgkinson and Griffin (1982) state that as chenopod regeneration after fire is by seed alone, there is a risk of completely exhausting the seed bank if grazing pressure is not relaxed post-fire.

Many of the areas now supporting extensive grasslands once supported a mosaic of chenopod shrubland and grassland. In years of good annual growth these areas have sufficient fuel to burn readily. In combination with increased fire regimes, plague proportions of rabbits grazed on post-fire regrowth limiting the regeneration of chenopod shrubland. The expansion of grassland at the expense of chenopod species has further increased the susceptibility of the area to fire. The increased frequency of burning in combination with grazing of juvenile plants by rabbits has adversely affected the vegetation composition.

Threatened species

The Department of Environment and Conservation maintains a declared rare and priority flora list (Atkins 2005) under the provisions of the Wildlife Conservation Act. Fifteen species from the declared rare and priority flora list occur within the survey area (Table 17). No threatened ecological communities have been identified.

Table 17 Declared rare and priority flora listings for the survey area (Atkins 2005)

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Priority code (^1)</th>
<th>No. of inventory sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eremophila attenuata</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Grevillea phillipsiana</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Lepidium fasciculatum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thysanotus baueri</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Chthonocephalus multiceps</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Eucalyptus fraseri subsp. melanobasis</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Eucalyptus surgens</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Goodenia varia</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Harperia eyreana</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Oprecularia loganioides</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Phlegmatospermum eremaenum</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Allocasuarina eriochlamys</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Eremophila dendriticata</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Eucalyptus histophylla</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Eucalyptus pimpiniana</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Galium migrants</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Eremophila hillii</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Eremophila parviflora subsp. parviflora</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Myriophyllum balladoniense</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

Priority codes:
1 Taxa with few poorly known populations on threatened lands.
2 Taxa with few poorly known populations on conservation lands.
3 Taxa with several poorly known populations, some on conservation lands.
4 Rare taxa, not currently threatened, but require monitoring.
Of the declared rare and priority species which are known to exist in the Nullarbor area only eight were collected during the survey: *Eremophila dendritica*, *Eucalyptus fraseri* subsp. *melanobasis*, *E. surgens*, *Harperia eyreana*, *Lepidium fasciculatum*, *Myriophyllum balladoniense*, *Opercularia loganioides* and *Thysanotus baueri*.

*Eremophila dendritica* was collected during traversing through the Nyanga Plain on the Zanthus map sheet. Soils consisted of calcareous loamy soils that contained sheet or nodular calcrite at varying depth.

*Eucalyptus fraseri* subsp. *melanobasis* was collected on three occasions: at one inventory site and at two traverse locations. All locations occurred in the eucalypt woodland of the Caiguna and Gumbelt land systems on the Balladonia map sheet. These areas had calcareous loamy soils with sheet or nodular calcrite at varying depths.

*Eucalyptus surgens* was collected once during a reconnaissance trip on the Culver map sheet. The area consisted of scattered limestone and calcrite outcrop with shallow calcareous loamy soils.

*Harperia eyreana* was also collected on a reconnaissance trip on the Burnabbie map sheet. It occurred on a calcareous dune overlying a calcarenite plain.

*Lepidium fasciculatum* was collected at one inventory site. It was collected from a donga in the Kybo land system on the Madura map sheet. The soil was moderately light clay.

*Myriophyllum balladoniense* was collected during traversing from an ephemeral rock pool on a granite outcrop. It occurs as an aquatic, emergent perennial herb.

*Opercularia loganioides* was collected at one inventory site. It occurred in drainage foci of the Toolinna land system not far inland from the Baxter Cliffs on the Culver map sheet. The area had calcareous loamy soils.

The rating of *Thysanotus baueri* as Priority 1, taxa with few poorly known populations on threatened lands, is likely due to a lack of sampling in the areas in which it commonly occurs. *Thysanotus baueri* was found within the Balladonia and Culver map sheets in open woodland where the overstorey was dominated by eucalypts and the soil was calcareous loam overlying calcrite.

**Conclusion**

The vegetation of the Nullarbor is primarily Eremaean; it is adapted to a desert climate without an assured growing season. The majority of the survey area is covered by low shrubland dominated by bluebush and saltbush. Low open myall woodland over chenopod shrubland is present around the perimeter of the Nullarbor Plain. In the west diverse woodland of eucalyptus and sugarwood is also present.

The south-east of the survey area includes the Hampton Range which is dominated by mallee woodland. The calcareous Roe Plains below the Hampton Range supports myall and eucalypt open woodland trending towards coastal heath in the south. The south-west supports mixed eucalypt woodlands trending towards coastal heath in the south before terminating at the Baxter Cliffs.

The effect of European settlement in the Nullarbor has impacted both directly and indirectly on the vegetation communities. The increased fire frequency in combination with plague proportions of rabbits has substantially altered the vegetation. The vegetation has been further modified by the introduction of domestic stock and the development of water points. These have led to an increase in the presence and associated impacts of feral animals and kangaroos.

The vegetation associations dominated by chenopods that cover vast areas of the Nullarbor are relatively resistant to managed grazing. The areas of greatest degradation are those surrounding water points. This is a result of the high salt content of feed and water and the arid climatic conditions that compel stock to drink frequently. Away from the piosphere effects that surround water points, the vegetation is generally considered to be in good condition. However, natural areas of water accumulation such as dongas and drainage areas are prone to degradation due to their often close proximity to water points and because they contain highly palatable vegetation. These areas often support unique flora and fauna communities that are crucial to the health and productivity of the Nullarbor ecosystem.

Land managers have a major contribution to make to regional conservation through the integration of nature conservation and primary production objectives. Pastoralists can make substantial progress towards ecological
sustainability by adopting strategies to manage the total grazing pressure of domestic, feral and native stock and by improved control of stock movement, including the development of infrastructure away from ecologically fragile locations.

References

Atkins, K 2005, Declared rare and priority flora list for Western Australia, Department of Conservation and Land Management, Western Australia.

Beard, JS 1975, Vegetation survey of Western Australia: Nullarbor, 1:1 000 000 Vegetation Series, Explanatory notes to sheet 4, University of Western Australia Press, Perth.

Burnside, D, William, A & Curry, P 1990, Spacing water points in the southern pastoral areas of Western Australia, Western Australian Department of Agriculture, Bulletin 4162.


Cridland, S & Stafford Smith, M 1993, Development and dissemination of design methods for rangeland paddocks which maximise animal production and minimise land degradation, Department of Agriculture, Western Australia, Miscellaneous Publication 42/1993.

Eckersley, T 1988, ‘The effect of salinity of feed and water on the grazing behaviour of sheep and cattle’, in Animal production in the spinifex and shrubland regions of Western Australia, Western Australian Department of Agriculture, Miscellaneous Publication 23/87.

Environment Australia 2000, Revision of the Interim Biogeographic Regionalisation of Australia (IBRA) and the Development of Version 5.1 – Summary Report, Department of Environment and Heritage, Canberra.

Gardiner, HG 1986a, ‘Dynamics of perennial plants in the mulga (Acacia aneura F. Muell.) zone of Western Australia. I. Rates of population change’, Australian Rangeland Journal, 8, 18–27.

Gardiner, HG 1986b, ‘Dynamics of perennial plants in the mulga (Acacia aneura F. Muell.) zone of Western Australia. II. Survival of perennial shrubs and grasses’, Australian Rangeland Journal, 8, 28–36.

Gilfillan, S 1999, Monitoring the impacts of reduced rabbit numbers due to Rabbit Calicivirus Disease on native fauna and vegetation in the Nullarbor Region, Western Australia, Department of Conservation and Land Management, Western Australia.


Mitchell, AA, McCarthy, R & Hacker, RB 1979, A range inventory and condition survey of part of the Western Australian Nullarbor Plain, 1974, Agriculture Western Australia, Technical Bulletin No. 47.


Oliver, AJ 1986, ‘Social organisation and dispersal in the red kangaroo’, PhD thesis (unpublished), Murdoch University, Western Australia.


Payne, AL, Van Vreeswyk, AME, Pringle, HJR, Leighton, KA & Hennig, P 1998, An inventory and condition survey of the Sandstone-Yalgoo-Paynes Find area, Western Australia, Agriculture Western Australia, Technical Bulletin No. 90.

Pringle, HJR 1994, Pastoral resources and their management in the north-eastern Goldfields, Western Australia, Department of Agriculture, Western Australia, Miscellaneous Publication 22/94.

Woolnough, AP, Gray, GS, Lowe, TJ, Kirkpatrick, WE, Rose, K & Martin, GR 2005, Distribution and abundance of pest animals in Western Australia: a survey of institutional knowledge, Department of Agriculture, Western Australia, Miscellaneous Publication 30/2005.
Habitat type ecology
PA Waddell and AK Gardner

Habitats as ecological units

The interrelationships between the physical environment and the plant communities it supports can be described by classifying sampling points (inventory sites) into habitat types. Habitat types are classified in terms of combinations of landforms, soil types and plant communities. They closely resemble the 'ecological site' of the Society for Range Management (1991) and the habitat of Tinley (1991). In previous rangeland surveys of pastoral areas in Western Australia, habitat types have been referred to as 'pasture lands' (Payne, Mitchell & Holman 1988), 'pasture types' (Payne, Curry & Spencer 1987), 'vegetation types' (Curry et al. 1994), 'site types' (Pringle, Van Vreeswyk & Gilligan 1994) and 'habitat types' (Payne et al. 1998). 'Habitat type' was chosen as it most accurately fits the ecological classification below and is relevant to those not familiar with rangeland survey.

Habitat types are generally referred to by their land surface, dominant taxon and dominant vegetation stratum and given an appropriate four letter code (e.g. PXCS—Plain with mixed chenopod shrubland). Many of the habitat types identified on the Nullarbor are distinguished by vegetation, as so much of the survey area occurred on limestone and calcrete plains of similar geomorphic origin.

Habitat types are described within broader habitat groups so as to aggregate ecologically similar habitat types. Habitat types within a habitat type group are generally located in the same position in the landscape as well as having similar vegetation and soils. The broader habitat type groups are categorised in terms of:

- general information (physical environment, distribution patterns, general ecology)
- vegetation physiognomy (Projected Foliar Cover—PFC) and composition (by stratum)
- patterns of variation (including the impact of grazing and fire)
- gradational associations, and
- land system representation (a habitat is defined as being a major type if it occurs on 30 per cent or more of the land system; as common where it occurs on 20–29 per cent of the land system; and as minor where it occurs on < 20 per cent of the land system).

Terminology used in describing habitat composition

Vegetation formations

The following definitions were used to describe the vegetation formations:

**Woodland**—dominant stratum is trees or mallees (trees have a single stem to a height of 1.3 m above ground level and mallees are multi-stemmed plants to a height of 6 m)

**Grove**—dominant stratum is trees and tall shrubs confined to small areas

**Shrubland**—dominant stratum is shrubs; shrub referring to a perennial woody multi-stemmed plant which branches from below or near ground level

**Scrub**—dominant stratum is collectively composed of stunted trees and shrubs of variable height (< 5 – < 0.5 m), where plants generally have a distinguishable single stem or trunk

**Heathland**—dominant stratum is perennial low shrubs

**Grassland**—dominant stratum is tussock grasses

**Herbland**—dominant stratum is subshrubs and annual herbs.

Where a habitat type is described as a shrubland or woodland the dominant stratum for locations supporting this habitat type may occur as either shrubs or trees, respectively.

Number of plant species

The survey average is the average number of plant species recorded at each of the 392 inventory sites sampled. This was calculated as 11 perennial species and three annual species.

Dominant and common plant species

The following definitions have been used to categorise the structure of the dominant and common plant species for each habitat type:

**Tree**—a plant over 2 m high with a single trunk to at least 1.3 m, including single trunk eucalyptus

**Mallee**—a multi-stemmed eucalypt
**Tall shrub**—a perennial woody plant over 2 m tall with more than one trunk below 1.3 m

**Mid shrub**—a perennial woody plant between 1 and 2 m in height

**Low shrub**—a perennial woody plant less than 1 m in height

**Subshrub**—a seasonally dependent, weakly facultative perennial, generally less than 0.5 m (50 cm) in height, usually persisting for less than two years

**Perennial grass**—a grass species usually persisting for at least two years

**Annual**—a short-lived plant usually persisting for less than one year

**Other plant forms**—plants such as creepers, mistletoes and sedges.

Dominant species are those which were recorded as dominant in a stratum at a quarter or more of the inventory sites. Common species are subordinate species recorded at a quarter or more sampling sites. Where less than eight inventory sites were sampled for a vegetation unit, dominant and common species were considered those present at two or more sites. Other species refers to uncommon species that were infrequently recorded at less than a quarter of sampling sites.

**Taxonomic conventions**

The plant taxonomy adopted in this survey is based on advice from the Western Australian Herbarium.

Species conservation status has been assigned according to the declared rare and priority flora list for Western Australia (Atkins 2005).

**Declared Rare Flora (R) – Extant**—Taxa which have been adequately searched for, and for which populations in the wild are deemed to be rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.

**Priority One (P1) – Poorly Known**—Taxa which are known from one or a few (generally < 5) populations which are under threat, due to small population size, being on lands under immediate threat (e.g. road verges, urban areas, farmland, active mineral leases) or the plants are under threat (e.g. from disease, grazing by feral animals). It may include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as ‘rare flora’, but are in urgent need of further survey.

**Priority Two (P2) – Poorly Known**—Taxa which are known from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as ‘rare flora’, but are in urgent need of further survey.

**Priority Three (P3) – Poorly Known**—Taxa which are known from several populations, at least some of which are not under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as ‘rare flora’, but are in urgent need of further survey.

**Priority Four (P4) – Rare**—Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5–10 years.

**Assessment of ecological disturbances**

Habitat types are described in terms of common or distinctive characteristics and internal variation; this reduces natural variation into a manageable number of ecological types within which there is strong similarity. This facilitated the assessment of range condition. The validity of assessments has been achieved by comparing the prominence of groups of plant species and soil surface condition at reference inventory (ungrazed or lightly grazed) sites with normally grazed sites.

Influences on internal variation, such as disturbances, are discussed in ecological terms rather than in terms of pastoral impacts on pastoral productivity, though it is common for most changes in productivity to be related to ecological changes.

Ecological disturbances are considered in recognition of their widespread influence on the plants common to each habitat type. ecological disturbance is discussed in terms of how disturbances, natural or influenced by man, have affected natural resources which may have implications for future land management and nature conservation. Additionally, the patterns discussed may assist present land managers to
better understand and work with the ecological processes operating throughout their leases.

Factors considered responsible for substantially influencing the ecology of Nullarbor habitats include fire, rabbit plagues and grazing impacts, particularly in association with extended dry periods. In many instances more than one disturbance factor was involved. Where a combination of factors had contributed to disturbance it was difficult to determine any one factor as the major cause or to distinguish disturbance from natural variation. This was particularly relevant in areas where there was little prior knowledge of the ecology of the habitat types and their associated communities.

The ecological changes some habitat types have undergone have been so dramatic the original species composition of the perennial vegetation has been significantly replaced by an annual component. The combination of ‘drought’, fire and rabbit plagues has eliminated large areas of chenopod shrubland throughout the survey area. These areas are now considered to be in a state of irreversible transition (Beard 1975; Davey 1978; Mitchell, McCarthy & Hacker 1979; Westoby, Walker & Noy-Meir 1989). As such, these areas were assessed on their present form rather than considering them as a habitat type of a former state in poor condition.

Plant species indicator values for the grazed situation are defined as:

**Decreaser**—Highly palatable plants whose cover and density decline under excessive grazing pressure. Such plants are often referred to as ‘desirables’.

**Intermediate**—Moderately palatable plants which, under grazing, initially increase in cover and density as they utilise niches vacated by decreasers. Intermediate plants may dominate the stand. They decline under extreme grazing pressure, and may be common in areas regenerating from severe degradation.

**Increaser**—Generally unpalatable plants which increase in number and cover as decreaser species decline under excessive grazing pressure. They are commonly found in disturbed areas (e.g. burnt patches, water sources). In a grazing context such plants are often referred to as ‘undesirables’.

**No indicator value**—The abundance of these species is not primarily related to grazing history. They usually only decrease after natural disturbances such as fire or hail damage. These species are usually not palatable or only slightly palatable or are out of reach of browsing animals. They have been termed ‘stability desirables’ in recognition of the role they play in maintaining soil stability and ecosystem function.

Key increaser (KI) and key decreaser (KD) species were identified for most habitat types. The designations of these attributes is based on field observations of reference sites, severely degraded areas and at fence effects. This information is provided to assist in future assessment and monitoring of grazing impacts.

Scattered myall trees (*Acacia papyrocarpa*) surrounded by pearl bluebush (*Maireana sedifolia*) shrubland. This vegetation community represents a stable state.

Considered to be in an irreversible transition of myall woodland, this landscape is unlikely to return to its former state as there are no living myall of any age remaining.
In a broadscale survey such as this, it is difficult to establish rigorous scientific linkages between disturbances such as grazing and ecological variation (except where very obvious, such as a recently burnt area). It is therefore important to appreciate that many of the interpretations are based on the experience of survey team members and their ability to recognise and explain the cause of disturbance.

**This chapter in context**

This chapter focuses on habitat types and plant community descriptions and ecology. At a broader scale landscape characteristics are covered in the Geomorphology and Land System chapters. Summaries of visual traverse assessments of range condition are presented in the Resource Condition chapter.

**Description of habitat types within their broader habitat type groups**

Fifty-three habitat types split into 10 habitat type groups are described in some detail (Table 18).

---

**Table 18 Habit type groups and their component habitat types; structural definitions according to Muir’s (1977) classification method are provided in the rightmost column**

<table>
<thead>
<tr>
<th>A. Myall shrubland and woodland on calcareous plains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MSCW Myall, sugarwood mixed chenopod woodland</td>
</tr>
<tr>
<td>2. MFBW Myall, false bluebush shrubland or woodland</td>
</tr>
<tr>
<td>3. MXCS Myall mixed chenopod shrubland or woodland</td>
</tr>
<tr>
<td>4. MSAS Myall saltbush shrubland or woodland</td>
</tr>
<tr>
<td>5. MPBS Myall, pearl bluebush shrubland</td>
</tr>
<tr>
<td>6. MHXS Myall mixed halophyte shrubland</td>
</tr>
<tr>
<td>7. MXSS Myall mixed shrub shrubland</td>
</tr>
<tr>
<td>8. MBIG Myall bindii grassland</td>
</tr>
<tr>
<td>9. MSOG Myall, speargrass open grassland</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. Eucalypt shrubland and woodland on calcareous plains</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. ESCW Eucalypt, sugarwood mixed chenopod woodland</td>
</tr>
<tr>
<td>11. EXCW Eucalypt mixed chenopod woodland</td>
</tr>
<tr>
<td>12. ESAW Eucalypt saltbush shrubland or woodland</td>
</tr>
<tr>
<td>13. EXSW Eucalypt mixed scrub woodland</td>
</tr>
<tr>
<td>14. EXHS Eucalypt mixed halophytic shrubland</td>
</tr>
<tr>
<td>15. ESOG Eucalypt, speargrass open grassland</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Casuarina shrubland and woodland on calcrete plains</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. CXCS Casuarina mixed chenopod shrubland or woodland</td>
</tr>
<tr>
<td>17. CXSS Casuarina mixed scrub shrubland</td>
</tr>
<tr>
<td>18. CAOS Casuarina, acacia open shrubland</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D. Shrubland and woodland on calcrete plains overlain by shallow sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>19. MHGW Mallee hummock grass (spinifex) woodland</td>
</tr>
<tr>
<td>20. MUXW Mulga mixed shrub woodland</td>
</tr>
<tr>
<td>21. ACMS Acacia mixed shrubland</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E. Shrubland associated with granitic outcrop</th>
</tr>
</thead>
<tbody>
<tr>
<td>22. DEXS Dodonaea, eremophila mixed shrubland</td>
</tr>
<tr>
<td>23. GROS Granite outcrop shrubland</td>
</tr>
</tbody>
</table>
Table 18 (continued)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.</td>
<td>Shrubland on calcareous plains</td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>SWCS Sugarwood mixed chenopod shrubland</td>
<td>Scrub / Low Scrub B</td>
</tr>
<tr>
<td>25.</td>
<td>PBLS Pearl bluebush low shrubland</td>
<td>Low Scrub B</td>
</tr>
<tr>
<td>26.</td>
<td>PBAC Pearl bluebush, acacia shrubland</td>
<td>Low Scrub B</td>
</tr>
<tr>
<td>27.</td>
<td>PXCS Plain mixed chenopod shrubland</td>
<td>Low Scrub B / Dwarf Scrub C</td>
</tr>
<tr>
<td>28.</td>
<td>NXCS Nitraria mixed chenopod shrubland</td>
<td>Low Scrub B</td>
</tr>
<tr>
<td>29.</td>
<td>BSSL Bladder saltbush shrubland</td>
<td>Dwarf Scrub C</td>
</tr>
<tr>
<td>30.</td>
<td>LAWS Lawrenzia squamata shrubland</td>
<td>Dwarf Scrub C</td>
</tr>
<tr>
<td>G.</td>
<td>Open shrubland and grassland on calcareous plains</td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>XAOS Mixed acacia open shrubland</td>
<td>Scrub / Low Scrub A</td>
</tr>
<tr>
<td>32.</td>
<td>XSBG Mixed shrub bindii grassland</td>
<td>Open Scrub / Very Open Herbs</td>
</tr>
<tr>
<td>33.</td>
<td>OBIG Open bindii grassland</td>
<td>Open Herbs / Very Open Herbs</td>
</tr>
<tr>
<td>34.</td>
<td>SWOG Speargrass and wallaby grass open grassland</td>
<td>Tall Grass / Very Tall Grass</td>
</tr>
<tr>
<td>35.</td>
<td>ANNH Annual herland</td>
<td>Open Herbs / Very Open Herbs</td>
</tr>
<tr>
<td>H.</td>
<td>Drainage foci shrubland</td>
<td></td>
</tr>
<tr>
<td>36.</td>
<td>DOGR Donga grove</td>
<td>Scrub / Dense Low Grass</td>
</tr>
<tr>
<td>37.</td>
<td>DDSS Drainage depression saltbush shrubland</td>
<td>Open Scrub / Dwarf Scrub C</td>
</tr>
<tr>
<td>38.</td>
<td>DDXS Drainage depression mixed shrub shrubland</td>
<td>Very Open Tree Mallee / Open Scrub</td>
</tr>
<tr>
<td>39.</td>
<td>DRAS Drainage tract acacia shrubland</td>
<td>Open Scrub / Open Low Scrub A</td>
</tr>
<tr>
<td>40.</td>
<td>GGSL Gilgai grassy shrubland</td>
<td>Dense Low Grass</td>
</tr>
<tr>
<td>41.</td>
<td>LISW Lignum swamp</td>
<td>Low Scrub B</td>
</tr>
<tr>
<td>42.</td>
<td>PXLs Plain mixed low shrubland</td>
<td>Low Scrub A / B</td>
</tr>
<tr>
<td>I.</td>
<td>Shrubland and woodland on lake margins and saline depressions</td>
<td></td>
</tr>
<tr>
<td>43.</td>
<td>KOPI Kopi dune woodland</td>
<td>Open Low Woodland / Dwarf Scrub C</td>
</tr>
<tr>
<td>44.</td>
<td>SBLS Sandy bank lake shrubland</td>
<td>Thicket</td>
</tr>
<tr>
<td>45.</td>
<td>PXHS Plain mixed halophytic shrubland</td>
<td>Low Scrub B / Dwarf Scrub C</td>
</tr>
<tr>
<td>46.</td>
<td>SAMP Samphire shrubland</td>
<td>Dwarf Scrub D</td>
</tr>
<tr>
<td>J.</td>
<td>Coastal zone heath and woodland</td>
<td></td>
</tr>
<tr>
<td>47.</td>
<td>EMCW Eucalypt, melaleuca mixed chenopod shrubland or woodland</td>
<td>Open Tree Mallee</td>
</tr>
<tr>
<td>48.</td>
<td>EMEW Eucalypt, melaleuca woodland</td>
<td>Open Tree Mallee</td>
</tr>
<tr>
<td>49.</td>
<td>LOMW Low mallee woodland</td>
<td>Open Tree Mallee</td>
</tr>
<tr>
<td>50.</td>
<td>EHEW Eucalypt heath woodland</td>
<td>Open Tree Mallee</td>
</tr>
<tr>
<td>51.</td>
<td>ECHW Eucalypt coastal heath woodland</td>
<td>Open Tree Mallee</td>
</tr>
<tr>
<td>52.</td>
<td>BCHS Banksia coastal heath and scrubland</td>
<td>Shrub Mallee</td>
</tr>
<tr>
<td>53.</td>
<td>COAS Coastal shrubland</td>
<td>Heath B / Open Dwarf Scrub D</td>
</tr>
</tbody>
</table>
A. MYALL SHRUBLAND AND
WOODLAND ON CALCAREOUS
PLAINS

This group of habitat types is common throughout the survey area on calcareous plains. The overstorey is dominated by *Acacia papyrocarpa* (myall) and the understorey by low shrubs of the Chenopodiaceae and Asteraceae families. Throughout the survey area the understorey has commonly been reduced or removed, through the combined effects of fire, grazing by rabbits and to a lesser extent domestic stock, replaced by stands of perennial grasses, subshrubs and herbs. The presence of myall is strongly influenced by its growing medium and rainfall. In the south myall corresponds with the location of the Hampton Tableland gradually disappearing as the landscape transitions into the Nullarbor land zone from which it is absent, this may also relate to the gradational decrease of rainfall from the coast. In the north and west myall corresponds with the calcrite and Recrystallised Limestone plains of the Nyanga land zone. With the reduction in rabbit numbers, due to the rabbit calicivirus, recruitment of juvenile myall throughout myall woodland is common. Most frequently observed in the north of the survey area this phenomenon also corresponds with areas destocked of sheep. In the south in the Hampton Tableland juvenile myall is less common and though rabbit numbers are reduced, sheep grazing on juvenile trees is affecting myall recruitment.

1. Myall, sugarwood mixed chenopod woodland (MSCW)

*Sampling*

1 inventory site, 91 traverse points

*General information*

MSCW is found on calcrete plains overlain by calcareous loam and on low calcrete rises. Gentle slopes to 4 per cent with an abundant surface covering (50–90 per cent) of calcrete fragments. Soils are calcareous loamy earths. This vegetation association is common in the west of the survey area.

*Physiognomy and composition of vegetation*

MSCW occurs as a scattered (10–15 per cent PFC) low woodland of *Acacia papyrocarpa* (myall). *Myoporum platycarpum* (sugarwood) dominates the tall shrub stratum and is commonly denser than *Acacia papyrocarpa*. The mid shrub layer is commonly dominated by scattered *Cratystylis conocephala* (false bluebush) (15–20 per cent PFC).

14 perennial species and one annual species were recorded at the inventory site.

The following species (by strata) are dominant and/or common:

<table>
<thead>
<tr>
<th>Strata</th>
<th>Dominant Species</th>
<th>Common Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trees:</strong></td>
<td><em>Acacia papyrocarpa</em></td>
<td><em>Myoporum platycarpum</em></td>
</tr>
<tr>
<td><strong>Tall shrubs:</strong></td>
<td><em>Myoporum platycarpum</em></td>
<td><em>Myoporum platycarpum</em></td>
</tr>
<tr>
<td><strong>Mid shrubs:</strong></td>
<td><em>Cratystylis conocephala</em></td>
<td><em>Atriplex nummularia</em></td>
</tr>
<tr>
<td><strong>Low shrubs:</strong></td>
<td><em>Not present as a recognisable stratum</em></td>
<td><em>Atriplex vesicaria</em> (KD), <em>Maireana sedifolia</em>, <em>Olearia calcarea</em>, <em>Solanum nummularium</em>.</td>
</tr>
<tr>
<td><strong>Subshrubs:</strong></td>
<td><em>Not present as a recognisable stratum</em></td>
<td><em>Eriochiton sclerolaenoides</em>, <em>Maireana trichoptera</em> (KD), <em>Sclerolaena diacantha</em> (KD).</td>
</tr>
<tr>
<td><strong>Perennial grasses:</strong></td>
<td><em>Not present as a recognisable stratum</em></td>
<td><em>Austrostipa platychaeta</em>.</td>
</tr>
</tbody>
</table>

Annual species recorded include *Salsola tragus*.

*Ecological disturbance*

Palatable low shrubs and subshrubs such as *Atriplex vesicaria* (bladder saltbush), *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) may be removed through overgrazing. Where this habitat type occurs on low rises crossed by vehicle tracks these areas are prone to water erosion. Prolific *Myoporum platycarpum* regrowth may be a response to a reduction in rabbit numbers due to the rabbit calicivirus. At the time of survey *Myoporum platycarpum* dominated the tall shrub stratum. In future years it may become dominant in the tree strata, though natural competition or fire may also reduce its abundance.
Gradational associations

MSCW commonly grades into Myall mixed chenopod shrubland or woodland (MXCW) as Myoporum platycarpum becomes less dense through the tall shrub stratum. Where both myall and sugarwood are replaced in dominance by species of eucalyptus MSCW grades into Eucalypt mixed chenopod woodland (EXCW)

Land systems

MSCW is a major habitat on Nyanga land system.

2. Myall, false bluebush shrubland or woodland (MFBW)

Sampling

6 inventory sites, 45 traverse points

General information

MFBW is most common in the south-east of the survey area near the Hampton Scarp, either on the calcarenite Roe Plains or on the Bunda Plateau on residual aeolian sand deposits. Coarse (2–6 cm) calcareous fragments, commonly calcite nodules, are sparsely distributed across 2–10 per cent of the surface. Soils are calcareous loamy earths.

Physiognomy and composition of vegetation

MFBW occurs as a scattered to moderately closed (10–25 per cent PFC) low woodland or shrubland. The tree stratum is dominated by Acacia papyrocarpa (myall) and the low to mid shrub stratum by Cratystylis conocephala (false bluebush). Very scattered to scattered (2.5–15 per cent PFC) Geijera lineifolia (oilbush) occur in the medium to tall shrub stratum.

50 perennial species were recorded at the six inventory sites, with an average of 17 per site, six more than the survey average. Four annual species were recorded, with an average of one per site.

The following species (by strata) are dominant and/or common:

Trees:

Dominant—Acacia papyrocarpa
Common—Myoporum platycarpum
Others—Eremophila longifolia, Eucalyptus gracilis (mallee), E. oleosa subsp. oleosa (mallee), E. yalatensis, Santalum acuminatum, S. lanceolatum.

Tall shrubs:

Dominant—Geijera lineifolia
Others—Eremophila alternifolia, Melaleuca lanceolata.

Mid shrubs:

Dominant—Cratystylis conocephala, Geijera lineifolia
Common—Atriplex nummularia
Others—Nitraria billiardierei, Senna artemisioides subsp. artemisioides.

Low shrubs:

Dominant—Atriplex vesicaria (KD), Cratystylis conocephala
Common—Enchyela tomentosa (KD), Eremophila deserti, Maireana erioclada, Olearia calcarea, Westringia rigida
Others—Eremophila glabra, E. latrobei (KD), E. parvifolia, Gunniposis calcarea, Lycium australis, Maireana radiata, M. sedifolia, Olearia ramossissima, Rhygoxia grassifolia, Solanum lansiophyllum, S. nummularium, Zygophyllum australiacum.

Subshrubs:

Dominant—Sclerolaena diacantha (KD), S. patenticuspis (KI)
Common—Maireana trichoptera (KD)
Others—Maireana tomentosa (KD), Ptilotus symoni, Sclerolaena obliquicusopsis, Senecio spanomerus, Solanum ellipticum, Zygophyllum apiculatum.

Perennial grasses:

Dominant—Not present as a recognisable stratum

Annual species recorded include Carrichtera annua (KI), Salsola tragus, Sonchus oleraceus and Zygophyllum glaucum.

Ecological disturbance

The palatable herbs and subshrubs Maireana tomentosa (felty bluebush), M. trichoptera (pink-seeded bluebush) and Sclerolaena diacantha (grey bindii) when abundant in combination with Atriplex vesicaria (bladder saltbush), Enchyela tomentosa (ruby saltbush), and Eremophila latrobei (warty-leaf eremophila) may
indicate good range condition. Such subshrubs may also indicate seasonal conditions and the level of use of the current season’s production. *Cratystylis conocephala* is only occasionally eaten by stock and has no known indicator value (Mitchell & Wilcox 1994). *Cratystylis conocephala* and *Atriplex vesicaria* are fire intolerant and may be removed from areas frequently or intensely burnt.

**Gradational associations**

MFBW commonly grades into *Myall mixed Chenopod shrubland or woodland* (MXCW) as chenopods become increasingly prominent in the understorey or *Plain mixed Chenopod shrubland* (PXCS) where myall disappears from the overstorey.

**Land systems**

MFBW is a common habitat type on Moodini and Mundrabilla land systems, and is a minor habitat type on Nyanga and Roe land systems.

**3. Myall mixed Chenopod shrubland or woodland (MXCS)**

**Sampling**

22 inventory sites, 625 traverse points

**General information**

MXCS is predominantly found on calcrete plains in the west and north of the survey area. MXCS commonly has a mantle of small to large pebbles and nodules (6–60 mm), at some locations covering up to 90 per cent of the surface. Soils are calcareous shallow loams and loamy earths. This vegetation association is also located in the south on the limestone hummocks (low rises) of the Thampanna land system and on the Roe Plains in the Mundrabilla land system.

**Physiognomy and composition of vegetation**

MXCS occurs as a very scattered (10–20 per cent PFC) shrubland or low woodland. The tree stratum is dominated by *Acacia papyrocarpa* (myall) and the lower shrub stratum by *Atriplex vesicaria* (bladder saltbush) and *Maireana sedifolia* (pearl bluebush). The mid shrub stratum commonly comprises very scattered (2.5–10 per cent PFC) *Atriplex nummularia* (old man saltbush); occasionally co-dominated with *Cratystylis conocephala* (false bluebush).

60 perennial species were recorded at the 22 inventory sites, with an average of 14 species per site, three above the survey average. 12 annual species were recorded, with an average of three species per site.

The following species (by strata) are dominant and/or common:

**Trees:**

Dominant—*Acacia papyrocarpa*  
Common—*Myoporum platycarpum*  
Others—*Acacia aneura*, *Alectryon oleifolius*, *Casuarina pauper*, *Eremophila longifolia*, *Eucalyptus yalatensis*, *Pittosporum angustifolium*, *Santalum acuminatum*, *S. spicatum*.

**Tall shrubs:**

Dominant—Not present as a recognisable stratum  
Common—*Myoporum platycarpum*  
Other—*Geijera linearifolia*.

**Mid shrubs:**

Dominant—*Atriplex nummularia*, *Cratystylis conocephala*  
Common—*Senna artemisioides* subsp. *coriacea*  
Others—*Acacia ancistrophylla* var. *ancistrophylla*, *A. nyssophylla*, *Eremophila decipiens*, *E. latrobei*, *E. scoparia*, *Nitraria billardierei*, *Senna artemisioides* subsp. *artemisioides*.

**Low shrubs:**

Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia*  
Common—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Lycium austrole*, *Maireana erioclada*, *M. turbinata*, *Ptilotus obovatus*, *Sida calyxhymenia*  
Others—*Gunniopsis calcarea*, *Maireana georgei* (KD), *M. pentatropis*, *M. radiata*, *Rhagodia crassifolia*, *Solana nummularium*, *Zygophyllum aurantiacum*.

**Subshrubs:**

Dominant—Not recognisable as a dominant stratum  
Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides* (KD), *Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD)  
Others—*Maireana tomentosa* (KD), *Minuria cunninghamii*, *Sclerolaena densiflora* (KI), *S. obliquicuspis* (KI),
S. patenticuspis (KI), Senecio spanomerus, Sida spodochroma, Solanum ellipticum.

**Perennial grasses:**
Dominant—Not recognisable as a dominant stratum
Common—Austrodanthonia caespitosa, Austrostipa scabra

**Other plant forms:**
Occasional—Amyema quandang var. quandang (mistletoe).

Annual species recorded include Angianthus conocephalus, Carrichtera annua (KI), Dysphania melanocarpa forma leucocarpa, Erodium cicutarium, Euphorbia drummondi, Nicotiana occidentalis, Rhodanthe floribunda (KI), Salsola tragus (KI), Sonchus oleraceus, Vittadinia humerata, Zygophyllum eremaeum and Z. iodocarpum (KI).

**Ecological disturbance**
The palatable low shrubs Atriplex vesicaria (bladder saltbush), Chenopodium curvispicatum, Enchylaena tomentosa (ruby saltbush) and Maireana georgei (golden bluebush) and subshrubs Eriochiton sclerolaenoides (woolly bindii), Maireana tomentosa (felty bluebush), M. trichoptera (pink-seeded bluebush) and S. diacantha (grey bindii) may be reduced through heavy grazing pressure. In areas of poor condition palatable subshrubs are replaced by Atriplex acutibractea (toothed saltbush), Sclerolaena densiflora (hairy bindii), S. obliquicuspis (limestone bindii), S. patenticuspis (spear-fruit copperburr) and annuals such as Carrichtera annua (Ward’s weed), Rhodanthe floribunda, Salsola tragus (roly poly) and Zygophyllum iodocarpum.

Within myall mixed chenopod woodland tree-based clumps exist as groves around trees such as Alectryon oleifolius (mingah bush, bullock bush), Eremophila longifolia (berrigan), Myoporum platycarpum (sugarwood), Santalum acuminatum (quandong) and S. spicatum (sandalwood) as well as myall. Browsing pressure is commonly indicated by the condition of these groves and the clump understorey. Browse lines indicate moderate grazing but broken limbs and absent canopies indicate heavy grazing at an unsustainable level. Improving range condition is indicated by the development of dense clumps of palatable shrubs under trees and seedlings or suckers from the palatable trees.

**Gradational associations**
MXCS commonly grades into Plain mixed chenopod shrubland (PXCS) or Nitraria mixed chenopod shrubland (NXCS) as the myall tree stratum disappears. As the presence of Myoporum platycarpum becomes denser through the tall shrub stratum MXCS commonly grades into Myall, sugarwood mixed chenopod woodland (MSCW) or Sugarwood mixed chenopod shrubland or woodland (SWCS) where it replaces myall in the tree stratum. In the north-west MXCS grades into Casuarina mixed chenopod shrubland or woodland (CXCS) or Mulga mixed shrub woodland (MUXW) as casuarina or mulga begins to dominate the tree stratum.

As the low to mid shrub stratum becomes dominated by one species MXCS grades into Myall, false bluebush shrubland or woodland (MFBW) or Myall, pearl bluebush shrubland (MPBW). As the diversity of chenopod species decreases in the understorey becoming replaced by non-chenopod species MXCS grades into Myall mixed shrubland or woodland (MXSS). As the salinity of the soil increases and samphires become more frequent MXCS grades into Myall mixed halophyte shrubland (MHXS).

In the north-west MXCS grades into Acacia mixed shrubland (ACMS) where aeolian sand patches thinly cover the calcrete plain of the Nyanga land system.

**Land systems**
MXCS is a dominant habitat type on Mundrabilla and Nyanga land systems, a major habitat type on Thampanna and Virginia land systems and a minor habitat type on Koonjarra and Pondana land systems.

4. **Myall saltbush shrubland or woodland (MSAS)**

**Sampling**
5 inventory sites, 176 traverse points

**General information**
MSAS occurs in the south-east of the survey area on low rises (limestone hummocks) with very gently inclined slopes of up to 2 per cent
and on stony plains. The mantle can have a sparse to moderate covering (2–50 per cent) of limestone fragments with some limestone outcrop (< 10 per cent). Soils are shallow calcareous loams and loamy earths. This vegetation association is also found in the north, though here it is restricted to the Nyanga land system where MSAS occurs on calcrite plains overlain by calcareous loams of varying depth.

**Physiognomy and composition of vegetation**

MSAS occurs as a scattered (10–20 per cent PFC) low woodland or shrubland. *Acacia papyrocarpa* (myall) dominates the tree stratum and *Atriplex vesicaria* (bladder saltbush) the low shrub stratum. Juvenile *Myoporum platycarpum* (sugarwood), to a height of 3 m, commonly dominate the tall shrub stratum, and *Atriplex nummularia* (old man saltbush) the mid shrub stratum.

23 perennial species were recorded at the five inventory sites, with an average of 10 species per site, one less than the survey average. Eight annual species were recorded with an average of four species per site.

The following species (by strata) are dominant and/or common:

**Trees:**
- Dominant—*Acacia papyrocarpa*
- Other—*Alectryon oleifolius*.

**Tall shrubs:**
- Dominant—*Myoporum platycarpum*
- Common—Nil.

**Mid shrubs:**
- Dominant—*Atriplex nummularia*
- Other—*Eremophila scoparia*.

**Low shrubs:**
- Dominant—*Atriplex vesicaria* (KD)
- Common—*Chenopodium curvispicatum*, *Enchylaena tormentosa*, *Maireana sedifolia*
- Others—*Lycium austral*, *Maireana erioclada*, *M. pentatropis*, *Solanum nummularium*, *Zygophyllum aurantiacum*.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Atriplex acutibractea*, *Eriochiton sclerolaenoides*, *Sclerolaena diacantha*
- Others—*Maireana trichoptera*, *Sclerolaena obliquicuspis*, *Sida spodochroma*.

**Perennial grasses:**
- Dominant—Not present as a recognisable stratum
- Common—*Austrostipa scabra*
- Others—*Austrodanthonia caespitosa*, *Enneapogon cylindricus*.

Annual species recorded include *Erodium aureum*, *Euphorbia drummondii*, *Lepidium goodspeedii*, *Rhodanthe floribunda*, *Salsola tragus*, *Vittadinia* sp. and *Zygophyllum iodocarpum*.

**Ecological disturbance**

The density of *Atriplex vesicaria* (bladder saltbush) populations is generally a reliable indicator of range condition. Areas of MSAS with sparse stands of bladder saltbush should be considered as in poor condition. *Atriplex vesicaria* responds to moisture stress by shedding its leaves, but vegetatively responds quickly to rainfall. During this recovery phase it needs protection from grazing to regain vigour and set seed. *Acacia papyrocarpa* (myall) is long-lived with mature trees providing a slightly palatable source of browse. Studies have shown juvenile myall do not survive grazing (Mitchell & Wilcox 1994). However, many juvenile myall were found within this habitat type in the north of the survey area in zones of stock disturbance near water points, formerly used by sheep but now stocked with cattle. In these areas it is possible the destocking of sheep and reduction in rabbit numbers, due to rabbit calicivirus, has allowed *Acacia papyrocarpa* to regenerate prolifically.

**Gradational associations**

In the south-east MSAS is commonly found on limestone hummocks (low rises) grading downslope into loamy or saline depressions supporting *Bladder saltbush shrubland* (BSSL) or Plain mixed halophyte shrubland (PXHS). As eucalypts start to dominate the overstorey MSAS grades into *Eucalypt saltbush shrubland or woodland* (ESAW). In the north in the Nyanga land system MSAS commonly grades into *Bladder saltbush shrubland* (BSSL).

**Land systems**

MSAS is a major habitat type on Chowilla, Nyanga and Thamppana land systems.
5. Myall, pearl bluebush shrubland (MPBS)

Sampling

6 inventory sites, 155 traverse points

General information

MPBS is commonly found on stony limestone plains with 10–50 per cent of the surface covered by coarse limestone fragments of mixed size. MPBS occurs predominantly in two areas: in the southern portion of the Chowilla and Shakehole land systems merging into the north of the Thampanna land system; and on the Recrystallised Limestone plains of the Kanandah land system and the adjacent Seemore land system which border the Nullarbor Plain in the north-west. The vegetation association is also found in the west and north of the survey area on calcrete plains overlain by calcareous loams within the Nyanga land zone or on adjacent systems on elongated low limestone ridges. Soils are shallow calcareous loams and loamy earths.

Physiognomy and composition of vegetation

MPBS consists of a scattered to moderately closed (10–30 per cent PFC) low to mid shrubland of *Maireana sedifolia* (pearl bluebush). The overstorey is dominated by isolated to very scattered (2.5–10 per cent PFC) *Acacia papyrocarpa* (myall).

34 perennial species were recorded at the six inventory sites, with an average of 13 species per sites, two more than the survey average. 13 annual species were recorded with an average of 6 per site.

The following species (by strata) are dominant and/or common:

**Trees:**
Dominant—*Acacia papyrocarpa*
Others—*Acacia aneura, Alectryon oleifolius, Myoporum platycarpum, Pittosporum angustifolium, Santalum acuminatum.*

**Mid shrubs:**
Dominant—Not present as a recognisable stratum
Common—*Atriplex nummularia, Senna artemisioides* subsp. *x coriacea* (KI)
Others—*Acacia burkittii, A. oswaldii, Eremophila scoparia, Pimelea microcephala.*

**Low shrubs:**
Dominant—*Maireana sedifolia*
Common—*Atriplex vesicaria (KD), Chenopodium curvispicatum (KD), Lycium australe, Solanum lasiophyllum, S. nummularium*
Others—*Enchylaena tomentosa (KD), Eremophila pustulata, Lawrenzia squamata, Pililotus obovatus, Zygothyllum aurantiacum.*

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—*Maireana trichoptera, Sclerolaena diacantha, S. obliquicuspis*
Others—*Ericichthon sclerolaenoides, Erodium aureum.*

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Common—*Austrostipa scabra, Enneapogon cylindricus*
Others—*Austrodanthonia caespitosa, Enneapogon caerulescens.*

**Other plant forms:**
Occasional—*Amyema quandang var. quandang* (mistletoe), *Lysiana* sp. (mistletoe).

Annual species recorded include *Asphodelus fistulosus, Brachyscome sp., Calendria sp., Calotis hispida, Carrichtera annua* (KI), *Euphorbia drummondii, Lepidium sp., Podolepis canescens, Pililotus exaltatus, Rhodanthe floribunda, Salsola tragus, Sonchus sp. and Vittadinia humerata.*

Ecological disturbance

*Maireana sedifolia* leaves contain up to 10 per cent salt (Mitchell & Wilcox 1994) and may be eaten by stock particularly if fresh water is available. Pastoralists report stock eating only the tips of the plants, particularly when new growth occurs. Pearl bluebush is not a sensitive indicator of range condition on the Nullarbor.

Myall, pearl bluebush shrubland in good condition will support dense clumps of palatable shrubs, such as *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush). Grazing pressure can be estimated by the structure of bush clumps under trees, the presence of the browse lines and the condition of the tree canopy.

Whilst pearl bluebush can regenerate from low to moderate intensity burns *Acacia papyrocarpa* (myall) and *Atriplex vesicaria* (bladder saltbush)
are fire sensitive (Mitchell, McCarthy & Hacker 1979). However all three species will be removed by frequent fires. Large areas where they have been lost through the combined effects of frequent fires and/or grazing by rabbits and domestic stock are considered to be in poor condition. These areas now support the vegetation association Myall bindii grassland (MBIG).

**Gradational associations**

In the south of the survey area the limestone plains undulate with MPBS on low rises (limestone hummocks) and low ridges grading into Pearl bluebush low shrubland (PBLS) on marginal slopes or into Bladder saltbush shrubland (BSSL) in the loamy or clay depressions. As soil salinity increases and samphires become common MPBS grades into Myall mixed halophyte shrubland (MHXS). In the north as other chenopod species become increasingly common within the understorey MPBS grades into Myall mixed chenopod shrubland or woodland (MXCS).

**Land systems**

MPBS is the dominant habitat type on Kanandah land system and a major type on Chowilla, Nyanga, Seemore, Thampanna and Vanesk land systems and a minor habitat type on Colville, Arubiddy, Jubilee, Kybo and Shakehole land systems.

**6. Myall mixed halophyte shrubland (MHXS)**

**Sampling**

3 inventory sites, 38 traverse points

**General information**

MHXS is predominantly found on the stony limestone plains in the south of the survey area. It commonly has a sparse to common (2–20 per cent) mantle of medium-sized (6–20 mm) limestone fragments. Soils are saline calcareous loamy earths. It occasionally occurs on the calcrete plain of the Nyanga land system on Koonjarra and Virginia pastoral leases.

**Physiognomy and composition of vegetation**

MHXS consists of a scattered low shrubland (10–20 per cent PFC) of Atriplex vesicaria (bladder saltbush) and Maireana sedifolia (pearl bluebush). The tree stratum is composed of very scattered (2.5–5 per cent PFC) Acacia papyrocarpa (myall). Myoporum platycarpum (sugarwood) occasionally dominates these habitats as a tall shrub. The characteristic feature is the presence of Tecticornia sp. (samphire) in the lower stratum.

20 perennial species were recorded at the three inventory sites, with an average of 10 per site, one less than the survey average. Three annual species were recorded.

---

Scattered myall trees (Acacia papyrocarpa) surrounded by pearl bluebush (Maireana sedifolia) shrubland. This vegetation community is considered to represent a stable state.

Myall trees (Acacia papyrocarpa) surrounded by bindii grassland (MBIG). This is considered to be in an irreversible transition from a Myall pearl bluebush shrubland (MPBS).
The following species (by strata) are dominant and or common:

**Trees:**
- Dominant—*Acacia papyrocarpa*
- Common—Nil.

**Tall shrubs:**
- Dominant—Occasionally *Myoporum platycarpum*
- Common—Nil.

**Mid shrubs:**
- Dominant—*Atriplex nummularia*
- Other—*Nitraria billardierei.*

**Low shrubs:**
- Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia*, *Tecticornia* sp.
- Common—*Enchylaena tomentosa*, *Solanum nummularium*
- Others—*Guniopsis calcarea*, *Maireana pentatropis*, *M. turbinata*, *Olearia muelleri*.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum

**Perennial grasses:**
- Dominant—Not present as a recognisable stratum
- Common—*Austrostipa scabra*
- Other—*Austrostipa platychaeta* (KD).

Annual species recorded include *Euphorbia drummondii*, *Nicotiana occidentalis* and *Salsola tragus*.

**Ecological disturbance**
Species of *Tecticornia* (samphire) are only valuable as forage where fresh water is available, as they may contain up to 24 per cent salt. As fresh water is often uncommon samphire has no indicator value for Nullarbor rangeland condition. *Atriplex vesicaria* (bladder saltbush) is a more reliable indicator. Where *Atriplex vesicaria* populations show a declining abundance rangeland condition is considered to be deteriorating. The higher salt content of feed in the lower stratum may place increased pressure on *Acacia papyrocarpa*. The development of prominent browse lines and trampling of bush clumps also indicates increased grazing pressure.

**Gradational associations**
As soil salinity decreases and samphires become less frequent, MHXS grades into *Myall mixed chenopod shrubland or woodland* (MXCS) or *Myall pearl bluebush shrubland* (MPBS). Where stony limestone plains grade into saline plains or depressions the taller stratum disappears and MHXS grades into *Plain mixed halophyte shrubland* (PXHS).

**Land systems**
MHXS is a minor habitat type on Nyanga, Vanesk and Virginia land systems.

7. **Myall mixed shrub shrubland**

**Sampling**
1 inventory site, 45 traverse points

**General information**
MXSS is predominantly found on stony limestone plains commonly with a moderate covering (20–50 per cent) of limestone fragments. MXSS is also located in the north-west of the survey area.

**Physiognomy and composition of vegetation**
MXSS consists of a moderately closed (20–25 per cent PFC) mid shrubland of variable composition. *Atriplex nummularia* (old man saltbush), *Eremophila scoparia* (broom bush) and *Senna artemisioides* subsp. *x coriacea* (desert cassia) are commonly present within the mid shrub layer. The tree stratum is dominated by very scattered (5–10 per cent PFC) *Acacia papyrocarpa* (myall).

20 perennial species and two annual species were recorded at the one inventory site.

The following species (by strata) are dominant and/or common:

**Trees:**
- Dominant—*Acacia papyrocarpa*
- Common—*Myoporum platycarpum*.

**Tall shrubs:**
- Dominant—Not present as a recognisable stratum
- Others—*Acacia oswaldii*, *A. tetragonophylla*, *Senna cardiosperma* (KI).

**Mid shrubs:**
- Dominant—Variable; commonly *Eremophila scoparia* (KI)
- Common—*Atriplex nummularia*, *Senna artemisioides* subsp. *x coriacea* (KI)
- Others—*Acacia ancistrophylla* var. *ancistrophylla*, *Eremophila* sp.
Low shrubs: Dominant—Not present as a recognisable stratum
Common—Chenopodium curvispicatum (KD), Enchylaena tomentosa (KD), Maireana sedifolia
Other—Ptilotus obovatus.

Subshrubs: Dominant—Not present as a recognisable stratum
Common—Atriplex acutibractea, Eriochiton sclerolenoides, Maireana trichoptera
Others—Sclerolaena diacantha, Sida spodochroma.

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—Enneapogon caerulescens.

Annual species recorded include Lepidium sp. and Salsola tragus.

Gradational association
As the diversity of chenopod species increases in the understorey MXSS grades into Myall mixed chenopod shrubland or woodland (MXCS).

Land systems
MXSS is a major habitat type on Kanandah land system and a minor habitat type on Kinclaven and Nyanga land systems.

8. Myall bindii grassland (MBIG)

Sampling
2 inventory sites, 44 traverse points

General information
MBIG predominantly occurs on stony Recrystallised Limestone in the north-west or calcrite plains in the north of the survey area. Soils are calcareous shallow loams and loamy earths, with coarse limestone or calcrite fragments covering 20–50 per cent of the surface. MBIG is considered to be a degraded vegetation association. The original understorey is likely to have been reduced by frequent fires and overgrazing, primarily by rabbits. It is unlikely the lower shrub layer will support shrubs in any great density, since the dominance of grasses renders the area susceptible to fire. Stands of juvenile myall were observed between and recorded at several traverse points. This could be because of fewer rabbit numbers due to the calicivirus.

Physiognomy and composition of vegetation
MBIG occurs as a very scattered (2.5–10 per cent PFC) low woodland of Acacia papyrocarpa (myall). Myoporum platycarpum (sugarwood) can be common to absent; groves of Alectryon oleifolius (mingah or bullock bush) and Eremophila longifolia (berrigan) occur infrequently. The low shrub stratum is commonly dominated by Maireana trichoptera (felty bluebush), Sclerolaena obliquicuspis (lime stone bindii) and the annuals Carrichtera annua (Ward’s weed) and Salsola tragus (roly poly). The mid and tall shrub strata are often poorly developed.

25 perennial species were recorded at the two inventory sites, with an average of 16 per site, five more than the survey average. Six annual species were recorded.
The following species (by stratum) are dominant and or common:

**Trees:**
- **Dominant**—Acacia papyrocarpa
- **Common**—Alectryon oleifolius, Eremophila longifolia
- **Others**—Acacia aneura (Colville land system), Myoporum platycarpum.

**Tall shrubs:**
- **Dominant**—Not present as a recognisable stratum
- **Common**—Acacia oswaldii.

**Mid shrubs:**
- **Dominant**—Not present as a recognisable stratum
- **Common**—Atriplex nummularia, Eremophila scoparia (KI), Senna artemisioides subsp. x artemisioides (KI), S. artemisioides subsp. x coriacea (KI)
- **Other**—Cratystylis conocephala.

**Low shrubs:**
- **Dominant**—Not present as a recognisable stratum
- **Common**—Maireana sedifolia, Enchylaena tomentosa (KD), Ptilotus obovatus
- **Other**—Chenopodium curvispicatum (KD).

**Subshrubs:**
- **Dominant**—Not present as a recognisable stratum
- **Common**—Atriplex acutibractea (KI), Dissocarpus paradoxus (KI), Maireana trichoptera, Sclerolaena diacantha (KD), S. obliquicuspis (KI), S. patenticuspis (KI), Sida spodochroma, Solanum ellipticum.

**Perennial grasses:**
- **Dominant**—Not present as a recognisable stratum
- **Common**—Austrostipa scabra, Enneapogon caeruleus.

Common annual species include Carrichtera annua, Erodium aureum (KI), Euphorbia drummondii, Salsola tragus, Salvia verbenaca (KI) and Zygophyllum iodocarpum (KI).

**Ecological disturbance**

It is likely an abundance of rabbits and/or heavy grazing pressure from stock during post-fire recovery periods has contributed to the removal of the original understorey of this vegetation association. In the Carlisle, Colville and Kyarra land systems active rabbit warrens are still common. MBIG is commonly found on marginal slopes to drainage areas, such as dongas, and receives considerable use resulting in regular padding and disturbed soil crust. Dry seasonal conditions exacerbate the deterioration as the non-perennial vegetation dies off exposing the soil surface to wind erosion. These factors have reduced the potential for this habitat type to support perennial shrubs in any abundance other than weakly perennial herbs and grasses.

The sparseness of perennial vegetation increases demand on palatable species present. The infrequent groves of Alectryon oleifolius (mingah/bullock bush) and Eremophila longifolia (berrigan) provide a sought after protein source. Excessive total grazing pressure will kill individuals as plant vigour is eventually reduced to below the point of recovery. The loss of such perennials further reduces the landscape’s ability to support herbivores during dry periods.

*Bindii grassland surrounds a berrigan grove (Eremophila longifolia) that has been heavily browsed by cattle and camels. Without a reduction in total grazing pressure plant vigour will continue to decline. Groves in this state indicate excessive grazing pressure and deteriorating range condition.*
Gradational association
MBIG commonly grades into Open bindii grassland (OBIG) as the Recrystallised Limestone or calcrite of the Nyanga land zone supporting the myall component gives way to the underlying Nullarbor Limestone.

Land systems
MBIG is a major habitat type on Carlisle, Colville, Kanandah and Kyarra land systems and a minor habitat type on Jubilee and Kinclaven land systems.

9. Myall, speargrass open grassland (MSOG)

Sampling
2 inventory sites, 7 traverse points

General information
MSOG predominantly occurs on stony Recrystallised Limestone and calcrite plains in the north of the survey area. MSOG can also infrequently occur wherever populations of myall are present. It commonly has a mantle of coarse (2–6 cm) limestone fragments covering 20–50 per cent of the surface. Soils are calcareous loamy earths. This vegetation association is considered degraded, with the original understorey removed by frequent fires and heavy grazing, particularly by rabbits.

Physiognomy and composition of vegetation
MSOG occurs as dense grassland of Austrostipa scabra (speargrass) in good seasonal conditions. In poor seasons only the basal portion of grass butts remains. The tree stratum consists of isolated (0–2.5 per cent PFC) Acacia papyrocarpa (myall). All other strata are poorly developed or absent.

17 perennial species were recorded at the two inventory sites, with an average of 12 per site, one greater than the survey average. Seven annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:
Dominant—Acacia papyrocarpa
Other—Myoporum platycarpum.

Mid shrubs:
Dominant—Not present as a recognisable stratum
Common—Cratystylis conocepha, Nitraria billardierei.

Low shrubs:
Dominant—Not present as a recognisable stratum
Common—Atriplex vesicaria (KD), Enchylaena tomentosa, Maireana erioclada, M. sedifolia
Other—Lawrencia squamata.

Subshrubs:
Dominant—Not present as a recognisable stratum
Common—Atriplex acutibractea, Eriochiton

This vegetation community of scattered myall trees (Acacia papyrocarpa) surrounded by pearl bluebush (Maireana sedifolia) shrubland is considered to represent a stable state. Disturbance mechanisms can irreversibly alter this state into Myall speargrass open grassland (MSOG).

Sparse myall trees (Acacia papyrocarpa) surrounded by grassland. Note at the front right the absence of a burnt stump in the centre of the dead tree; future fires will remove any remaining dead wood promoting the appearance of a grassland. The increase in grass continues to make the area more susceptible to fire.
**Perennial grasses:**

Dominant—*Austrostipa scabra*

Common—*Austrodanthonia caespitosa*

Annual species recorded include *Brachyscome ciliaris*, *Carrichtera annua* (KI), *Euphorbia drummondii*, *Nicotiana sp.*, *Salsola tragus*, *Senecio spanomerus* and *Zygophyllum ovatum*.

**Ecological disturbance**

*Austrostipa scabra* (speargrass) is highly responsive to good seasonal conditions. It is readily eaten when young and green but is not palatable once it has dried off. In dry seasons areas supporting such vegetation communities are susceptible to wind erosion. The lack of a mid or low shrub layer to offer protection further reduces an already declining soil crust. Less than 50 per cent soil crusting was recorded at inventory sites supporting MSOG.

The abundance of speargrass makes this habitat type especially prone to fire. The isolated occurrence of myall also alludes to its sensitivity to fire. Trees killed by earlier fires, rabbit ring-barking or old age are erased from the landscape by fires which burn all evidence that these areas once supported woodland. Stages of this process can be seen throughout the woodlands bordering the Nullarbor Plain. (Photos in the Resource Management chapter show examples of this process.)

**Gradational associations**

MSOG is commonly found on low rises of Recrystallised Limestone grading down onto Nullarbor Limestone into *Speargrass and wallaby grass open grassland* (SWOG). This gradational association shows the effects of an increased fire frequency in preventing the regrowth of shrubs. As the grasses come to dominate they further increase the susceptibility of the area to future fire.

**Land systems**

MSOG is a minor habitat type on Chowilla, Kanandah, Kitchener, Kyarra, Shakehole, Thampanna and Virginia land systems.

**B. EUCALYPT SHRUBLAND AND WOODLAND ON CALCAREOUS PLAINS**

This group consists of habitat types with a variable overstorey of eucalypt species found on calcareous plains. In the west and south-west of the survey area the eucalypts predominantly occur on calcrete plains, whilst in the south-east they are commonly found on limestone hummocks (low rises) within the limestone plains and the Roe Plains. The tree stratum typically contains various species of mallee-form eucalypts. Single-stemmed tree forms are also common, particularly in the Gumbelt land system.

**10. Eucalypt, sugarwood mixed chenopod woodland (ESCW)**

**Sampling**

3 inventory sites, 50 traverse points

**General information**

ESCW is predominantly located on calcrete plains overlain by calcareous loam in the west of the survey area. Medium to coarse (6–60 mm) limestone fragments and calcrete nodules cover up to 30 per cent of the surface. Soils are calcareous shallow loams and loamy earths.

**Physiognomy and composition of vegetation**

ESCW occurs as a scattered to moderately closed (10–25 per cent PFC) woodland. The tree stratum is composed of mallee-form *Eucalyptus gracilis* (yorrell), *E. oleosa* (giant mallee) and *Myoporum platycarpum* (sugarwood). *Myoporum platycarpum* also dominates the tall shrub stratum. *Cratystylis conocephala* (false bluebush) is common throughout the mid to low shrub stratum.

25 perennial species were recorded at the three inventory sites, with an average of 15 species per site, four greater than the survey average. Three annual species were recorded.

The following species (by strata) were recorded as dominant and/or common:

**Trees:**

Dominant—*Eucalyptus gracilis* (mallee)

Common—*Eucalyptus oleosa*, *Myoporum platycarpum*

Other—*Acacia papyrocarpa*. 
Tall shrubs: Dominant—*Myoporum platycarpum*
Others—*Acacia oswaldii, Eremophila dempsteri, Geijera linearifolia*.

Mid shrubs: Dominant—*Cratystylis conocephala*
Common—*Atriplex nummularia, Eremophila scoparia (KI)*
Other—*Nitraria billardierei*.

Low shrubs: Dominant—*Atriplex vesicaria (KD), Cratystylis conocephala*
Common—*Enchylaena tomentosa (KD), Maireana erioclada, M. radiata, M. sedifolia, Olearia calcarea, Rhagodia crassifolia*
Others—*Lycium austral, Maireana turbinata, Pitulotus symonii, Solanum nummularium*.

Subshrubs: Dominant—Not present as a recognisable stratum
Common—*Sclerolaena diacantha (KD)*.

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—*Austrostipa platychaeta (KD)*.

Annual species recorded include *Carrichtera annua (KI), Salsola tragus and Zygophyllum glaucum*.

Ecological disturbance
This is a minor site type and was not sampled for grazing impacts. It is likely that under heavy grazing palatable species will be reduced, particularly *Atriplex vesicaria* (bladder saltbush), *Enchylaena tomentosa* (ruby saltbush) and *Austrostipa platychaeta*. ESCW appears to be largely unaffected by grazing due to the low palatability of many of the shrubs. However, rabbits may have a significant impact on seedling recruitment and therefore floristic diversity influencing the present day species composition. This habitat type typically does not support grasses in great abundance.

Gradational associations
ESCW commonly grades into *Eucalypt mixed chenopod shrubland or woodland* (EXCS) or *Sugarwood chenopod shrubland or woodland* (SWCS).

Land systems
ESCW is a major habitat type on Caiguna and Gumbelt land systems.

11. Eucalypt mixed chenopod woodland (EXCW)

**Sampling**
5 inventory sites, 305 traverse points

**General information**
EXCW occurs in the west of the survey area on calcrete plains overlain by calcareous loam of varying depth. Fine to medium calcareous fragments and nodules (2–20 mm) are common. Soils are calcareous loamy earths. It also occasionally occurs on calcrete plains overlain by aeolian sand.

**Physiognomy and composition of vegetation**
EXCW occurs as a scattered to moderately closed (15–25 per cent PFC) woodland. When located on calcrete plains overlain with loam the tree stratum is dominated by *Eucalyptus gracilis* (yorrell) and *E. oleosa subsp. oleosa* (giant mallee). When the surface has a shallow aeolian sand cover *Eucalyptus salubris* (gimlet) is common. The low and mid shrub stratum is dominated by *Atriplex vesicaria* (bladder saltbush) and *Cratystylis conocephala* (false bluebush).

42 perennial species were recorded at the five inventory sites, with an average of 17 species per site, six greater than the survey average. Five annual species were recorded, with an average of two species per site.

The following species (by strata) are dominant and/or common:

**Trees:**
Dominant—*Eucalyptus gracilis, E. oleosa subsp. oleosa* (mallee)
Common—*Alectryon oleifolius, Casuarina pauper, Eucalyptus melanoxylon, E. salubris, Myoporum platycarpum*
Other—*Acacia papyrocarpa*.

**Tall shrubs:**
Dominant—Not present as a recognisable stratum
Common—*Geijera linearifolia*
Others—*Acacia densiflora (KI), A. hemiteles (KI), Eremophila dempsteri, Senna cardiosperma (KI), Exocarpos aphyllus*.

**Mid shrubs:**
Dominant—*Cratystylis conocephala*
Common—*Atriplex nummularia, Eremophila decipiens (KI), E. scoparia (KI), Pimelea microcephala, Scaevola*.
spinescens, Senna artemisioides subsp. x coriacea (Kl)
Other—Eremophila glabra.

**Low shrubs:**
Dominant—Atriplex vesicaria (Kd), Maireana sedifolia
Common—Eremophila pustulata, Frankenia sp., Maireana erioclada, Olearia calcarea, Pilotus obovatus, Rhagodia crassifolia, Solanum nummularium, Zygophyllum aurantiacum
Others—Enchylaena tomentosa, Maireana radiata, Olearia muelleri, Westringia rigida.

**Subshrubs:**
Dominant—Not recognisable as a dominant stratum
Common—Eriochiton sclerolaenoides, Maireana trichoptera, Sclerolaena diacantha (Kd)
Others—Sclerolaena obliquicuspis, Zygophyllum apiculatum.

**Perennial grasses:**
Dominant—Not recognisable as a dominant stratum
Other—Austrostipa platychaeta (Kd).

Annual species recorded include Nicotiana sp., Pilotus exaltatus, Salsola tragus, Zygophyllum compressum and Z. eremaeum.

**Ecological disturbance**
The composition of the understorey is the most reliable indicator of grazing impacts. Austrostipa platychaeta is sensitive to grazing pressure and may indicate good resource condition when plentiful. In good condition a mix and density of palatable low shrub species would be expected in the open and under trees and tall shrubs. An indication of grazing pressure is a reduction in floristic diversity, firstly in the open areas and then later in the more protected areas under trees and tall shrubs [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.] In poor condition increaser species belonging to the genera Eremophila, Senna and Acacia become abundant.

EXCW appears to be less susceptible to fire than similar eucalypt shrubland or woodland where Austrostipa scabra (speargrass) is common through the lower strata. EXCW tends to be more at threat from fire where it borders or is surrounded by grass-dominated habitat types. This can be observed along the northern boundary of the Caiguna land system where it borders the Nightshade land system.

Eucalyptus fraseri subsp. melanobasis is a Priority 2 species on the declared rare and priority flora list, and was recorded in this habitat type.

**Gradational associations**
EXCW grades into Eucalypt, sugarwood mixed chenopod woodland (ESCW) or Sugarwood mixed chenopod shrubland (SWCS) as Myoporum platycarpum increases in the tall shrub and/or tree stratum. Where Myoporum platycarpum and Acacia papyrocarpa replace eucalypts as the dominant species EXCW grades into Myall, sugarwood mixed chenopod woodland (MSCW).

EXCW grades into Eucalypt mixed halophytic shrubland (EXHS) where the topsoil becomes more saline. In the west of the survey area EXCW commonly grades into Eucalypt mixed scrub woodland (EXSW) forming a woodland mosaic of variable understorey alternating in dominance between chenopod and mixed shrubs. Where the soil becomes sandier EXCW grades into Mallee hummock grass (spinifex) woodland (MHGW).

EXCW grades into Eucalypt mixed halophytic shrubland (EXHS) where the topsoil becomes more saline. In the west of the survey area EXCW commonly grades into Eucalypt mixed scrub woodland (EXSW) forming a woodland mosaic of variable understorey alternating in dominance between chenopod and mixed shrubs. Where the soil becomes sandier EXCW grades into Mallee hummock grass (spinifex) woodland (MHGW).

In the Mardabilla land zone where granite outcrop occurs through the calcareous plains EXCW merges into Dodonaea, eremophila mixed shrubland (DEXS) or abuts Granite outcrop shrubland (GROS).

As the woodland becomes more scattered and open, EXCW commonly grades into Plain mixed chenopod shrubland (PXCS).

**Land systems**
EXCW is the dominant habitat type on Gumbelt land system and a major habitat type on Caiguna and Thampanna land systems.

**12. Eucalypt saltbush shrubland or woodland (ESAW)**

**Sampling**
4 inventory sites, 71 traverse points

**General information**
ESAW predominantly occurs on low rises (limestone hummocks) which are gently inclined with up to 6 per cent slope and stony
limestone plains in the south-east of the survey area. ESAW has a mantle composed of fine to coarse (2–60 mm) limestone fragments covering up to 50 per cent of the surface, with limestone outcrop occurring in up to 50 per cent of habitats. Soils are calcareous loamy earths. This vegetation unit commonly borders the Hampton Scarp.

**Physiognomy and composition of vegetation**

ESAW occurs as a scattered to moderately closed (10–30 per cent PFC) woodland. The tree stratum is dominated by variable eucalyptus species, though commonly contains *Eucalyptus gracilis* (yorrell) and/or *Eucalyptus yalatensis* (yalata mallee). *Atriplex nummularia* (old man saltbush) is commonly present within the mid shrub stratum and the lower shrub stratum is dominated by *Atriplex vesicaria* (bladder saltbush).

35 perennial species were recorded at the four inventory sites, with an average of 13 species per site, two greater than the survey average. Three annual species were recorded. The following species (by strata) are dominant and/or common:

**Trees:**
- Dominant—variable; *Eucalyptus diversifolia, E. gracilis, E. oleosa* subsp. *ampliata, E. yalatensis*
- Others—*Eucalyptus uralensis, Myoporum platycarpum*.

**Tall shrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Acacia oswaldii*
- Others—*Eremophila dempsteri* (KI), *Psydrax suaveolens* (KD).

**Mid shrubs:**
- Dominant—*Atriplex nummularia*
- Others—*Cratystylis conocephala, Scaevola spinescens, Senna artemisioides* subsp. *x coriacea* (KI).

**Low shrubs:**
- Dominant—*Atriplex vesicaria* (KD)
- Common—*Enchylaena tomentosa* (KD), *Maireana pentatropis, M. sedifolia, Olearia muelleri*
- Others—*Chenopodium curvispicatum* (KD), *Eremophila oblonga, Lawrencia squamata, Maireana erioclada, Ptilotus obovatus, Zygodium aurantiacum*.

**Subshrubs:**
- Dominant—Not recognisable as a dominant stratum
- Common—*Maireana tomentosa* (KD)
- Others—*Atriplex acutibractea* (KI), *Sclerolaena diacantha* (KD), *S. obliquicuspis, Zygodium apiculatum*.

**Perennial grasses:**
- Dominant—Not recognisable as a dominant stratum
- Common—*Austrostipa scabra*

**Other plant forms:**
- Occasional—*Dianella revoluta* (lily), *Marsdenia australis* (creepers).

Annual species recorded include *Caricntera annua* (KI), *Euphorbia drummondii* and *Nicotiana goodspeedii*.

**Ecological disturbance**

The close gradational association to chenopod shrubland in lower-lying areas results in limestone hummocks that support ESAW receiving increased utilisation from herbivores. The trees on these limestone rises provide shelter for both animals and other plants. ‘Tree-based clumps’ develop under trees and have an important role in arid environments in sustaining other plant species by improving conditions, such as retaining soil moisture and providing protection from desiccation by wind and sun. In good condition a mix and density of palatable shrub and perennial grass species, such as *Atriplex vesicaria, Austrostipa elegantissima* (feather speargrass), *A. platychaeta, Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Maireana tomentosa* (felty bluebush), *Ptilotus obovatus* (cotton bush), *Psydrax suaveolens* and *Scaevola spinescens* (currant bush), would be expected to radiate out from under the canopies into the spaces between tree clumps. An indication of decreasing rangeland condition would be a reduction in floristic diversity, first in the open areas and then later in the more protected areas under the trees [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.]

**Gradational associations**

ESAW grades downslope into *Plain mixed chenopod shrubland* (PXCS) or *Bladder saltbush shrubland* (BSSL) where colluvial-filled depressions lie adjacent to low rises (limestone...
hummocks) within limestone plains. Where myall begins to dominate the overstorey ESAW grades into Myall saltbush shrubland or woodland (MSAS).

Land systems
ESAW is a dominant habitat type on Thampanna land system and a minor type on Moodini land system.

13. Eucalypt mixed scrub woodland (EXSW)

Sampling
27 inventory sites, 232 traverse points

General information
EXSW is predominantly found on calcrete plains in the western perimeter of the survey area. Up to 90 per cent of the surface mantle of the plain is covered by medium to large (6–60 mm) calcrete nodules; occasionally a layer of sand is present. Soils are commonly calcareous loams or, occasionally, red loams and sandy earths where the surface is overlain by sand. This vegetation association is also present in the south-east of the survey area on limestone hummocks (low rises) with gentle slopes of up to 3 per cent, on residual depositional surfaces, formerly aeolian calcarenite, behind the Hampton scarp face and along the scarp.

Physiognomy and composition of vegetation
EXSW occurs as a scattered to moderately closed (10–25 per cent PFC) woodland or scrubland. The tree stratum is dominated by eucalypts, commonly Eucalyptus gracilis (yorrell) and E. oleosa subsp. oleosa (giant mallee). Other species are also common but their distribution may be restricted such as Eucalyptus yalatensis (yalata mallee) in the south on the Hampton Tableland and E. diversifolia (soap mallee) on the scarp of the Hampton Range. The composition of shrubs is variable though the tall shrub stratum is commonly dominated by Melaleuca lanceolata, the mid shrub stratum by Atriplex nummularia (old man saltbush) and the low shrub stratum by Westringia rigida.

104 perennial species were recorded at the 27 inventory sites, including two priority species, with an average of 17 species per site, six greater than the survey average. 11 annual species were recorded, with an average of one species per site.

The following species were dominant and/or common:

**Trees:**
Dominant—Eucalyptus gracilis, E. oleosa, E. yalatensis (mallee)
Common—Eucalyptus diversifolia (mallee)
Others—Acacia aneura, A. papyrocarpa, Alectryon oleifolius, Casuarina pauper, Eucalyptus conglobata (mallee), E. discreta (mallee), E. fraseri subsp. fraseri, E. oleosa subsp. oleosa (mallee), E. melanoxylon, E. salubris, E. uma, Myoporum platycarpum, Pittosporum angustifolium, Santalum acuminatum, S. lanceolatum.

**Tall shrubs:**
Dominant—Melaleuca lanceolata
Common—Eremophila dentstleri, E. scoparia (KI), Geijera lineariafolia
Others—Acacia hemiteles (KI), A. oswaldivi, A. tetragonophylla, Dodonaea lobulata (KI), Eremophila alternifolia, E. longifolia, Exocarpos aphyllus, Melaleuca quadrifaria, Senna cardiosperma (KI), Templetonia retusa, T. sulcata.

**Mid shrubs:**
Dominant—Atriplex nummularia
Common—Crasytystis concepheada, Dodonaea stenozygia, E. scoparia (KI), Scaevola spinescens, Senna artemisioides subsp. x coriacea (KI)
Others—Acacia anceps, A. ancistrophylla var. ancistrophylla, Alyxia buxifolia, Nitraria billardierei, Acacia nyssophylla, Eremophila decipiens (KI), E. deserti (KI), E. glabra (KI), E. ionantha, Leptomena pachyclada, Pomaderris myrtillifolia, Pulentinae heterochila, Senna artemisioides subsp. x artemisioides (KI), Sida calyxhymenia (KD).

**Low shrubs:**
Dominant—Westringia rigida
Common—Atriplex vesicaria (KD), Enchylaena tomentosa (KD), Eremophila weldii,
Maireana erioclada, M. sedifolia, Olearia calcarea, Ptilotus obovatus (KD), Rhagodia crassifolia

Subshrubs:
Dominant—Not recognisable as a dominant stratum
Common—Goodenia affinis, Maireana trichoptera, Wurmbea tenella, Zygophyllum apiculatum
Others—Atriplex acutibractea (KI), Sclerolaena diacantha (KD), S. obliquicuspis (KI), S. patenticuspis (KI), Sida spodochroma.

Perennial grasses:
Dominant—Not present as a recognisable stratum
Common—Austrostipa scabra
Others—Austrodanthonia caespitosa, Austrostipa elegansissima (KD), A. platychaeta (KD), Eragrostis leptocarpa, Triodia scariosa.

Other plant forms:
Occasional—Comesperma volubile (creepers), Dianella revoluta (lily).

Annual species recorded include Carrichtera annua (KI), Euphorbia drummondii, Podolepis canescens, Salsola tragus (KI), Swainsona formosa, Vittadinia nullaboriensis, Zygophyllum compressum, Z. eremaeum, Z. glaucum, Z. iodocarpum (KI) and Z. ovatum.

Ecological disturbance
EXSW is largely unaffected by grazing. The most reliable indication of grazing impact is the diversity and density of palatable low and subshrubs which are often most numerous under trees and sparse in the open. Rabbits are likely to have had an impact on seedling regeneration of many of the palatable species.

The increase in abundance of unpalatable species such as Acacia hemiteles (tan wattle), Dodonaea lobulata (bead hopbush), Eremophila scoparia (broom bush), Senna artemisioides subsp. x artemisioides (silver cassia) and Senna artemisioides subsp. x coriacea (desert cassia) may be in response to rabbit grazing during post-fire recovery phases.

The susceptibility of EXSW to fire is largely dependent on the development of the grass strata within the habitat type.

Thysanotus baueri a Priority 1 species, on the declared rare and priority flora list, and Eucalyptus fraseri subsp. melanobasis a Priority 2 species were recorded among this eucalypt woodland habitat type. Thysanotus baueri means the area has a high conservation value.

Gradational associations
EXSW occurring in the south-west of the survey borders poorly developed karst depression land units often supporting Plain mixed chenopod shrubland (PXCS). In areas where the topsoil becomes more saline EXSW grades into Eucalypt mixed halophytic shrubland (EXHS) or sandier Mallee hummock grass woodland (MHGW). In the west of the survey area EXSW commonly grades into Eucalypt mixed chenopod woodland (EXCW) forming a woodland mosaic of variable understory alternating in dominance between chenopod and mixed shrubs. Where Casuarina pauper begins to replace eucalypts as the dominant tree EXSW may grade into Casuarina mixed scrub shrubland (CXSS).

In specific coastal areas Banksia coastal heath and scrubland (BCHS) occurs between EXSW and the Baxter Cliffs. On the Roe Plains as the density of Melaleuca species increases EXSW grades into Eucalypt, melaleuca woodland (EMEW).

In the Mardabilla land zone where granite outcrop protrudes EXSW merges into Dodonaea, eremophila mixed shrubland (DEXS) or abuts Granite outcrop shrubland (GROS).

Land systems
EXSW is a dominant habitat type on Zanthus land system and a major habitat type on Caigua, Gumbelt, Moodini and Thampanna land systems.
14. Eucalypt mixed halophyte shrubland (EXHS)

**Sampling**
1 inventory site, 17 traverse points

**General information**
EXHS predominantly occurs in depressions in calccrete plains in the south of the survey area. Soils are commonly calcareous loamy earths with saline subsoils.

**Physiognomy and composition of vegetation**
EXHS occurs as a very scattered to moderately closed (5–25 per cent PFC) low shrubland of *Tecticornia* species (samphire) and *Atriplex vesicaria* (bladder saltbush). Very scattered (2.5–5 per cent PFC) eucalypts form the tree stratum.

19 perennial species, including two species of *Tecticornia*, and two annual species were recorded at the one inventory site and 17 traverse points.

The following species (by strata) are dominant and/or common:

**Trees:**
Dominant—*Eucalyptus gracilis*
Others—*Eucalyptus oleosa*, *E. oleosa* subsp. *oleosa* (mallee), *Myoporum platycarpum*.

**Tall shrubs:**
Dominant—Not present as a recognisable stratum
Others—*Eremophila dempsteri*, *Myoporum platycarpum*.

**Mid shrubs:**
Dominant—*Atriplex nummularia*
Other—*Cratystylis conocephala*.

**Low shrubs:**
Dominant—*Atriplex vesicaria* (KD), *Tecticornia doeleiformis*, *Tecticornia* sp.
Others—*Gunniopsis calcarea*, *Maireana erioclada*, *M. sedifolia*, *Olearia calcarea*.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Others—*Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis*.

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Others—*Austrostipa platycaltha* (KD), *A. scabra*.

Annual species recorded include *Brachyscome* sp. and *Salsola tragus*.

**Ecological disturbance**
This is a minor habitat type and was not sampled for grazing impacts. *Tecticornia* species can be of indicator value when stock water is fresh. If fresh water is available the presence of samphire can indicate good to fair condition. Palatable, less-saline shrubs such as *Atriplex vesicaria*, *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) are likely to be reduced under heavy grazing. In such saline locations rabbits may eat juvenile eucalypts and other plants in preference to halophytes.

**Gradational associations**
EXHS grades into *Eucalypt mixed scrub woodland* (EXSW) or *Eucalypt mixed chenopod woodland* (EXCW) as the topsoil becomes less saline with increasing soil depth. Where the subsoil remains saline and eucalypts are absent EXHS grades into *Plain mixed halophyte shrubland* (PXHS).

**Land systems**
EXHS is a minor habitat type on Caiguna, Gumbelt and Thampanna land systems.

15. Eucalypt, speargrass open grassland (ESOG)

**Sampling**
2 inventory sites, 15 traverse points

**General information**
ESOG is located in the central south of the survey area. It is considered to be an irreversible state of a former habitat possibly once similar to *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt saltbush shrubland or woodland* (ESAW). The lower shrub stratum has likely been removed by rabbit grazing in conjunction with frequent fires. ESOG occurs on gently inclined low rises (limestone hummocks) with up to 2 per cent slope and can extend down onto the edges of adjacent limestone and calcrite plains. Soils are calcareous shallow loams. Small (6–20 mm) fragments of limestone commonly cover up to 90 per cent of the surface and limestone outcrop occurs through up to 10 per cent of these habitats.
Physiognomy and vegetation composition

ESOG occurs as dense grassland of *Austrostipa scabra* (speargrass) under very scattered (2.5–10 per cent PFC) mallee-form *Eucalyptus yalatensis* (yalata mallee) and occasionally *E. gracilis* (yorrell).

21 perennial species were recorded at the two inventory sites, with an average of 13 species per site, two greater than the survey average. Four annual species were recorded.

The following species (by strata) are dominant and/or common:

**Trees:**
- Dominant—*Eucalyptus yalatensis* (mallee)
- Others—*Eucalyptus gracilis* (mallee), *Myoporum platycarpum*, *Pittosporum angustifolium*.

**Tall shrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Geijera linearifolia*
- Others—*Acacia oswaldii*, *Dodonaea stenozyga*, *Eremophila alternifolia* (KI), *E. dempsteri*.

**Mid shrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Eremophila scoparia* (KI)
- Others—*Chenopodium curvispicatum* (KD), *Cratystylis conocephala*.

**Low shrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Enchylaena tomentosa* (KD), *Maireana erioclada*
- Others—*Maireana sedifolia*, *Westringia rigida*.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Maireana trichoptera*
- Other—*Sclerolaena diacantha* (KD).

**Perennial grasses:**
- Dominant—*Austrostipa scabra*
- Others—*Austrodanthonia caespitosa*, *Austrostipa platychaeta* (KD).

Annual species recorded include *Carrichtera annua* (KI), *Podolepis canescens*, *Salsola tragus* and *Zygophyllum glaucum*.

**Ecological disturbance**

ESOG is an altered vegetation association in an irreversible state of transition. Large mallee roots are capable of upheaving limestone boulders as they grow. Many of these eucalypts and the associated understorey have been killed by increased fires. Holes containing burnt stumps and charcoal surrounded by upheaved limestone boulders are the only evidence for this vegetation association once supporting more eucalypts. The increased fire frequency is a result of activities associated with European settlement. Plant recovery is further hindered by the grazing of juvenile shrubs and tree shoots that germinate or resprout following fire. The dominance of *Austrostipa scabra* further increases the susceptibility of the area to fire. Speargrass is readily eaten when young and green, but has reduced palatability when dry. Dry conditions following good seasons make this a combustible fuel source.
Gradational associations

ESOG often occurs on low limestone rises, crests and gently undulating ridges grading down into *Speargrass and wallaby grass open grassland* (SWOG) surrounding the rise or ridge. On the land systems where ESOG occurs it is more common along the northern perimeter of the Hampton Tableland where it merges into the vegetation associations of the Nullarbor Plain often dominated by a grass component, maintaining increased fire susceptibility.

Land systems

ESOG is a minor habitat type on Caiguna, Nightshade and Thampanna land systems.

C. CASUARINA SHRUBLAND AND WOODLAND ON CALCRETE PLAINS

This group occurs on calcrete plains in the north-west of the survey area. The vegetation in this group is dominated by an overstorey of *Casuarina pauper* (black oak). Casuarina woodlands commonly occur on low rises or on low fault scarps within the calcrete plain of the Nyanga land zone, as well as on the plain itself. Isolated casuarina shrubland or woodland also occur on residual calcrete low rises overlying Nullarbor Limestone out on the Nullarbor Plain.

16. Casuarina mixed chenopod shrubland or woodland (CXCS)

Sampling

8 inventory sites, 111 traverse points

General information

CXCS is commonly found on calcrete plains and low rises with a common to abundant (20–90 per cent) mantle of fine to large calcrete fragments and nodules (0.6–20 cm) and occasional outcrop (< 10 per cent). Soils are calcareous shallow loams and loamy earths. Very gentle slopes rarely exceed 2 per cent. CXCS may also occur where shallow deposits of sand overlie calcrete plains.

Physiognomy and composition

CXCS occurs as a very scattered to moderately closed (2.5–30 per cent PFC) low woodland. The tree stratum is dominated by *Casuarina pauper* (black oak) and the shrub stratum by *Maireana sedifolia* (pearl bluebush). A very scattered (2.5–10 per cent PFC) mid shrub layer of *Atriplex nummularia* (old man saltbush) and *Cratystylis conexophala* (false bluebush) is commonly present.

39 perennial species were recorded at the eight inventory sites, with an average of 15 species per site, four more than the survey average. 11 annual species were recorded, with an average of three species per site.

The following perennial species (by stratum) are dominant and/or common:

**Trees:**

Dominant—*Casuarina pauper*

Common—*Acacia papyrocarpa*,

*Alectryon oleifolius*

Others—*Myoporum platycarpum*, *Pittosporum angustifolium*, *Santalum acuminatum*.

**Tall shrubs:**

Dominant—Not present as a recognisable stratum

Others—*Acacia burkittii* (KI),

*A. oswaldii*, *A. tetragonophylla*,

*Geijera linearifolia*.

**Mid shrubs:**

Dominant—*Atriplex nummularia*,

*Cratystylis conexophala*

Common—*Eremophila scoparia* (KI),

*Senna artemisioides subsp. x coriacea* (KI)

Other—*Eremophila glabra* (KI).

**Low shrubs:**

Dominant—*Maireana sedifolia*

Common—*Atriplex vesicaria* (KD),

*Chenopodium curvispicatum* (KD),

*Enchylaena tomentosa* (KD), *Maireana erioclada*, *Ptilotus obovatus*

Others—*Lycium australis*,

*Maireana radiata*, *Olearia calcarea*, *Rhagodia crassifolia* (KD),

*Solanum lasiophyllum*, *S. nummularium*.

**Subshrubs:**

Dominant—Not present as a recognisable stratum

Common—*Atriplex acutibractea* (KI),

*Maireana trichoptera*,

*Sclerolaena diacantha* (KD),

*Eriochiton sclerolaenoides*, *Sclerolaena obliquicuspis*.

**Perennial grasses:**

Dominant—Not present as a recognisable stratum

Common—*Austrostipa scabra*

Others—*Austrodanthonia caespitosa*, *Austrostipa elegantissima* (KD),
Other plant forms: Occasional—Marsdenia australis (creepers).

Annual species recorded include Brachyscome ciliaris, Calocephalus knappii, Carrichtera annua (KI), Euphorbia drummondii, Mesembryanthemum crystallinum, Pililotus exaltatus, Salsola tragus, Vittadinia humerata, Zygophyllum eremaeum, Z. iodocarpum (KI) and Z. ovatum.

Ecological disturbance
Palatable perennial species such as Atriplex vesicaria (bladder saltbush), Austrostipa elegantissima (feather speargrass), A. platychaeta, Chenopodium curvispicatum, Enchylaena tomentosa (ruby saltbush), Enneapogon caerulescens (limestone grass) Pililotus obovatus (cotton bush) and Rhagodia crassifolia may be removed through excessive grazing of the understorey. Browsing pressure is commonly indicated by the condition of Alectryon oleifolius (mingah bush, bullock bush) and, to a lesser degree, Pittosporum angustifolium (native willow) and Santalum acuminatum (quandong). Browse lines indicate moderate grazing but broken limbs and smashed canopies indicate heavy grazing and total grazing pressure at an unsustainable level. See tree-based clump condition monitoring photographic guide in the Resource Management chapter. Improving range condition is indicated by the development of clumps of palatable shrubs under trees and dense foliage on Alectryon oleifolius. Rabbit warrens were often common. The presence of warrens and/or past fires was often associated with poor condition ratings for CXCS.

Gradational associations
CXCS commonly grades into Myall mixed chenopod shrubland or woodland (MXCW), as Acacia papyrocarpa becomes increasingly dominant in the overstorey. Where CXCS is located on calcrete rises and faultline low ridges it commonly grades downslope into Plain mixed chenopod shrubland (PXCS). In the north-west CXCS grades into Mulga mixed shrub woodland (MUXW) as mulga begins to dominate the tree stratum.

Land systems
CXCS is a major habitat type on Nyanga land system and a minor habitat type on Gumbelt, Kanandah, Narethia, Nightshade, Pondana and Vanesk land systems.

17. Casuarina mixed scrub shrubland (CXSS)

Sampling
2 inventory sites, 17 traverse points

General information
CXSS occurs in the north-west of the survey area. It is most common on calcrete plains with a sparse (2–20 per cent) mantle composed of calcrete fragments and nodules. It is also found on calcrete plains overlain by sand. Soils are calcareous loamy earths and shallow loams or red shallow loams where the surface is overlain with sand.

Physiognomy and composition of vegetation
CXSS occurs as a scattered (10–20 per cent PFC) tall shrubland of acacias, eremophilas and sennas. The tree stratum comprises very scattered (2.5–5 per cent PFC) Casuarina pauper (black oak). The mid and low shrub stratum is commonly composed of very scattered Atriplex nummularia (old man saltbush) and Maireana sedifolia (pearl bluebush).

29 perennial species were recorded at the two inventory sites, with an average of 20 species per site, nine greater than the survey average. Two annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:
- Dominant—Casuarina pauper
- Common—Myoporum platycarpum
- Others—Acacia aneura, A. papyrocarpa, Alectryon oleifolius, Pittosporum angustifolium.

Tall shrubs:
- Dominant—Not present as a recognisable stratum
- Others—Acacia burkittii (KI), A. tetragonophylla.

Mid shrubs:
- Dominant—Atriplex nummularia
- Common—Eremophila latrobei subsp. latrobei, Scaevola spinescens, Senna artemisioides subsp. x coriacea (KI)
- Others—Eremophila glabra (KI), E. scoparia (KI), Senna artemisioides subsp. x artemisioides (KI).

Land systems
CXCS is a major habitat type on Nyanga land system and a minor habitat type on Gumbelt, Kanandah, Narethia, Nightshade, Pondana and Vanesk land systems.
**Low shrubs:**
Dominant—Maireana sedifolia (KD), Chenopodium curvispicatum (KD), Ptilotus obovatus (KD)
Common—Atriplex vesicaria (KD), Solanum nummularium, Westringia rigida
Others—Sida calyxhymenia (KD), Chenopodium curvispicatum (KD), Ptilotus obovatus (KD)

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—Maireana trichoptera (KD), Sclerolaena obliquicuspis
Others—Maireana erioclada, Sclerolaena obliquicuspis (KD), S. patenticuspis (KD)

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Common—Austrostipa scabra, Enneapogon cylindricus
Others—Austrodanthonia caespitosa, Enneapogon caerulescens

**Other plant forms:**
Occasional—Marsdenia australis (creeper)

Annual species recorded include Eriachne pulchella subsp. pulchella and Salsola tragus.

**Ecological disturbance**
A diverse mix of the following palatable perennials would be indicative of an area in good resource condition: Atriplex vesicaria (bladder saltbush), Chenopodium curvispicatum, Maireana trichoptera (pink-seeded bluebush), Ptilotus obovatus (cotton bush), Scaevola spinescens (currant bush) and Sida calyxhymenia (tall sida). Acacia burkittii (jam), Senna artemisioides subsp. x artemisioides (silver cassia) and Senna artemisioides subsp. x coriacea (desert cassia) may increase under heavy grazing or frequent burning.

**Gradational associations**
CXSS grades into Mixed acacia open shrubland (XAOS) and Mixed shrub bindii grassland (XSBG) where the underlying Nullarbor Limestone geology is indurated by calcrete.
Where soils become increasingly sandier and eucalypts begin to dominate the tree strata CXSS may grade into Eucalypt mixed scrub woodland (EXSW).

**Land systems**
CXSS is a minor habitat type on Gumbelt, Naretha and Nyanga land systems.

---

**18. Casuarina, acacia open shrubland (CAOS)**

**Sampling**
2 inventory sites, 8 traverse points

**General information**
CAOS is restricted to the mid-west of the survey area, primarily the 1:250 000 Naretha map sheet. It occurs on residual calcrete low rises with gentle slopes to 3 per cent. Large stones (6–20 cm) cover 50–90 per cent of the surface. Soils are calcareous shallow loams and loamy earths.

**Physiognomy and composition of vegetation**
CAOS occurs as a scattered tall shrubland of Acacia burkittii (jam) and Alectryon oleifolius (mingah bush, bullock bush) trees (up to 15 per cent PFC) with an overstorey of very scattered Casuarina pauper (black oak) to 10 per cent PFC.

19 perennial species were recorded at the two inventory sites, with an average of 11 species per site, the same as the survey average. Two annual species were recorded.

The following species (by strata) are dominant and or common:

**Trees:**
Dominant—Casuarina pauper
Common—Alectryon oleifolius
Others—Acacia aneura, A. papyrocarpa.

**Tall shrubs:**
Dominant—Acacia burkittii (KI)
Other—Acacia oswaldii.

**Mid shrubs:**
Dominant—Not present as a recognisable stratum
Other—Eremophila scoparia (KI).

**Low shrubs:**
Dominant—Not present as a recognisable stratum
Others—Chenopodium curvispicatum, Enchylaena tomentosa, Maireana erioclada, Ptilotus obovatus (KD).

**Subshrubs:**
Dominant—Not present as a recognisable stratum Common—Eriochiton sclerolaenoides, Sclerolaena diacantha (KD)
Others—Atriplex acutibractea (KI), Maireana trichoptera (KD), Sclerolaena obliquicuspis (KI), S. patenticuspis (KI).
Perennial grasses:
Dominant—Not present as a recognisable stratum
Common—Enneapogon cylindricus
Other—Enneapogon caerulescens.

Annual species recorded include Lepidium sp. and Salsola tragus.

Ecological disturbance
The limited structure and composition of the mid and low shrub strata are an indication of the level of animal usage these habitats receive. This is further demonstrated by the presence of rabbit warrens, recent cattle activity and remnant root stumps in deteriorating plant mounds. Commonly the soil surface is poor owing to the high level of animal disturbance, with less than 40 per cent surface crusting. The combination of the landform and associated vegetation mean these low calcrite rises appeal to herbivores. The soil development associated with the calcrite, compared to the surrounding skeletal soils associated with the Nullarbor Limestone, supports trees and provides suitable locations for rabbit warrens. Rabbit piospheres radiating out from warrens are common. Trees provide shelter and browse for large herbivores and many areas have the appearance of livestock 'camps', particularly when favourable browse such as Alectryon oleifolius is present. The condition of Alectryon oleifolius groves indicates the grazing pressure in an area. [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.] The breakdown of Alectryon oleifolius groves is an indication of poor range condition and overgrazing. The development of clumps of palatable shrubs under trees and dense foliage on Alectryon oleifolius indicates range condition is improving.

Gradational associations
CAOS grades into Mixed acacia open shrubland (XAOS) as residual calcrite low rises give way to the underlying Nullarbor Limestone.

Land systems
CAOS is a minor habitat type of the Nyanga and Kitchener land systems.

D. SHRUBLAND AND WOODLAND ON CALCRITE PLAINS OVERLAIN BY SHALLOW SAND

This group of habitat types commonly occurs on calcrite plains overlain by shallow sheets of aeolian sand. They typically support closed woodland or tall shrubland dominated by acacias or mallee-form eucalypts. This group of habitat types is found in the north-west of the survey area.

19. Mallee hummock grass (spinifex) woodland (MHGW)

Samples
7 inventory sites, 47 traverse points

General information
MHGW occurs on calcrite plains overlain by shallow aeolian sand or calcareous aeolian sandplain. Calcrite nodules are often present at a depth of greater than 30 cm. Fine to coarse calcrite nodules (2–60 mm) may cover up to 2 per cent of the surface. Soils are calcareous loamy earths and red shallow sand and loams. MHGW is located in the north-west and west of the survey area.

Physiognomy and composition of vegetation
MHGW consists of a scattered to closed (15–50 per cent PFC) low woodland of mallee-form eucalypts over an understorey of dense Triodia scariosa (spinifex). The most common eucalypt to dominate MHGW is Eucalyptus oleosa subsp. oleosa (giant mallee).

27 perennial species were recorded at the seven inventory sites, with an average of nine species per site, two less than the survey average. No annual species were recorded.

The following species (by strata) were dominant and/or common:

Trees:
Dominant—Eucalyptus oleosa subsp. oleosa
Common—Allocasuarina helmsii, Eucalyptus concinna, E. gracilis, E. oleosa, Santalum acuminatum
Other—Eucalyptus melanoxylon.

Tall shrubs:
Dominant—Not present as a recognisable stratum
Common—Exocarpos aphyllus, Melaleuca eleuterostachya
Others—Acacia densiflora, A. hemiteles, A. ligulata, A. rigens, Eremophila caperata, E. dempsteri.

**Mid shrubs:**
Dominant—Not present as a recognisable stratum
Common—Scaevola spiniscens
Others—Eremophila decipiens, Melaleuca uncinata, Rulingia craurophylla, Senna artemisioides subsp. x coriacea.

**Low shrubs:**
Dominant—Not present as a recognisable stratum
Common—Westringia rigida
Others—Acacia camptoclada, A. xerophila, Grevillea acuaria, Olearia calcarea.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Other—Scaevola collaris.

**Perennial grasses:**
Dominant—Triodia scariosa
Common—Nil.

**Ecological disturbance**
MHGW is largely unaffected by grazing. Spinifex hummock grass and most shrubs associated with this habitat are not favoured by stock. The grazing value is generally seasonally dependent, with heavy rains promoting new plant growth, particularly after fire.

**Gradational associations**
MHGW occurs as a component of a broader eucalypt woodland mosaic, grading into Eucalypt mixed chenopod woodland (EXCW), Eucalypt mixed scrub woodland (EXSW) and Sugarwood mixed shrubland or woodland (SWCS) on calcrete plains. Near Lake Boonderoo MHGW grades downslope into Sandy bank lake shrubland (SBLS).

**Land systems**
MHGW is the dominant habitat type on the Zanthus land system.

### 20. Mulga mixed shrub woodland (MUXW)

**Sampling**
1 inventory site, 7 traverse points

**General information**
This minor vegetation association is found on calcrete plains overlain by sand in the north-west of the survey area. Soils are red loamy earths. This site type is more closely related to mulga vegetation communities more common to the northern Coolgardie and south-western Great Victoria Desert Biogeographic Regions than those of the Nullarbor Biogeographic Region. The presence of MUXW represents the beginning of a transition between the three botanical regions.

**Physiognomy and composition of vegetation**
MUXW comprises a closed (30–50 per cent PFC) low woodland of Acacia aneura (mulga) with an understorey of mixed shrubs. The lower shrub stratum is commonly dominated by scattered (15–20 per cent PFC) Ptilotus obovatus (cotton bush).

18 perennial species were recorded at the one inventory site and seven traverse points. No annual species were recorded.

The following species were dominant and/or common:

**Trees:**
Dominant—Acacia aneura
Others—Acacia papyrocarpa, Casuarina pauper.

**Tall shrubs:**
Dominant—Not present as a recognisable stratum
Others—Acacia tetragonophylla, Alectryon oleifolius, Dodonaea lobulata (KI), Eremophila alternifolia (KI).

**Mid shrubs:**
Dominant—Not present as a recognisable stratum
Others—Atriplex nummularia, Senna artemisioides subsp. x coriacea (KI).

**Low shrubs:**
Dominant—Ptilotus obovatus (KD)
Others—Enchylaena tomentosa (KD), Maireana pentatropis, M. sedifolia, M. thesioides (KD), Solanum lasiophyllum, S. nummularium.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Other—Solanum ellipticum.

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Other—Enneapogon caerulescens.

**Ecological disturbance**
This site type was not adequately sampled to discuss grazing impacts. However, patterns for similar mulga-dominated woodlands from previous rangeland surveys in the Coolgardie,
Great Victoria Desert and Murchison Biogeographic Regions (Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998) provide some indication of the likely grazing impacts. In good condition, palatable shrubs such as Ptilotus obovatus, Enchylaena tomentosa (ruby saltbush) and Maireana thesioides (lax bluebush) would be expected to be common. Conversely, a history of heavy grazing would be indicated by an abundance of Dodonaea lobulata (bead hopbush) and Senna artemisioides subsp. x coriacea (desert cassia) and a noticeable absence of palatable species.

Gradedional associations
MUXW grades into Casuarina mixed chenopod shrubland or woodland (CXCS) and Myall mixed chenopod shrubland or woodland (MXCS) as Acacia aneura disappears from the tree strata, replaced by either Casuarina pauper or Acacia papyrocarpa respectively.

Land systems
MUXW is a minor habitat type on Gumbelt and Nyanga land systems.

21. Acacia mixed shrubland (ACMS)

Sampling
1 inventory site, 9 traverse points

General information
ACMS is a minor habitat type in the Western Nullarbor but has previously been described in the Carnarvon Basin (Payne, Curry & Spencer 1987). In the Western Nullarbor ACMS occurs on calcrite plains overlain by sand and/or calcareous loams in the north-west of the survey area. Soils are calcareous shallow loams or red sandy earths where the surface is overlain by aeolian sand.

Physiognomy and composition of vegetation
ACMS commonly occurs as a scattered to closed (10–50 per cent PFC) tall scrubland of sclerophyllous shrubs, commonly dominated by species of Acacia, Eremophila and Senna. When present Enneapogon cylindricus is the dominant perennial grass.

16 perennial species and two annual species were recorded at the one inventory site and nine traverse points.

The following species (by strata) are dominant and/or common:

**Trees:**
Dominant—Not present as a recognisable stratum
Others—Acacia aneura, A. papyrocarpa, Casuarina pauper.

**Tall shrubs:**
Dominant—Variable; Acacia oswaldii, A. tetragonophylla (KI)
Common—Nil.

**Mid shrubs:**
Dominant—Atriplex nunnularia
Common—Eremophila latrobei (KD), E. sp.
Others—Senna artemisioides subsp. artemisioides (KI), Sida calyxhymenia (KD).

**Low shrubs:**
Dominant—Not present as a recognisable stratum
Others—Atriplex vesicaria (KD), Chenopodium curvispicatum (KD), Maireana sedifolia, Ptilotus obovatus.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—Atriplex acutibractea (KI), Eriochiton sclerolaenoides.

**Perennial grasses:**
Dominant—Occasionally Enneapogon cylindricus
Common—Nil.

Annual species recorded include Euphorbia drummondii and Salsola tragus.

Ecological disturbance
ACMS was not sampled sufficiently for detailed analysis of grazing impacts. Continuous heavy grazing is likely to result in a reduction in palatable species such as Atriplex vesicaria (bladder saltbush), Enchylaena tomentosa (ruby saltbush), Chenopodium curvispicatum, Eremophila latrobei (wartyl-leaf eremophila) and Sida calyxhymenia (tall sida). With declining condition an increase in unpalatable species such as Acacia tetragonophylla (curara) and Senna artemisioides subsp. artemisioides (silver cassia) may occur.

Gradational associations
ACMS grades into Myall mixed chenopod shrubland or woodland (MXCS) as the overlying sand disappears.

Land systems
ACMS is a minor habitat type on Nyanga land system.
E. SHRUBLAND ASSOCIATED WITH GRANITIC OUTCROP

This group of habitat types predominantly occurs within the Mardabilla land zone, where granite outcrop protrudes through limestone and calcrete plains. These habitat types are dominated by sclerophyllous vegetation including Senna, Eremophila and Ptilotus, occurring as scattered to moderately closed, tall and mid shrubland. Sparse trees and grasses are also present. Soils tend to be shallow.

22. Dodonaea, eremophila mixed shrubland (DEXS)

Sampling

2 inventory sites, 11 traverse points.

General information

DEXS is commonly found associated with the slopes of granite domes and outcrop within the Mardabilla land zone. Increased water catchment at the margin of the granite outcrop promotes dense shrubland. Medium to large (6–60 cm) stones of granite mixed with calcrete fragments cover up to 90 per cent of the surface. Granite outcrop occurs through 10 per cent of these habitats. Soils are red shallow sands and calcareous shallow loams. DEXS also occur in the central west of the survey area where sand and calcrete nodules overlie calcrite plains of the Nyanga land zone.

Physiognomy and composition of vegetation

DEXS occurs as a moderately closed (20–25 per cent PFC) tall shrubland of variable composition, mostly dominated by Eremophila alternifolia or Dodonaea lobulata (bead hopbush).

24 perennial species were recorded at the two inventory sites, with an average of 13 species per site, two greater than the survey average. Two annual species were recorded.

The following species (by strata) were dominant and/or common:

Trees:  
Dominant—Not present as a recognisable stratum  
Common—Pittosporum angustifolium  
Others—Acacia aneura, Eucalyptus gracilis (mallee).

Tall shrubs:  
Dominant—Dodonaea lobulata (Ki)  
Common—Eremophila alternifolia  
Others—Acacia burkittii (Ki), A. tetragonophylla, Geijera linearifolia.

Mid shrubs:  
Dominant—Not present as a recognisable stratum  
Others—Atriplex nummularia, Eremophila decipiens, E. latrobei (KD), Senna artemisioides subsp. x artemisioides (Ki).

Low shrubs:  
Dominant—Ptilotus obovatus (KD)  
Common—Solanum nummularium  
Others—Chenopodium curvispicatum, Enchyphaena tomentosa, Maireana pentatropis, Olearia axillaris.

Subshrubs:  
Dominant—Not present as a recognisable stratum  
Others—Sclerolaena patenticuspis, Sida spodochroma, Solanum ellipticum.

Perennial grasses:  
Dominant—Not present as a recognisable stratum  
Others—Austrodanthonia caespitosa, Enneapogon caerulescens, E. cylindricus.

Annual species recorded include Brachyscome sp. and Salsola tragus.

Ecological disturbance

This habitat type was not sufficiently sampled to investigate disturbance impacts as the proportion it occupies in the survey area is small. DEXS appeared to be largely unaffected by domestic grazing.

Gradational associations

In the south-west of the survey area DEXS abuts Granite outcrop shrubland (GROS) or grades into the Eucalypt mixed chenopod woodland (EXCW) or Eucalypt mixed scrub woodland (EXSW) surrounding the granite outcrop. In the central west of the survey area DEXS commonly grades into Mixed acacia open shrubland (XAOS).

Land system

DEXS is a major habitat type on Balladonia land system and a minor type on Nyanga land system.
23. Granite outcrop shrubland (GROS)

**Sampling**

4 inventory sites, 9 traverse points

**General information**

GROS is found in association with granite outcrop and low granite rises in the south-west of the survey area within the Mardabilla land zone. Soils are red shallow loams. Coarse granitic and calcareous fragments (2–20 cm) cover up to 10 per cent of the surface with granite outcrop occurring through up to 50 per cent of the area. The granite outcrop may rise to 5 m.

**Physiognomy and composition of vegetation**

GROS comprises a very scattered to scattered mid to tall shrubland (5–20 per cent PFC) of variable composition. The lower shrub stratum is commonly dominated by *Ptilotus obovatus* (cotton bush).

32 perennial species were recorded at the four inventory sites, with an average of 13 species per site, two greater than the survey average. 10 annual species were recorded, with an average of four species per site.

The following species (by strata) were dominant and/or common:

**Tall shrubs:**
- Dominant—Variable; *Dodonaea lobulata* (KI)
- Common—*Acacia ligulata* (KI), *Eremophila altemifolia*, *Myoporum platycarpum*.

**Mid shrubs:**
- Dominant—Variable; *Acacia ligulata* (KI), *Atriplex nummularia*
- Common—*Sida calyxhymenia* (KD)
- Others—*Eremophila deserti* (KI), *Pimelea microcephala*

**Low shrubs:**
- Dominant—Variable; *Ptilotus obovatus* (KD)
- Common—*Atriplex vesicaria*, *Enchylaena tomentosa* (KD), *Rhagodia ulicina*
- Others—*Atriplex stipitata*, *Chenopodium curvispicatum* (KD), *Maireana erioclada*, *M. georgei* (KD), *M. sedifolia*, *Olearia calcura*, *Tecticornia* sp.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Boerhavia repleta*, *Sclerolaena patenticuspis*, *Sida spodochromis*, *Solanum nummularium*
- Others—*Eriochiton sclerolaenoides*, *Sclerolaena cuneata*, *S. diacantha*, *S. obliquicuspis*.

**Perennial grasses:**
- Dominant—Not present as a recognisable stratum
- Common—*Austrodanthonia caespitosa*, *Austrostipa scabra*.

**Other plant forms:**
- Occasional—*Carpobrotus* sp., (succulent perennial herb), *Cheilanthes lasiophylla* (fern).

Annual species recorded include *Brachyscome* sp., *Calandrinia* sp., *Carrichtera annua* (KI), *Eriachne aristidea*, *Goodenia* sp., *Mesembryanthemum crystallinum*, *M. nodiflorum*, *Salsola tragus*, *Senecio quadridentatus* and *Vittadinia nullarboresis*.

**Ecological disturbance**

Different soil chemistries associated with granitic and calcareous rock types are the likely reason for the natural variation in the species composition of this habitat. An abundance of palatable species such as *Austrodanthonia caespitosa* (wallaby grass), *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush), *Maireana georgei* (golden bluebush), *Ptilotus obovatus* and *Sida calyxhymenia* (tall sida) indicates that GROS is in good condition. Rainwater accumulation in depressions within granite outcrop offers an ephemeral water source. These areas will receive concentrated grazing pressure from native and introduced animals whilst ephemeral pools remain. In such instances palatable flora is likely to be greatly reduced and the immediate area may become dominated by unpalatable species such as *Acacia ligulata*, *Dodonaea lobulata* (bead hopbush) and *Eremophila deserti*.

**Gradational associations**

GROS commonly abuts *Dodonaea*, *eremophilia mixed shrubland* (DEXS) or is bordered by *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt mixed scrub woodland* (EXSW) with the resumption of the overlying calcareous plains.

**Land systems**

GROS is a major habitat type on Balladonia land system.
F. SHRUBLAND ON CALCAREOUS PLAINS

This group of habitats consists of ‘succulent steppe’ according to Beard (1975). It is characterised by a dominant low shrub stratum frequently containing species from the genera *Atriplex* and *Maireana* of the Chenopodiaceae family. These shrubs are well adapted to arid environments. This habitat is common throughout the Nullarbor.

This habitat group occurs from the Nullarbor through to the Pilbara and is considered to have some of the highest pastoral value in the arid southern shrublands. Hacker (1979) researched the ecology and impact of grazing on chenopod shrubland present on depositional landscapes. The research was conducted on Glenorn Station in the north-eastern Goldfields. Hacker concluded excessive grazing pressure reduced shrub cover which in turn led to the extension of naturally present small scalds. Once scalds had extended beyond a certain threshold a reduction in grazing pressure was not enough to reverse the process. Scalded surfaces are less productive and become unsuitable as germination sites for most plants. These findings are reinforced throughout the Nullarbor survey area and are particularly evident from satellite imagery highlighting the piosphere effect around water points, especially within the Nullarbor land zone. The coalescing effect of scalds in heavily utilised areas emphasises the importance of monitoring vegetation, and appropriately responding to deteriorating condition, in order to prevent this process, which leads to reduced landscape function and resilience.

24. Sugarwood mixed chenopod shrubland (SWCS)

**Sampling**

4 inventory sites, 106 traverse points

**General information**

SWCS is predominantly found on stony limestone or calcrete plains overlain by calcareous loams in the west of the survey area. Soils are calcareous shallow loams or clay loams.

**Physiognomy and composition of vegetation**

SWCS comprises a scattered (10–20 per cent PFC) tall shrubland. The tree and/or tall shrub stratum is dominated by *Myoporum platycarpum* (sugarwood) and the shrub stratum by *Maireana sedifolia* (pearl bluebush).

35 perennial species were recorded at the four inventory sites, with an average of 13 species per site, two greater than the survey average. Four annual species were recorded, with an average of two species per site.

The following species (by strata) are dominant and or common:

**Trees:**

Dominant—*Myoporum platycarpum*

Common—Nil.

**Tall shrubs:**

Dominant—*Myoporum platycarpum*

Common—*Geijera linearifolia*

Other—*Exocarpos aphyllus*.

**Mid shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Atriplex nummularia*, *Cratystylis conocephala*

Others—*Acacia nyssophylla*, *Eremophila decipiens* (KI), *E. deserti* (KI), *E. glabra* (KI), *Nitraria billardieri*, *Scaevola spinescens*.

**Low shrubs:**

Dominant—*Maireana sedifolia*

Common—*Atriplex vesicaria* (KD), *Gunniposis calcarea*, *Lycium australe*, *Maireana erioclada*, *Ragodia ulicina*


**Subshrubs:**

Dominant—Not present as a recognisable stratum

Common—*Maireana trichoptera*, *Sclerolaena diacantha* (KD), *Sida spodochroma*

Others—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides*, *Sclerolaena patentcuspis* (KI).

**Perennial grasses:**

Dominant—Not present as a recognisable stratum

Common—*Austrodanthonia caespitosa*, *Austrostipa scabra* Others—*Austrostipa platychaeta* (KD), *Panicum effusum*.
Annual species recorded include *Brachyscome* sp., *Euphorbia drummondii*, *Nicotiana goodspeedii* and *Salsola tragus*.

**Ecological disturbance**

Dense stands of juvenile *Myoporum platycarpum* frequently occur in the south of the survey area. It is thought this is in response to reduced grazing pressure from rabbits due to the rabbit calicivirus. *Myoporum platycarpum* was also observed recolonising some recently burnt areas.

**Gradational associations**

SWCS often occurs as a transitional habitat type, as shallow calcareous loams marginally deepen, between *Myall mixed chenopod shrubland or woodland* (MXCS), *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt, sugarwood mixed chenopod woodland* (ESCW) and *Plain mixed chenopod shrubland* (PXCS), occurring in clay depressions or corridors between low-lying ridges. Where the soil surface becomes sandier SWCS grades into *Mallee hummock grass (spinifex) woodland* (MHGW).

**Land systems**

SWCS is a major habitat type on Nanambinia land system and a minor habitat type on Woorla land system.

### 25. Pearl bluebush low shrubland (PBLS)

**Sampling**

24 inventory sites, 1202 traverse points

**General information**

PBLS is the most common vegetation association in the Nullarbor land zone as well as one of the most common communities throughout the entire survey area. It is found on the stony slopes and crests of the undulating limestone plains of the Nullarbor Plain. PBLS occurs on gently undulating stony slopes up to 3 per cent, but often less than 2 per cent, with up to 90 per cent of the surface covered by medium to coarse limestone fragments (6–60 mm). Soils are shallow calcareous loams with limestone outcrop generally occurring through less than 10 per cent of the habitat type. On the calcrete plains of the Nyanga Plain PBLS is less common. The mantle is variably stony.

**Physiognomy and composition of vegetation**

PBLS comprises a very scattered to scattered (10–15 per cent PFC) low shrubland of *Maireana sedifolia* (pearl bluebush), occasionally moderately closed (< 25 per cent PFC). A sparse mid shrub stratum of mixed shrubs is sometimes present.

47 perennial species were recorded at the 24 inventory sites, with an average of 10 species per site, one less than the survey average. 23 annual species were recorded, with an average of five species per site.

The following species by strata were dominant and/or common:

**Trees:**

Dominant—Not present as a recognisable stratum

Common—*Myoporum platycarpum* (in the south)

Others—*Acacia papyrocarpa*, *Eremophila longifolia*, *Pittosporum angustifolium*.

**Tall shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Acacia oswaldii*.

**Mid shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Senna artemisioides* subsp. *artemisioides* (KI)

Others—*Atriplex nummularia*, *Cratystylis conocephala*, *Eremophila maculata*, *Senna artemisioides* subsp. *x coriacea* (KI), *S. artemisioides* subsp. *petiolaris*, *Sida calyxhymenia*.

**Low shrubs:**

Dominant—*Maireana sedifolia*


**Subshrubs:**

Dominant—Not present as a recognisable stratum

Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis* (KI), *S. patenticuspis* (KI), *Sida spodochroma*, *Solanum ellipticum*, *Wurmbea tenella*
Others—Desmocladus myriocladus, Maireana trichoptera, Minuria cunninghamii

**Perennial grasses:**

Dominant—Austrostipa scabra

Common—Austrodanthonia caespitosa, Austrostipa platychaeta (KD)

Others—Austrostipa nitida, Enneapogon caerulescens, E. cylindricus, Eragrostis setifolia.

**Other plant forms:**

Occasional—Glycine rubiginosa (creeper), Marsdenia australis (creeper).

Annual species recorded include Angianthus conocephalus, Brachyscome ciliaris, Calandrinia sp., Carrichtera annua (Ki), Dysphania melanocarpa forma leucocarpa, Erodium cicutarium, E. cygnorum, Euphorbia drummondii, E. tannensis subsp. eremophila, Goodenia pinnatifida, Isoetopsis graminifolia, Lepidium sp., Mesembryanthemum crystallinum, Podolepis canescens, Rhodanthe chlorocephala, R. floribunda, Salsola tragus (Ki), Senecio pinnatifolius, Sonchus oleraceus, Tetragonia eremaea, Vittadinia humerata, Zygophyllum iodocarpum (Ki) and Z. ovatum.

**Ecological disturbance**

Maireana sedifolia leaves contain up to 10 per cent salt (Mitchell & Wilcox 1994) and may be eaten by stock if fresh water is available. Pastoralists have observed stock eating only the tips of the plants particularly when there are new shoots. Maireana sedifolia is not a sensitive indicator of range condition in the Nullarbor. When in good condition this vegetation association has good diversity, including palatable perennials such as Atriplex vesicaria (bladder saltbush) and Chenopodium curvispicatum, numerous subshrubs (i.e. Eriochiton sclerolaenoides, Sclerolaena diacantha) and palatable grasses such as Austrodanthonia caespitosa (wallaby grass) and Austrostipa platychaeta. In fair condition these species will be reduced and replaced by less palatable, seasonally dependent facultative perennials Atriplex acutibractea (toothed saltbush), Sclerolaena obliquicuspis (limestone bindi) and S. patenticuspis (spine-fruits copperburr); and in poor condition by unpalatable annuals such as Carrichtera annua (Ward’s weed), Salsola tragus (roly poly) and Zygophyllum iodocarpum, with Austrostipa scabra (speargrass) dominating the areas between the bluebush mounds. Soils in healthy PBLs communities have well developed cryptogamic crusts of algae, lichens and liverworts, which improve nutrient cycling, soil moisture retention, and provide protection against raindrop impact, sheet flow and wind erosion. The loss of cryptogamic crust is an indicator of deteriorated soil condition.

Following a fire of moderate to low intensity Maireana sedifolia can regenerate if not severely grazed during its recovery (Mitchell, McCarthy & Hacker 1979), though it can be eliminated by frequent or intense fires. The ability to regenerate from fire and cope with arid conditions has allowed it to become a dominant climax species throughout the Nullarbor landscape.

*Pearl bluebush (Maireana sedifolia) regrowth after a low intensity fire caused by lightning.*
On the Nullarbor Plain *Maireana sedifolia* is immensely important in providing habitat and shelter to animals, including steppe and grassland birds, to other plants and soil protection from wind erosion. Its function in reducing wind speed at ground level is significant, reducing the wind’s desiccating effect on inter-mound subshrubs. Whilst not diminishing its ecological importance there is concern the continuous grazing pressure by all herbivores, particularly through dry seasons, is reducing the diversity of PBLS to homogenous communities dominated by *Maireana sedifolia* and *Austrostipa scabra*. In some locations within the landscape PBLS also represents a degraded state of a *Plain mixed chenopod shrubland* (PXCS). The loss of many fire-sensitive and/or palatable species leaves a PBLS community with extensive interpatch areas with only the *Maireana sedifolia* bush mounds remaining.

**Gradational associations**

PBLS commonly occur on crests and marginal slopes adjacent to depressions dominated by *Plain mixed chenopod shrubland* (PXCS), *Plain mixed halophyte shrubland* (PXHS), *Bladder saltbush shrubland* (BSLS), *Speargrass and wallaby grass open grassland* (SWOG), *Annual herbland* (ANNH), areas prone to water inundation, i.e. *Lignum swamp* (LISW), *Drainage depression saltbush shrubland* (DDSS), donga groves (DOGR) and *Gilgai grassy shrubland* (GGSL). On the Naretha land system as acacia tall shrubs become more common PBLS grades into *Pearl bluebush, Acacia shrubland* (PBAC), elsewhere degraded PBLS is replaced by *Mixed acacia open shrubland* (XAOS).

**Land systems**

PBLS is the dominant habitat on Balgair, Lowry, Moonera and Morris land systems. PBLS is a major habitat type on Arubiddy, Chowilla, Gafa, Kinclaven, Kybo, Pondana, Reid, Seemore, Shakehole, Skink, Thampanna, and Vanesk land systems and a minor habitat type on Bullseye, Jubilee, Nurina, Oasis and Woorba land systems.

**26. Pearl bluebush, acacia shrubland (PBAC)**

**Sampling**

2 inventory sites, 38 traverse points

**General information**

PBAC predominantly occurs on stony limestone plains with up to 20 per cent of the surface covered by medium-sized limestone fragments (6–20 mm). Soils are commonly calcareous shallow loams. PBAC occurs in the central west of the survey area.

**Physiognomy and composition of vegetation**

PBAC occurs as a very scattered to scattered (5–15 per cent PFC) mid to low shrubland. Species of *Acacia* dominate the mid shrub stratum. The lower shrub stratum is commonly co-dominated by *Maireana sedifolia* (pearl bluebush) and *Ptilotus obovatus* (cotton bush).

23 perennial species were recorded at the two inventory sites, with an average of 15 species per site, four greater than the survey average. Six annual species were recorded.

The following species (by strata) are dominant and/or common:

**Trees:**

- Dominant—Not present as a recognisable stratum
- Other—*Pittosporum angustifolium*.

**Tall shrubs:**

- Dominant—*Acacia burkittii* (KI), *A. tetragonophylla* (KI)
- Other—*Dodonaea lobulata* (KI).

**Mid shrubs:**

- Dominant—Not present as a recognisable stratum

**Low shrubs:**

- Dominant—*Maireana sedifolia*, *Ptilotus obovatus* (KD)
- Others—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Solanum orbiculatum*.

**Subshrubs:**

- Dominant—Not present as a recognisable stratum
- Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides* (KD), *Sida spodochroma*, *Solanium ellipticum*.
- Others—*Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis* (KI).

**Perennial grasses:**

- Dominant—Not present as a recognisable stratum
- Common—*Austrodanthonia caespitosa*, *Austrostipa scabra*, *Enneapogon cylindricus*.
- Others—*Enneapogon caerulescens*.
Annual species recorded include *Aristida contorta*, *Carrichtera annua* (Ki), *Erodium aureum*, *Euphorbia drummondii*, *Oxalis* sp. and *Salsola tragus*.

**Ecological disturbance**

*Acacia tetragonophylla* (curara) is well adapted to arid conditions and may be browsed but generally only during extended dry periods when other species are suffering from water stress (Mitchell & Wilcox 1994). Palatable perennial herbs and grasses, such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana trichoptera* (pink-seeded bluebush), *Austrodanthonia caespitosa* (wallaby grass) and *Enneapogon caerulescens* (limestone grass) are likely to be preferentially sought when seasonal conditions are favourable.

The vegetation structure and composition of PBAC is unique. Grazing may have altered the floristic composition resulting in an increase of the more dominant, unpalatable species *Acacia burkittii* (jam), *Acacia tetragonophylla* and *Dodonaea lobulata* (bead hopbush). However, the vegetation association may also be influenced by ancient river courses nearby and proximity to the adjacent calcrete plain. These components of the physical geography may have influenced soil characteristics. These factors in combination or individually form a floristic interzone of mixed species composition between the calcrete plain of the Nyanga land zone and the Nullarbor Plain of the Nullarbor land zone.

**Gradational associations**

PBAC commonly grades into *Pearl bluebush low shrubland* (PBLS) as acacia species become less common. In areas altered by fires and overgrazing PBAC is commonly replaced by *Open bindii grassland* (OBIG) and/or *Mixed acacia open shrubland* (XAOS).

**Land systems**

PBAC is a major habitat type on Naretha land system and a minor habitat type on Moonera land system.

---

27. Plain mixed chenopod shrubland (PXCS)

**Sampling**

16 inventory sites, 705 traverse points

**General information**

PXCS is common throughout the survey area. On the limestone plains of the Bunda Plateau it can occur on either stony surfaces with fine to coarse calcareous fragments (2–60 mm) covering up to 20 per cent of the surface, on marginal slopes to drainage floors with calcareous loams of varying depth or in the lower-lying depressions. In the west PXCS also occurs on the calcrete plains of the Nyanga Plain which are overlain by calcareous loam of variable depth. Soils are calcareous loamy earths. In the south on the Roe Plains PXCS also occurs on the calcareous loamy earths overlying the Roe Calcarenite.

**Physiognomy and composition of vegetation**

PXCS exists as a scattered (10–20 per cent PFC) mid to low shrubland, co-dominated by *Maireana sedifolia* (pearl bluebush) and *Atriplex vesicaria* (bladder saltbush).

41 perennial species were recorded at the 16 inventory sites, with an average of 11 species per site, the survey average. 12 annual species were recorded, with an average of three species per site.

The following species (by strata) were dominant and/or common:

**Trees:**

- Dominant—Not present as a recognisable stratum
- Others—*Myoporum platycarpum*, *Pittosporum angustifolium*.

**Tall shrubs:**

- Dominant—Not present as a recognisable stratum
- Others—*Acacia oswaldii*, *Exocarpos aphyllus*.

**Mid shrubs:**

- Dominant—Not present as a recognisable stratum
- Common—*Atriplex nummularia*, *Geijera linearifolia*
- Others—*Cratystylis conocephala*, *Eremophila decipiens*, *E. scoparia*, *Nitraria billardierei*, *Pimelea microcephala*.

**Low shrubs:**

- Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia*

---

175
Common—*Enchylaena tomentosa* (KD), *Lawrencia squamata* (KI), *Lycium australe*, *Maireana erioclada*
Others—*Chenopodium curvispicatum* (KD), *Gunniospis calcaria*, *Maireana radiata*, *M. turbinata*, *Olearia calcaria*, *O. ramosissima*, *Rhogodia ulicina*.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—*Eriochiton sclerolaenoides*, *Maireana trichoptera*, *Sclerolaena obliquicuspis* (KI), *S. patenticuspis* (KI), *Sida spodochroma*
Others—*Erodium aureum*, *Minuria cunninghamii*, *Sclerolaena densiflora* (KI), *S. diacantha* (KD), *Tecticornia sp.*

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Common—*Austrodanthonia caespitosa* (KD), *A. setacea*, *Austrostipa platychaeta* (KD), *A. scabra*
Others—*Austrodanthonia setacea*, *Enneapogon cylindricus* (KD).

**Other plant forms:**
Occasional—*Marsdenia australis* (creeper).


**Ecological disturbance**
Curry et al. (1994) suggested excessive grazing pressure reduced projected foliar cover (PFC), leaving PXCS habitats susceptible to accelerated soil erosion and/or increases in unpalatable shrubs. Pringle, Van Vreeswyk and Gilligan (1994) found the prominence of key decreaser species was the most sensitive indicator of range condition and to a lesser extent increaser species rather than PFC. Key decreaser shrub species include *Atriplex vesicaria*, *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) and palatable grasses include *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa platychaeta* and *Enneapogon cylindricus*.

Increaser species include *Lawrencia squamata* (grey fan leaf), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr) and the annuals *Carrichtera annua* (Ward’s weed), *Rhodanthe floribunda*, *Salsola tragus* (roly poly) and *Zygophyllum iodocarpum*. Pringle, Van Vreeswyk and Gilligan (1994) also found the extent of cryptogamic crusting was less in grazed areas, leaving such areas susceptible to soil erosion.

Fire can alter the species composition of these habitats considerably. At graded fencelines and tracks acting as firebreaks, the ability of *Maireana sedifolia* to recover from moderate to low intensity fires is visible, unlike fire-sensitive *Atriplex vesicaria* that is unable to recover, particularly in the presence of high rabbit numbers or continuous grazing. Across some locations with the same geophysical characteristics PXCS has been reduced to a homogenous stand of *Maireana sedifolia* (similar to a *Pearl bluebush low shrubland* PBLS), whilst nearby in fire excluded areas PXCS remains diverse.

**Gradational associations**
PXCS commonly grades into *Myall mixed chenopod shrubland or woodland* (MXCS), *Myall, false bluebush shrubland or woodland* (MFBW), *Eucalypt mixed chenopod woodland* (EXCW), *Sugarwood mixed chenopod shrubland or woodland* (MXCS) or *Casuarina mixed chenopod shrubland or woodland* (CXCS) as tree species begin to dominate the upper strata. In the south-west of the survey area PXCS is commonly found in the depressions and lower-lying ‘corridors’ between the undulating patterns of joint controlled limestone ridges supporting *Pearl bluebush low shrubland* (PBLs), *Eucalypt saltbush shrubland or woodland* (ESAW) or *Eucalypt mixed scrub woodland* (EXSW). PXCS can also occur on marginal slopes to drainage floors as a vegetation transition between PBLs-dominated low ridges and lower-lying *Bladder saltbush shrubland* (BSSL) or *Samphire shrubland* (SAMP). On the Roe Plains PXCS grades into *Nitraria mixed chenopod shrubland* (NXCS) as *Nitraria billardierei* begins to dominate the mid shrub layer.

Curry et al. (1994) suggested excessive grazing pressure reduced projected foliar cover (PFC), leaving PXCS habitats susceptible to accelerated soil erosion and/or increases in unpalatable shrubs. Pringle, Van Vreeswyk and Gilligan (1994) found the prominence of key decreaser species was the most sensitive indicator of range condition and to a lesser extent increaser species rather than PFC. Key decreaser shrub species include *Atriplex vesicaria*, *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) and palatable grasses include *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa platychaeta* and *Enneapogon cylindricus*.

Increaser species include *Lawrencia squamata* (grey fan leaf), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr) and the annuals *Carrichtera annua* (Ward’s weed), *Rhodanthe floribunda*, *Salsola tragus* (roly poly) and *Zygophyllum iodocarpum*. Pringle, Van Vreeswyk and Gilligan (1994) also found the extent of cryptogamic crusting was less in grazed areas, leaving such areas susceptible to soil erosion.

Fire can alter the species composition of these habitats considerably. At graded fencelines and tracks acting as firebreaks, the ability of *Maireana sedifolia* to recover from moderate to low intensity fires is visible, unlike fire-sensitive *Atriplex vesicaria* that is unable to recover, particularly in the presence of high rabbit numbers or continuous grazing. Across some locations with the same geophysical characteristics PXCS has been reduced to a homogenous stand of *Maireana sedifolia* (similar to a *Pearl bluebush low shrubland* PBLS), whilst nearby in fire excluded areas PXCS remains diverse.

**Gradational associations**
PXCS commonly grades into *Myall mixed chenopod shrubland or woodland* (MXCS), *Myall, false bluebush shrubland or woodland* (MFBW), *Eucalypt mixed chenopod woodland* (EXCW), *Sugarwood mixed chenopod shrubland or woodland* (MXCS) or *Casuarina mixed chenopod shrubland or woodland* (CXCS) as tree species begin to dominate the upper strata. In the south-west of the survey area PXCS is commonly found in the depressions and lower-lying ‘corridors’ between the undulating patterns of joint controlled limestone ridges supporting *Pearl bluebush low shrubland* (PBLs), *Eucalypt saltbush shrubland or woodland* (ESAW) or *Eucalypt mixed scrub woodland* (EXSW). PXCS can also occur on marginal slopes to drainage floors as a vegetation transition between PBLs-dominated low ridges and lower-lying *Bladder saltbush shrubland* (BSSL) or *Samphire shrubland* (SAMP). On the Roe Plains PXCS grades into *Nitraria mixed chenopod shrubland* (NXCS) as *Nitraria billardierei* begins to dominate the mid shrub layer.
Land systems

PXCS is a dominant habitat type on Koonjarra and Woorlba land systems and a major habitat type on Chowilla, Gafa, Moonera, Morris, Nanambinia, Nyanga, Reid, Shakehole, Thampanna and Vanesk land systems.

28. Nitraria with mixed chenopod shrubland (NXCS)

Sampling

3 inventory sites, 17 traverse points

General information

NXCS is named after the dominance of Nitraria billardieri (nitre bush). Soils are calcareous loamy earths overlying the calcarenite Roe Plains. It occurs in the south of the survey area on the north of the Roe Plains, where the soils overlying the Roe Calcarenite remain shallow and are less sandy.

Physiognomy and composition of vegetation

NXCS varies considerably from a very scattered to moderately closed (5–25 per cent PFC) shrubland. Nitraria billardieri (nitre bush) dominates the mid shrub stratum with the lower shrub stratum dominated by Atriplex vesicaria (bladder saltbush).

21 perennial species were recorded at the three inventory points, with an average of 12 species per site, one greater than the survey average. Eight annual species were recorded, with an average of five species per site.

The following species (by strata) are dominant and/or common:

**Trees:**

Dominant—Not present as a recognisable stratum

Common—Acacia papyrocarpa.

**Tall shrubs:**

Dominant—Not present as a recognisable stratum

Other—Geijera linearifolia.

**Mid shrubs:**

Dominant—Nitraria billardieri (KI)

Common—Atriplex nummularia.

**Low shrubs:**

Dominant—Atriplex vesicaria (KD)

Common—Enchytraea tomentosa (KD), Guniopsis calcarea, Lawrenzia squamata (KI), Maireana erioclada

Others—Maireana georgei (KD), M. sedifolia, Zygophyllum aurantiacum (KD).

**Subshrubs:**

Dominant—Not present as a recognisable stratum

Common—Eriochiton sclerolaenoides, Sclerolaena patenticuspis (KI), Tetragonia implexicoma

Others—Maireana trichoptera, Sclerolaena diacantha (KD).

**Perennial grasses:**

Dominant—Not present as a recognisable stratum

Common—Austrodanthonia caespitosa, Austrostipa drummondii, A. scabra

Other—Austrostipa platychaeta (KD).

Annual species recorded include Brachyscome lineariloba, Carrichtera annua (KI), Erodium cicutarium, Nicotiana goodspeedii, N. occidentalis, Senecio pinnatifolius, Sonchus oleraceus and Trichanthodium skirrophorum.

Ecological disturbance

Nitraria billardieri is not highly desirable to stock, except for the fruit which is eaten by sheep, and may increase at the expense of palatable low shrubs such as Atriplex vesicaria, Enchytraea tomentosa (ruby saltbush) and Maireana georgei (golden bluebush) which decrease under excessive grazing pressure. In areas of heavy grazing pressure Nitraria billardieri shelters palatable grasses such as Austrostipa platychaeta within its spreading clump-like form.

Nitraria billardieri can also increase in response to track or roadside disturbances. This is evident along the Eyre Highway and the old Eyre telegraph line where Nitraria billardieri has increased due to the combination of disturbance opening the tree canopy and greater accumulation of water at the road or track edge.

Nitraria billardieri is readily dispersed by birds and as a result it commonly occurs under potential perch sites including telegraph poles and fence posts.

Gradational associations

NXCS commonly grades into Plain mixed chenopod shrubland (PXCS) or Myall mixed chenopod shrubland or woodland (MXCS) as Nitraria billardieri becomes less common.
Land systems
NXCS is a major habitat type on Mundrabilla land system and a minor habitat type on Roe land system.

29. Bladder saltbush shrubland (BSSL)

Sampling
31 inventory sites, 578 traverse points

General information
BSSL can occupy a variety of positions within the landscape. It predominantly occurs in the loamy depressions of undulating limestone plains in the south-east of the survey area. In the south-west BSSL occurs in clay depressions with saline subsoils. In the north BSSL occurs on deflated marginal slopes to drainage floors with limestone fragments of mixed size (1–30 cm) generally covering up to 50 per cent of the surface. BSSL also dominates drainage floors and ancient river courses throughout the survey area. Shrub patches are commonly intersected with naturally occurring scalded interbands. Soils are calcareous loamy earths. When present in clay depressions and drainage floors red/brown non-cracking clays dominate.

Physiognomy and composition of vegetation
BSSL comprises a scattered to moderately closed (10–25 per cent PFC) low shrubland of Atriplex vesicaria (bladder saltbush).

52 perennial species were recorded at the 31 inventory sites, with an average of eight species per site, three less than the survey average. 23 annual species were recorded, with an average of four species per site.

The following species (by strata) are dominant and/or common:

**Tall shrubs:**
Dominant—Not present as a recognisable stratum
Others—Acacia tetragonophylla, Geijera linearifolia.

**Mid shrubs:**
Dominant—Not present as a recognisable stratum
Common—Atriplex nummularia
Others—Cratystylis conocephala, Eremophila decipiens (KI), E. deserti, E. glabra (KI), E. scoparia (KI), Pimelea microcephala.

**Low shrubs:**
Dominant—Atriplex vesicaria
Common—Maireana georgei (KD), M. sedifolia

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—Eriochiton sclerolenoides (KD), Sclerolaena diacantha (KD), S. obliquicuspis (KI), S. patenticuspis (KI), Sida spodochroma
Others—Atriplex acutibractea (KI), Maireana trichoptera (KD), Sclerolaena brevifolia, Solanum ellipticum.

**Perennial grasses:**
Dominant—Austrostipa scabra

**Other plant forms:**
Occasional—Glycine rubiginosa (creeper).

Annual species recorded include Arabidella trisecta, Brachyscome sp., Carrichtera anua (KI), Centaurea melitensis, Dysphania melanocarpa forma leucocarpa, Erodium aureum, Euphorbia drummondi, Lepidium rotundum, Lotus cruentus, Mesembryanthemum crystallinum, Nicotiana goodspeedii, N. occidentalis, Oxalis corniculata, Podolepis canescens, Rhodanthe floribunda (KI), Salsola tragus (KI), Senecio pinnatifolius, S. quadridentatus, Senecio spanomerus, Swainsona microphylla, Vittadinia humerata, Zygophyllum iodocarpum and Zygophyllum ovatum.

Ecological disturbance
Atriplex vesicaria responds to moisture stress by shedding leaves, but will recover quickly in response to rainfall and soil moisture conditions that stimulate germination. During this recovery phase Atriplex vesicaria needs protection from grazing pressure to allow germinant.
establishment and for mature plants to regain vigour and set seed. Sustained heavy grazing is likely to reduce perennial vegetation cover as well as reducing other palatable species such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana georgei* (golden bluebush), *M. trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii). This may lead to the expansion of naturally occurring scalded interbands. Further threats to *Atriplex vesicaria* include its lack of tolerance to fire and inability to regenerate after burning.

In BSSL an increase in unpalatable species such as *Eremophila* spp., *Atriplex acutibractea* (toothed saltbush), *Sclerolaena obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr), *Carrichtera annua* (Ward’s weed), *Rhodanthe floribunda* and *Salsola tragus* (roly poly) indicates declining range condition.

Gradational associations

BSSL commonly grades out of depressions and lower-lying areas into Plain mixed chenopod shrubland (PXCS), Pearl bluebush low shrubland (PBLs) or Open bindii grassland (OBIG) occupying the marginal slopes and crests of the gentle undulating Nullarbor Plain. Transitional associations can also occur in the same land unit, usually lower-lying depressions, between BSSL and Speargrass and wallaby grass open grassland (SWOG) and, depending on soil salinity, Plain mixed halophyte shrubland (PXHS). In ancient river courses BSSL commonly surrounds the drainage foci supporting *Lignum swamp* (LISW).

Due to the common occurrence of BSSL in depressions and low-lying areas, other habitat associations may occur on the surrounding higher slopes of undulating country such as eucalypt and/or myall shrubland or woodland.

**Land systems**

BSSL is a major habitat type on Arubiddy, Balgair, Chowilla, Gafa, Haig, Moonera, Morris, Reid, Shakehole, Skink, Thampanna and Woorlba land systems and a minor habitat type on Bullseye, Jubilee, Kanandah, Moodini, Nurina, Nyanga, Oasis, Pondana and Vanesk land systems.

### 30. Lawrencia squamata shrubland (LAWS)

#### Sampling

3 inventory sites, 16 traverse points

#### General information

LAWS is a minor vegetation association predominantly occurring on the calcrite breakaway slopes of the Koonjarra land system. Moderately inclined slopes of up to 10 per cent have outcrop occurring through 50 per cent of the area, with 90 per cent of the surface covered by loose calcrite fragments of mixed size. Soils are commonly red/brown non-cracking clays. LAWS are found in the central west of the survey area. LAWS are also found infrequently on stony limestone plains of the Kinclaven and Shakehole land system where it replaces mixed chenopod shrubland.

**Physiognomy and composition of vegetation**

LAWS comprises scattered (10–15 per cent) low shrubland of *Lawrencia squamata* (grey fan leaf).

16 perennial species were recorded at the three inventory sites, with an average of nine species per site, two less than the survey average. Four annual species were recorded.

The following species (by strata) were dominant and/or common:

**Trees:**

- Dominant—Not present as a recognisable stratum
- Common—*Acacia papyrocarpa*.

**Mid shrubs:**

- Dominant—Not present as a recognisable stratum
- Common—*Atriplex nummularia*, *Nitraria billardierei* Other—*Cratystylis conocephala*.

**Low shrubs:**

- Dominant—*Lawrencia squamata* Common—*Atriplex vesicaria* (KD), *Maireana sedifolia* Others—*Cratystylis subspinescens*, *Frankenia sp.*, *Maireana turbinata*, *Rhagodia crassifolia*.

**Subshrubs:**

- Dominant—Not present as a recognisable stratum
- Common—*Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD).
**Perennial grasses:** Dominant—Not present as a recognisable stratum
Common—Austrostipa scabra
Others—Austrodanthonia caespitosa, Eragrostis dielsii.

Annual species recorded include Carrichtera annua (KI), Euphorbia drummondii, Nicotiana occidentalis and Salsola tragus.

**Ecological disturbance**

Whilst Lawrencia squamata is occasionally eaten by stock, in some areas it may be increasing in abundance in response to a loss of more palatable flora. If Atriplex vesicaria (bladder saltbush), Maireana trichoptera (pink-seeded bluebush) and Sclerolaena diacantha (grey bindii) are present in large numbers and with numerous juveniles the area can be assumed to be in good condition. The latter two species are subject to seasonal conditions and caution should be used when selecting them alone to determine range condition.

The breakaway slopes of this habitat are highly susceptible to water erosion. Vehicle tracks have resulted in rilling and gullyng. Short spaced bunds across the tracks would divert water flow off the tracks. This would prolong the tracks usefulness, reduce erosion and the deteriorating condition of the breakaway slopes impacted by the tracks.

**Gradational associations**

In the Koonjarra land system LAWS is commonly found midslope between sparse Myall mixed chenopod shrubland or woodland (MXCS) and grading downslope into Plain mixed chenopod shrubland (PXCS). Where it is present on limestone plains it often grades into Open bindii grassland (OBIG).

**Land systems**

LAWS is a minor habitat type on Kinclaven, Koonjarra and Shakehole land systems.

**G. OPEN SHRUBLAND AND GRASSLAND ON CALCARCEOUS PLAINS**

This group of habitat types occurs on the limestone and calcrite plains of the Bunda Plateau and is predominantly altered vegetation associations now in an irreversible state of transition. These habitat types are thought to have once supported a low shrub stratum which has since been removed through the combined effects of increased fire frequency and over-grazing, primarily by rabbits. The replacement of perennial shrubs by grasses, particularly Austrostipa scabra (speargrass), has increased the susceptibility of these habitats to fire. These irreversibly altered vegetation associations are unlikely to support a low shrub stratum of palatable perennial shrubs in the future. They now carry open grassland and sparse shrubland. Low-lying areas such as claypans, clay plains and drainage areas in some locations may originally have supported these seasonally dependent vegetation associations, but with a more diverse suite of palatable perennials or subshrubs than what is supported by these areas today. In good seasons these habitats support dense stands of perennial and annual grasses and herbs. In dry periods these habitats are susceptible to wind erosion due to the scarcity of plants.

**31. Mixed acacia open shrubland (XAOS)**

**Sampling**

4 inventory sites, 66 traverse points

**General information**

XAOS commonly occurs in the central west of the survey area on stony limestone plains where up to 90 per cent of the surface is covered by coarse (2–20 cm) limestone fragments. It occasionally occurs on calcrite plains overlain by stony calcareous loams. Soils are red shallow loams and calcareous shallow loams.

**Physiognomy and composition of vegetation**

XAOS occurs as a scattered (10–15 per cent PFC) tall shrubland of acacias. The most dominant acacia is Acacia burkittii (jam), though A. aneura (mulga) is also common. Ptilotus obovatus (cotton bush) commonly dominates the low shrub stratum.

34 perennial species were recorded at the four inventory sites, with an average of 17 species per site, six greater than the survey average. Nine annual species were recorded, with an average of five species per site.
The following species (by strata) are dominant and/or common:

**Trees:**
Dominant—Not present as a recognisable stratum
Occasional—Acacia aneura, A. papyrocarpa, Alectryon oleifolius, Myoporum platycarpum, Pittosporum angustifolium, Santalum spicatum.

**Tall shrubs:**
Dominant—Acacia burkittii (KI)
Common—Acacia aneura
Others—Acacia oswaldii, A. tetragonophylla (KI), Dodonaea lobulata (KI), Myoporum platycarpum.

**Mid shrubs:**
Dominant—Not present as a recognisable stratum
Others—Eremophila latrobei subsp. glabra, E. scoparia (KI), Scaevola spinescens, Senna artemisioides subsp. x artemisioides (KI), S. artemisioides subsp. x coriacea (KI), Sida calyxhymenia (KD).

**Low shrubs:**
Dominant—Ptilotus obovatus
Common—Atriplex vesicaria, Enchylaena tomentosa, Maireana sedifolia
Other—Solanum nummularium.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—Eriochiton sclerolaenoides (KD), Sclerolaena diacantha (KD), S. patenticuspis (KI), Sida spodochroma, Solanum ellipticum
Others—Maireana trichoptera (KD), Minuria cunninghamii, Sclerolaena obliquicuspis (KI).

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Common—Austrostipa scabra, Enneapogon caerulescens, E. cylindricus
Other—Austrodanthonia caespitosa.

**Other plant forms:**
Occasional—Marsdenia australis (creeper).

Annual species recorded include Abutilon oxycarpum subsp. prostratum, Aristida contorta, Carrichtera annua (KI), Dysphania melanocarpa forma leucocarpa, Erodium cygnorum, Euphorbia drummondii, Lepidium sp., Malvastrum americanum and Salsola tragus.

**Ecological disturbance**

*Acacia burkittii* is not grazed by stock and this may have contributed to its dominance through this habitat type. In many areas *Acacia burkittii* was of uniform height and therefore possibly of similar age. This may be a post-fire related response.

XAOS represents a floristic ecotone of mixed species composition between the calccrete plain of the Nyanga land zone and the Nullarbor Plain of the Nullarbor land zone. The occurrence of red shallow loam soils through the XAOS of the Naretha land system indicates the vegetation association may be influenced by the proximity to the calccrete plain and ancient water courses. Alternatively, the soil surface may reflect sand mobility caused through past or present disturbance events.

*Ptilotus obovatus* is palatable though its condition and presence varies with seasonal conditions. The grasses *Enneapogon caerulescens* (limestone grass) and *Enneapogon cylindricus* are highly palatable to stock, but abundance depends with seasonal conditions. Dense stands of such species may indicate fair to good rangeland condition.

**Gradational associations**

XAOS commonly grades into low shrubland such as *Pearl bluebush low shrubland* (PBLS) and *Pearl bluebush, acacia shrubland* (PBAC). In the Naretha land system ancient river courses supporting Drainage Acacia shrubland (DRAS) meander through XAOS.

Where residual calcrite rises occur over the Nullarbor Limestone and *Casuarina pauper* (black oak) begins to occur in the overstorey XAOS grades into *Casuarina, acacia open shrubland* (CAOS) or *Casuarina mixed scrub shrubland* (CXSS). Where sand overlies calcrite rises, XAOS grades into *Dodonaea, eremophila mixed shrubland* (DEXS).

**Land systems**

XAOS is a major habitat type on Kitchener and Naretha land system and a minor habitat type on Nyanga land system.
32. **Mixed shrub bindii grassland (XSBG)**

**Sampling**
6 inventory sites, 269 traverse points

**General information**
XSBG is predominantly found on stony limestone plains. Up to 90 per cent of the stony surface is strewn with limestone fragments of mixed size, and outcrop is common through up to 50 per cent of these habitats. Soils are calcareous loamy earths and shallow loams. XSBG is found in the north-west of the survey area.

**Physiognomy and composition of vegetation**
XSBG is highly variable and may occur as a very scattered to scattered (2.5–15 per cent PFC) herbland, mid or tall shrubland. The mid and tall shrubland is commonly dominated by sclerophyllous shrubs and the herbland by species of *Sclerolaena* (bindii).

36 perennial species were recorded at the six inventory sites, with an average of 15 species per site, four greater than the survey average. 13 annual species were recorded, with an average of six species per site.

The following species (by strata) are dominant and/or common:

**Trees:**
- Dominant—Not present as a recognisable stratum
- Common—*Pittosporum angustifolium*  
  Other—*Acacia papyrocarpa*.

**Tall shrubs:**
- Dominant—Variable; occasionally *Eremophila longifolia*, *A. tetragonophylla* (KI)*
- Common—*Acacia burkittii* (KI), *A. oswaldii*.

**Mid shrubs:**
- Dominant—Variable; occasionally *Senna artemisioides* subsp. *x coriacea* (KI)*
- Common—*Atriplex nummularia*  

**Low shrubs:**
- Dominant—Occasionally *Lawrencia squamata* (KI)*
- Common—*Chenopodium curvispicatum*, *Enchylaena tomentosa* (KD), *Maireana sedifolia*  
  Others—*Atriplex vesicaria* (KD), *Lycium australe*, *Maireana radiata*, *Ptilotus obovatus* (KD), *Solanum nummularium*.

**Subshrubs:**
Dominant—*Sclerolaena obliquicuspis* (KI)*  
 Common—*Atriplex acutibactea* (KI), *Eriochiton sclerolaenoides* (KD), *Sclerolaena diacantha* (KD), *S. patentisciupsis* (KI), *Sida spodochroma*, *Solanum ellipticum*  
 Others—*Maireana trichoptera* (KD), *Sclerolaena brevifolia*.

**Perennial grasses:**
Dominant—*Austrodanthonia caespitosa*, *Austrostipa scabra*  
 Common—*Eriophorum caeruleum*, *E. cylindricus*  
 Other—*Eragrostis setifolia*.

**Other plant forms:**
Occasional—*Glycine rubiginosa* (creepers), *Marsdenia australis* (creepers).

Annual species recorded include *Carrichtera annua* (KI), *Dysphania melanocarpa* forma *leucocarpa*, *Erodium aureum*, *E. cygnorum*, *Euphorbia drummondii*, *Lepidium sp.*, *Malvastrum americanum*, *Rhodanthe floribunda* (KI), *Salsola tragus* (KI), *Salvia verbenaca* (KI), *Sisymbrium erisimoides*, *Xanthium spinosum* and *Zygophyllum iodocarpum*.

**Ecological disturbance**
XSBG is an altered vegetation association. The presence of *Maireana sedifolia* (pearl bluebush) stumps and remnant bush mounds indicates these areas previously supported chenopod shrubland. Many of the shrubs now dominating these areas are unpalatable, including increaser species such as *Acacia burkittii* (jam), *A. tetragonophylla* (curara) and *Senna artemisioides* subsp. *x coriacea* (desert cassia). These shrubs are generally resilient, capable of surviving dry conditions and known to respond in abundance after a fire.

The lower stratum of XSBG is regularly dominated by unpalatable subshrubs and annuals such as *Atriplex acutibactea* (toothed saltbush), *Sclerolaena obliquicuspis* (limestone bindii), *S. patentisciupsis* (spear-fruit copperburr), *Carrichtera annua* (Ward’s weed), *Rhodanthe floribunda*, *Salsola tragus* (roly poly) and *Salvia verbenaca* (wild sage). During dry periods these seasonally dependent plants disappear and the area becomes prone to wind erosion. This further reduces the capacity to support
vegetative growth. The extensively stony surface of this habitat is evidence of active erosive processes.

**Gradational associations**

XSBG is a common component in areas with a record of long-term continuous grazing and a history of fire. This degraded habitat type commonly grades into *Open bindii grassland* (OBIG).

In the northern Nullarbor Plain XSBG commonly surrounds dongas supporting berrigan and curara groves (DBGR and DCGR) as well as small areas of *Gilgai grassy shrubland* (GGSL).

Where Nullarbor Limestone is overlain by thick calcrite and *Casuarina pauper* (black oak) begins to appear in the overstorey XSBG grades into *Casuarina mixed scrub shrubland* (CXSS).

**Land systems**

XSBG is the dominant habitat on Kinclaven land system, a major type on Kanandah and Kitchener land systems and a minor habitat type on Naretha land system.

33. **Open bindii grassland (OBIG)**

**Sampling**

11 inventory sites, 492 traverse points

**General information**

OBIG predominantly occurs on stony limestone and calcrite plains across the north of the survey area. Coarse gravel and stones (2–20 cm) of limestone may cover up to 90 per cent of the surface. OBIG also commonly occurs on the marginal slopes to drainage floors of clay plains and claypans in the north. Soils are commonly calcareous shallow loams, and where present on clay plains, red/brown non-cracking clays.

**Physiognomy and composition of vegetation**

OBIG occurs as a very scattered to moderately closed (2.5–25 per cent PFC) grassland with mixed *Sclerolaena* species, most commonly *Sclerolaena patenticuspis* (spear-fruit copperburr).

25 perennial species were recorded at the 11 inventory sites, with an average of six species per site, five less than the survey average. 10 annual species were recorded, with an average of five species per site.

The following species (by strata) are dominant and/or common.

**Trees:**

- Dominant—Not present as a recognisable stratum
- Occasional—*Acacia papyrocarpa, Casuarina pauper, Eremophila longifolia, Pittosporum angustifolium.*

**Mid shrubs:**

- Dominant—Not present as a recognisable stratum
- Occasional—*Atriplex nummularia, Scaevola spinescens.*

**Low shrubs:**

- Dominant—Not present as a recognisable stratum
- Others—*Atriplex acutibractea, A. vesicaria, Enchylaena tomentosa, Lycium australe, Maireana sedifolia, Ptilotus obovatus.*

**Subshrubs:**

- Dominant—*Sclerolaena patenticuspis* (KI), *Eriochiton sclerolaenoides* (KD)

**Perennial grasses:**


**Other plant forms:**

- Occasional—*Glycine rubiginosa* (creep).

Annual species recorded include *Carrichtera annua* (KI), *Eriodaphyllum eleni, Euphorbia drummondii, Lepidium sp., Mesembryanthemum crystallinum, Nicotiana occidentalis, Rhodanthe floribunda* (KI), *Salsola tragus* (KI), *Vittadinia sp. and Zygophyllum iodicarpum* (KI).

**Ecological disturbance**

Total grazing pressure has influenced the floristic composition of this habitat type in different locations. In good condition, palatable perennial herbs such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) and perennial grasses such as *Austrodanthonia caespitosa* (wallaby grass) and *Enneapogon cylindricus* are abundant. In poor condition, unpalatable species dominate. These include *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward’s weed),
Salsola tragus (roly poly), Sclerolaena obliquicuspis (limestone bindii), S. patenticuspis, Rhodanthe floribunda and Zygophyllum iodocarpum. In dry seasons these areas are prone to erosion and scalding as there is very little protection offered by the seasonally dependent plants.

**Gradational associations**

OBIG commonly grades into Myall bindii grassland (MBIG) as myall begins to appear. In the northern Nullarbor land zone OBIG commonly surround the various forms of donga and small patches of Gilgai grassy shrubland (GGSL). Southwards in the Nullarbor land zone, as dongas give way to claypans and clay plains, OBIG surrounds vegetation associations commonly occupying such depressions such as Bladder saltbush shrubland (BSSL), Annual herbland (ANNH) or Speargrass and wallaby grass open grassland (SWOG). As the density of shrubs begins to increase in the mid and tall shrub strata OBIG grades into Mixed shrub bindii grassland (XSBG) or Pearl bluebush, acacia shrubland (PBAC).

**Land systems**

OBIG is the dominant habitat on Oasis and Rabbit land systems, a major habitat type on Bullseye, Carlisle, Gafa, Jubilee, Kinclaven, Kitchener, Kyarra, Kybo and Nurina land systems and a minor type on Haig, Moonera, Pondana, Reid, Shakehole and Skink land systems.

34. **Speargrass and wallaby grass open grassland (SWOG)**

**Sampling**

29 inventory sites, 635 traverse points

**General information**

SWOG is considered a fire-induced vegetation association. Patches are likely to have always existed in a mosaic state and transition pattern between saltbush and bluebush low shrubland. The vegetation has become irreversibly altered as a result of increased fire frequency and through grazing by rabbits in plague proportions. SWOG now dominates extensive areas, having replaced other habitat types by increasing the fire susceptibility of much of the Nullarbor.

SWOG occurs across the survey area on limestone plains with up to 50 per cent of the surface overlain by coarse (2–20 cm) limestone fragments. It also occurs in both closed and open depressions on calcareous loamy plains, clay plains and claypans. Soils are calcareous shallow loams and loamy earths, and red/brown non-cracking clays in claypans.

**Physiognomy and composition of vegetation**

SWOG consists of open grassland of Austrostipa scabra (speargrass) and Austrodanthonia caespitosa (wallaby grass).

52 perennial species were recorded at the 29 inventory sites, with an average of six species per site, five less than the survey average. 27 annual species were recorded, with an average of four species per site.

The following species (by strata) were dominant and/or common:

**Trees:**

- Dominant—Not present as a recognisable stratum
- Occasional—Acacia papyrocarpa, Eremophila longifolia, Eucalyptus gracilis, E. yalatensis, Myoporum platycarpum.

**Tall shrubs:**

- Dominant—Not present as a recognisable stratum
- Occasional—Acacia burkittii, A. hemiteles, A. oswaldii, Geijera linearifolia.

**Mid shrubs:**

- Dominant—Not present as a recognisable stratum
- Common—Atriplex nummularia
- Others—Atriplex vesicaria, Acacia nyssophylla, Cratystylis conocephala, Nitraria billardiarei, Pimelea microcephala, Scaevola spinescens, Senna artemisioides subsp. x coriacea.

**Low shrubs:**

- Dominant—Not present as a recognisable stratum
- Common—Atriplex vesicaria, Maireana sedifolia
### Subshrubs:
- Dominant—Not present as a recognisable stratum
- Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides*, *Sclerolaena diacantha*, *S. obliquicuspusis*, *S. patenticuspis*, *Sida spodochroma*
- Others—*Maireana tomentosa*, *M. trichoptera*, *Sclerolaena brevifolia*, *S. densiflora*, *Solanum ellipticum*, *Swainsona affinis*, *Teucrium racemosum*, *Wurmbea tenella*.

### Perennial grasses:
- Dominant—*Austrostipa scabra*
- Common—*Austrodanthonia caespitosa* (KD)
- Others—*Austrostipa drummondii*, *Enneapogon cylindricus* (KD), *Eragrostis dielsii*, *E. setifolia*.

### Other plant forms:
- Occasional—*Marsdenia australis* (creeper).


### Ecological disturbance
In good seasons SWOG is highly productive and during the active growth phase is readily grazed. *Austrostipa scabra* has maximum nutritional value when it has new green shoots, becoming less appealing as it becomes dry and harsh. *Austrodanthonia caespitosa* is highly palatable and is preferentially sought by herbivores. If total grazing pressure is not effectively managed wallaby grass can be eliminated with SWOG becoming dominated by only speargrass and unpalatable species such as *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward’s weed), *Nicotiana* spp., *Salsola tragus* (roly poly), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspusis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr), *Rhodanthe floribunda* and *Zygophyllum* spp. reducing the long-term carrying capacity of the grassland.

### Gradational association
SWOG is often extensive and grades into *Open bindii grassland* (OBIG), *Pearl bluebush low shrubland* (PBLS) and *Bladder saltbush shrubland* (BSSL). Where soil salinity increases SWOG may grade into *Plain mixed halophytic shrubland* (PXHS) or *Samphire shrubland* (SAMP). As eucalypt mallee or myall begin to occur on ridges and rises SWOG grades into *Eucalypt, speargrass open grassland* (ESOG) or *Myall, speargrass open grassland* (MSOG).

### Land systems
SWOG is the dominant habitat type on Nightshade land system, a major type on Bullseye, Carlisle, Chowilla, Gafa, Kybo, Oasis, Nurina, Shakehole and Skink land systems and a minor habitat type on Culver, Jubilee, Kitchener, Kyarra, Moonera, Morris, Nanambinia, Nyanga, Rabbit, Reid, Thampanna and Woorlba land systems.

### 35. Annual herbland (ANNH)

#### Sampling
7 inventory sites, 28 traverse points

#### General information
ANNH is located in areas receiving local drainage such as the claypans and clay plains. Occurring throughout the Nullarbor Plain, such drainage areas are more common in the north, becoming less frequent in the south. Soils are red/brown non-cracking clays.

#### Physiognomy and composition of vegetation
ANNH occurs as a very scattered to scattered (2.5–15 per cent PFC) herbland of perennial and annual herbs and grasses.

28 perennial species were recorded at the seven inventory sites, with an average of six species per site, five less than the survey average. 20 annual species were recorded, with an average of seven species per site.

The following species (by stratum) are dominant and/or common:

**Trees:**
- Dominant—Not present as a recognisable stratum
- Occasional—*Eremophila longifolia*, *Pittosporum angustifolium*.

**Tall shrubs:**
- Dominant—Not present as a recognisable stratum
Occasional—Acacia tetragonophylla.

**Low shrubs:**
Dominant—Not present as a recognisable stratum
Occasional—Atriplex cryptocarpa, A. vesicaria, Chenopodium curvispicatum, Enchylaena tomentosa, Maireana turbinata, Olearia calarea, Westringia rigida.

**Subshrubs:**
Dominant—Sclerolaena patenticuspis (KI)
Common—Atriplex acutibractea (KI), Sclerolaena obliquicuspis (KI), Sida spodochroma
Others—Cullen cinereum, Eriochiton sclerolaenoides (KD), Maireana trichoptera (KD), Sclerolaena brevifolia, S. diacantha (KD), Solanum ellipticum, Swainsona affinis, S. formosa.

**Perennial grasses:**
Dominant—Austrostipa scabra
Common—Austrodanthonia caespitosa (KD)
Others—Austrostipa drummondii, Enneapogon cylindricus (KD), Eragrostis dielsii.

**Other plant forms:**
Occasional—Glycine rubiginosa (creeper).

Annual species recorded include Angianthus conocephalus, Asteridea athrixioides, Calotis multicaulis, Carrichtera annua (KI), Cephalipterum drummondii, Dysphania melanocarpa forma leucocarpa, Erodioptimum elderi, Erodium aureum, Euphorbia drummondii, Goodenia pinnatifida, Lotus cruentus, Malvastrum americanum, Mesembryanthemum crystallinum, Nicotiana occidentalis, Podolepis canescens, Rhodanthe floribunda (KI), Salsola tragus (KI), Sisymbrium erysinoideis, Sonchus oleraceus and Zygophyllum iodocarpum (KI).

**Ecological disturbance**

When this vegetation association is in good condition palatable perennial herbs such as Eriochiton sclerolaenoides (woolly bindii), Maireana trichoptera (pink-seeded bluebush) and Sclerolaena diacantha (grey bindii) and perennial grasses such as Austrodanthonia caespitosa (wallaby grass) and Enneapogon cylindricus are abundant with good cryptogamic crusting. In overgrazed areas palatable species are replaced by Atriplex acutibractea (toothed saltbush), Carrichtera annua (Ward’s weed), Salsola tragus (roly poly), Sclerolaena obliquicuspis (limestone bindii), S. patenticuspis (spear-fruit copperburr), Rhodanthe floribunda and Zygophyllum iodocarpum and the cryptogamic crust is breaking down or absent. In dry periods these areas are highly susceptible to wind erosion as the annuals and subshrubs die leaving the ground surface exposed.

**Gradational associations**

ANNH is commonly found in low-lying areas such as claypans grading onto marginal slopes of the surrounding stony plains which support low shrubland such as Pearl bluebush low shrubland (PBLS) or their degraded equivalents such as Open bindii grassland (OBIG).

**Land systems**

ANNH is a major habitat type on Kybo land system and a minor habitat on Culver, Kinclaven, Oasis, Pondana, Reid and Vanesk land systems.

**H. DRAINAGE FOCI SHRUBLAND**

This group of habitat types usually occurs as small localised drainage foci being the lowest parts in the immediate area, commonly vast undulating plains. These drainage sumps are highly fertile and often support unique vegetation associations such as Donga groves (DOGR), Lignum swamp (LISW) and Gilgai grassy shrubland (GGSL). Most of these habitats are uncommon and make up a very small proportion of the survey area, with the exception of Donga groves which are a common habitat through the north of the Nullarbor Plain.

**36. Donga groves (DOGR)**

**Sampling**
18 inventory sites, 45 traverse points

**General information**

Dongas are predominantly found in the north of the survey area. They are rounded, shallow, closed depressions, generally 1.5–3 m below the surrounding stony plain. Donga arrangement can occur randomly or parallel with neighbouring ridge and corridor relief. They commonly have flat clay floors up to several hundred metres across with gently sloped margins. The whole depression may be up to 2 km in diameter, however generally they are significantly smaller. The clay floors often
contain gilgai or crabhole structure with irregular surfaces. Limestone floaters (boulders and slabs) of mixed size have been bought to the surface by alternating wetting and drying cycles associated with gilgai soils. Boulders and slabs can protrude through up to 10 per cent of donga surfaces. Their formation is believed to have occurred by water run-off ponding in depressions in the limestone plain and solution further dissolving the limestone. Dongas are considered solution dolines rather than collapsed caves (Jennings 1963; Lowry 1970). Soils are variable: commonly they consist of deep red/brown non-cracking clays or cracking clays, less commonly of silty-clay loam often with fine aeolian sand deposits.

The donga floors commonly support a sparse tree cover or clumps of small groves over a variety of perennial shrubs, annual herbs and grasses. Dongas are some of the most pastorally productive land units in the survey area. In the pastoral areas water point location is commonly associated with dongas, to the detriment of the associated vegetation. Donga groves serve an important role in ‘arid proofing’ the northern Nullarbor as a source of browse to be protected for dry periods. The close spacing of water points in dongas and the preferential grazing of the associated vegetation is leading to their deterioration within pastoral boundaries. Mature trees and shrubs are browsed out of reach with no recruitment stages of seedlings or saplings in the lower layers. When these mature trees eventually die, or are killed, there are no younger trees to replace them. The benefits donga groves offer to the local ecosystem, as well as their significant regional ecological value, will be lost.

Donga habitat types were split into four subgroups according to the dominant genus in the tree or tall shrub strata;

- **Donga berrigan grove** (DBGR) consists of small groves of *Eremophila longifolia* (berrigan) interspersed with perennial shrubs of the low to mid strata and a diverse variety of annuals. DBGR occurs predominantly within dongas in the north-west of the survey area.

- **Donga curara grove** (DCGR) consists of stands of *Acacia tetragonophylla* (curara) that form a sparse perimeter around the centre of a donga. DCGR is commonly found in the north-west and central-north of the survey area.

- **Donga grevillea grove** (DGGR) consists of *Grevillea nematophylla* groves with a low shrub understorey surrounded by dense grass patches. DGGR is predominantly found in the north-east of the survey area.

- **Donga pittosporum grove** (DPGR) consists of scattered stands of *Pittosporum angustifolium* (native willow) surrounded by dense grass patches. DPGR is commonly found in dongas in the north-east of the survey area.

In many instances, dongas contain trees or tall shrub species from all varieties of donga grove habitats. The differences occur in the density within the tall, mid and low shrub strata.

**Physiognomy and composition of vegetation**

**Donga berrigan grove** (DBGR) consists of scattered to very scattered (2.5–15 per cent PFC) stands of *Eremophila longifolia* (berrigan) occupying a central location within the donga. Very scattered (5–10 per cent PFC) *Lycium australic* (water bush) or scattered to moderately closed (10–25 per cent PFC) *Atriplex cryptocarpa* commonly surround these berrigan groves. *Austrostipa scabra* (speargrass) commonly dominates the perennial grasses.

**Donga curara grove** (DCGR) is predominantly vegetated with perennial grasses and annuals in the centre of the donga. The perimeter of these dongas support very scattered to scattered (2.5–15 per cent PFC) stands of *Acacia tetragonophylla* (curara).

**Donga grevillea grove** (DGGR) consists of a scattered to moderately closed (10–25 per cent PFC) tall shrubland of *Grevillea nematophylla* groves with a low shrub understorey dominated by *Chenopodium curvispicatum* surrounded by dense grass patches of variable composition.

**Donga pittosporum grove** (DPGR) consists of very scattered to scattered (2.5–15 per cent PFC) stands of *Pittosporum angustifolium* (native willow) with a scattered to moderately closed (10–25 per cent PFC) understory of *Chenopodium curvispicatum*. The grove is commonly densely surrounded by grasses of variable composition. Very scattered to scattered (2.5–15 per cent PFC) stands of *Acacia tetragonophylla* (curara) commonly occur on the perimeter.

56 perennial species were recorded at the 18 inventory sites, with an average of 10 species.
per site, one less than the survey average. 27 annual species were recorded with an average of six species per site.

The following species (by strata) are dominant and/or common:

**Trees:**
- Dominant—DBGR: *Eremophila longifolia*
- Dominant—DGGR: *Grevillea nematophylla*
- Occasional—*Acacia salicina* (north-east only)
- Dominant—DPGR: *Pittosporum angustifolium*
- Common—*Eremophila longifolia*, *Pittosporum angustifolium*
- Others—*Acacia aneura*, *Alectryon oleifolius*, *Santalum spicatum*.

**Tall shrubs:**
- Dominant—DCGR: *Acacia tetragonophylla*
- Common—*Acacia tetragonophylla* (KI), *A. oswaldii, Exocarpos aphyllus*.

**Mid shrubs:**
- Dominant—*Lycium australe*
- Common—*Pimelea microcephala, Scaevola spinescens*

**Low shrubs:**
- Dominant—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD)
- Common—*Atriplex cryptocarpa, Lycium australe*
- Others—*Atriplex vesicaria, Maireana radiata, M. sedifolia, M. turbinata, Ptilotus obovatus, Solanum nummularium, Zygophyllum aurantiacum*.

**Subshrubs:**
- Dominant—*Sclerolaena patenticuspis* (KI)
- Common—*Atriplex acutibractea* (KI), *Cullen cinereum, Eriochiton sclerolaenoides, Erodium aureum, Sclerolaena diacantha, S. obliquicuspis, Sida spodochroma*
- Others—*Maireana trichoptera, Malvastrum americanum, Sclerolaena brevifolia*, *Solanum ellipticum, S. nigrum, Teucrium racemosum*.

**Perennial grasses:**
- Dominant—Variable; *Austrostipa scabra, Eragrostis dielsii, E. setifolia*
- Common—*Austrodanthonia caespitosa, Enneapogon cylindricus*
- Others—*Austrostipa platychaeta* (KD), *Enneapogon caerulescens*.

**Other plant forms:**
- Occasional—*Amyema quandang var. quandang* (mistletoe), *Glycine rubiginosa* (creeper), *Marsdenia australis* (creeper).


**Ecological disturbance**

The inward drainage of the surrounding landscape results in soil accumulation and improved soil moisture storage. This provides favourable conditions for plant growth. Donga groves offer shelter, a valuable source of browse and support annual plant growth for longer than other areas, typically stony limestone plains. Animals preferentially visit and graze them. The extra soil moisture-holding capacity of dongas means dongas in good condition can support a diverse variety of perennial trees, shrubs and annual herbs.

In the pastoral areas there has been a tendency for water points to be located in dongas leading to the degradation of the vegetation through continuous grazing and the destruction of bush clumps, as herbivores attracted to the water seek browse and shelter. *Eremophila longifolia, Grevillea nematophylla and Pittosporum angustifolium* are palatable to stock with foliage that persists during dry periods. They provide an important source of browse during dry conditions. In dongas with water points continuous grazing can eventually lead to the trees’ death and reduces the population to only older trees as seedlings and juveniles are eaten.
The dominant genera that differentiate donga habitat types and form the structural nuclei around which donga groves develop are referred to as ‘tree-based clumps’. Bush clumps are partly developed by frugivorous birds dispersing the seeds of berry-fruited plants such as Chenopodium curvispicatum, Enchylaena tomentosa (ruby saltbush) and Rhagodia species. These clumps offer important habitat refuges in these exposed and arid landscapes not only to animals but also to other plants, prolonging the life of annuals and subshrubs, that otherwise do not endure the climatic extremes of the Nullarbor as successfully out in the open. The destruction of nuclei trees and the deterioration of understorey clumps reduces the ecological value of donga groves leading to a reduction in the overall carrying capacity of the landscape as it loses ability to support herbivores during dry periods.

The structure and diversity of the tree-based clumps indicates the condition of donga groves. Those in good condition often have an abundance of the palatable grasses Eragrostis dielsii (mallee lovegrass) and E. setifolia (neverfail) surrounding groves over dense clumps of berry-fruited plants. Dongas near water points are regularly degraded. Degraded donga groves lack tree-based clumps, have no bird dispersed palatable berry plants and have prominent browse lines as a result of herbivorous grazing. The abundance of Acacia tetragonophylla-dominated dongas without the development of an understorey through northern pastoral leases indicates the deteriorating condition of donga habitats as a consequence of grazing.

Browsing pressure sequence of dongas dominated by Grevillea nematophylla. As browsing pressure increases the structure and diversity of the groves deteriorates. If grazing pressure does not ease the forage reserve offered by the donga, which herbivores rely on during dry periods, will be lost.
In poor condition, donga groves can be reduced to sparse stands of aged trees surrounded by undesirable short-lived species such as *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward’s weed), *Euphorbia drummondii* (balsam), *Mesembryanthemum crystallinum*, *Nicotiana occidentalis*, *Salsola tragus* (roly poly), *Salvia verbenaca* (wild sage), *Sclerolaena patenticuspis* (spear-fruit copperburr), *Rhodanthe floribunda* and *Zygophyllum iodocarpum*. Considerable soil loss occurs during dry periods as the donga gradually becomes more open and exposed. The increase in unpalatable species is also compounded by the susceptibility of this vegetation association to invasion by exotic species such as the declared weeds *Cardthamus lanatus* (saffron thistle), *Emex australis* (doublegee) and *Xanthium spinosum* (Bathurst burr).

**Gradational associations**

All forms of donga groves grade upslope from the donga floor into stony plains supporting vegetation associations such as *Mixed shrub bindii grassland* (XSBG), *Open bindii grassland* (OBIG) and/or *Pearl bluebush low shrubland* (PBLS). DBGR and DCGR can also grade upslope from the donga into *Mixed shrub bindii grassland* (XSBG).

**Land systems**

- DBGR is a minor habitat type on Balgair, Kanandah, Kitchener, Kybo, Nurina and Nyanga land systems.
- DCGR is a major habitat type on Kinclaven land systems and a minor habitat type on Balgair, Bullseye, Gafa, Kanandah, Kitchener, Kybo, Naretha, Nyanga and Oasis land systems.
- DGGR a major habitat type on Bullseye and Oasis land systems and is a minor habitat type on Carlisle, Jubilee, Kinclaven, Nyanga, Reid and Seemore land systems.
- DPGR is a major habitat type on Oasis land system and a minor habitat type on Carlisle, Bullseye, Gafa, Jubilee, Kyarra, Reid and Skink land systems.

**37. Drainage depression saltbush shrubland (DDSS)**

**Sampling**

1 inventory site, 7 traverse points

**General information**

DDSS occurs in claypans and clay plains in the west of the survey area. DDSS can also occur in narrow drainage tracts associated with ancient river courses. Soils are red/brown non-cracking clays.

**Physiognomy and composition of vegetation**

DDSS comprises a moderately closed (20–25 per cent PFC) low shrubland of *Atriplex* species. *Acacia burkittii* (jam) and *Eremophila longifolia* (berrigan) occur as closed stands or as isolated individuals.

11 perennial species and four annual species were present at the one inventory site. The following species are dominant and/or common:

**Trees:**

- Dominant—Not present as a recognisable stratum
- Occasional—*Eremophila longifolia*, *Pittosporum angustifolium*.

**Tall shrubs:**

- Dominant—Not present as a recognisable stratum
- Common—*Acacia burkittii* (KI)
- Other—*Acacia oswaldii*.

**Low shrubs:**

- Dominant—Variable; *Atriplex cryptocrarpa* (KI)
- Common—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Maireana sedifolia*
- Other—*Solanum nummularium*. 

Curara (*Acacia tetragonophylla*) dominated donga in poor condition. Trampling and grazing have reduced the soil to a loose, powdery surface that is readily deflated by wind.
Subshrubs:
- Dominant—Not present as a recognisable stratum
- Common—Atriplex acutibractea (KI), Sclerolaena patenticuspis (KI)
- Other—Swainsona affinis.

Annual species recorded include Erodium elden, Mesembryanthemum crystallinum, Nicotiana occidentalis (KI) and Sisymbrium erysimoides.

Ecological disturbance

Due to a lack of sampling not much is known of the disturbance mechanisms for DDSS. The low-lying landscape position makes it prone to receiving concentrated flow with potential for greater soil moisture retention. This makes it prone to preferential grazing. Past grazing pressure is likely to have favoured the emergence of more grazing tolerant, less palatable species such as Atriplex acutibractea (toothed saltbush), A. cryptocarpa and Sclerolaena patenticuspis (spear-fruit copperburr).

Tree-based clumps commonly develop around Acacia burkittii (jam), A. oswaldii, Eremophila longifolia (berrigan) and Pittosporum angustifolium (native willow) with bird-dispersed berry-fruited plants common in the understorey. Such palatable shrubs as Chenopodium curvispicatum and Enchylaena tomentosa (ruby saltbush) may decrease under continuous grazing pressure.

Gradational associations

DDSS grades upslope into stony plains supporting Pearl bluebush low shrubland (PBLS).

Land systems

DDSS is a minor habitat type on Naretha and Pondana land systems.

38. Drainage depression mixed shrub shrubland (DDXS)

Sampling

1 inventory site

General information

DDXS occurs in drainage foci at the base of limestone hummocks (low rises) on the Toolinna and Abrakurrie Limestone towards the coast in the south of the survey area. The surface has a sparse (2 per cent) stony mantle of large (20–60 cm) limestone fragments. Soils are light calcareous loams overlain by dark ‘organic’ loams.

Physiognomy and composition of vegetation

DDXS occurs as a scattered (15–20 per cent PFC) tall shrubland of Acacia cyclops (coastal wattle) with very scattered (2.5–5 per cent PFC) Eucalyptusyalatensis (yalata mallee) forming the tree stratum. Acacia cyclops and Eucalyptusyalatensis form bush clumps providing shelter and support for a variety of perennial shrubs.

21 perennial species, including one priority species, and two annual species were recorded at the one inventory site.

The following species (by stratum) were dominant and/or common:

- **Trees:**
  - Dominant—Eucalyptusyalatensis (mallee)
  - Common—Santalum acuminatum.

- **Tall shrubs:**
  - Dominant—Acacia cyclops
  - Common—Templetonia retusa, Exocarpos sparteus.

- **Mid shrubs:**
  - Dominant—Not present as a recognisable stratum
  - Common—Acacia aniceps, Scaevola spinescens,

- **Low shrubs:**
  - Dominant—Not present as a recognisable stratum
  - Common—Acacia erinacea, Enchylaena tomentosa, Rhagodia crassifolia
  - Others—Acrotricha patula, Eremophila decipiens subsp. decipiens.

- **Subshrubs:**
  - Dominant—Not present as a recognisable stratum
  - Common—Heliotropium asperrum, Sclerolaena patenticuspis
  - Other—Opercularia loganioides.

- **Perennial grasses:**
  - Dominant—Not present as a recognisable stratum
  - Common—Austrodanthonia caespitosa.

- **Other plant forms:**
  - Common—Billardiera fusiformis (creep), Cassytha melantha (creep), Lepidosperma sp.
  - (perennial sedge), Tettraria capillaris (perennial sedge),

Annual species recorded include Euphorbia drummondii and Podolepis canescens.
Ecological disturbance
This habitat occurs outside of pastoral lease boundaries. Insufficient sampling precludes detailed quantitative description of disturbance mechanisms. These areas receive localised water shed from the stony surfaces of the limestone hummocks. In comparison to the surrounding land units these drainage foci have accumulated deeper soils, infrequently being areas with higher soil moisture content supporting subshrubs, *Austrodanthonia caespitosa* (wallaby grass) and annuals. This makes DDXS ecologically important as a preferentially sought after food source for the native herbivores living among the closed low woodland (LOMW) and scrub that dominate the area back from the Baxter Cliffs.

Much of the species diversity in this habitat type is found within the bush clumps under *Acacia cyclops*, *Eucalyptus yalatensis* and tall shrubs. Deterioration in bush clump health is likely to have a significant impact on the floristic diversity of the associated plant community.

*Thysanotus baueri*, a Priority 1 species on the declared rare and priority flora list, was recorded in this habitat. As such these habitat types are considered areas of high conservation value.

Gradational associations
DDXS is surrounded by irregular limestone hummocks supporting *Low mallee woodland* (LOMW).

Land systems
DDXS is a minor habitat on Toolinna land system.

39. Drainage tract acacia shrubland (DRAS)

Sampling
1 inventory site, 5 traverse points

General information
DRAS was previously described in the north-eastern Goldfields survey (Pringle, Van Vreeswyk & Gilligan 1994) as *Drainage mulga shrubland* (DRMS). It was re-described in the Sandstone–Yalgoo–Paynes Find survey (Payne et al. 1998) as DRAS to recognise the prominence of acacias other than *Acacia aneura* (mulga). On the Nullarbor, DRAS is restricted to Rawlinna Station and occurs in both narrow and wide drainage tracts. Some of these shallow drainage lines may represent ancient river courses draining from the north-west. Some drainage tracts feature fine well-worked quartz grains in the soil profile. Soils are calcareous loamy earths.

Physiognomy and composition of vegetation
DRAS occurs as a very scattered (2.5–5 per cent PFC) shrubland of acacias and *Ptilotus obovatus* (cotton bush).

13 perennial species and four annual species were recorded at the one inventory site.

The following species (by strata) were dominant and/or common:

**Trees:**
- Dominant—Not present as a recognisable stratum
- Common—*Acacia aneura*, *Myoporum platycarpum*
- Other—*Santalum spicatum*.

**Tall shrubs:**
- Dominant—*Acacia burkittii* (KI), *A. tetragonophylla*
- Common—Nil.

**Low shrubs:**
- Dominant—*Ptilotus obovatus* (KD)

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Sclerolaena patenticuspis* (KI), *Sida spodochroma*.

**Perennial grasses:**
- Dominant—Not present as a recognisable stratum
- Common—*Austrostipa scabra*, *Enneapogon caerulescens*, *E. cylindricus*.

Annual species recorded include *Carrichtera annua* (KI), *Nicotiana occidentalis*, *Salsola tragus* (KI) and *Sisymbrium erysimoides*.

Ecological disturbance
Insufficient information was obtained for a detailed report on disturbance. From similar occurrences of DRAS from other surveys, overgrazing will cause decline in rangeland condition, resulting in the reduction of palatable perennial shrubs and grasses such as *Enchylaena tomentosa* (ruby saltbush), *Sida calyxhymenia* (tall sida), *Ptilotus obovatus* (cotton bush) and *Enneapogon* species may result. *Santalum spicatum* (sandwalwood) is a
common source of browse; the presence of juveniles indicates improving range condition. Unpalatable species such as *Carrichtera annua* (Ward's weed), *Sclerolaena patenticuspis* (spear-fruit copperburr) and *Salsola tragus* (roly poly) may increase under continuous grazing pressure.

**Gradational associations**

DRAS grades out of the drainage line into the surrounding *Mixed acacia open shrubland* (XAOS).

**Land systems**

DRAS is a minor habitat type on Naretha land system.

40. Gilgai grassy shrubland (GGSL)

**Sampling**

11 inventory sites, 24 traverse points

**General information**

Gilgai formations result from the wetting and drying of clays with high montmorillonite content. Areas with gilgai soils are commonly found in the north of the survey area. Gilgai structures often occur in dongas or at the base of depressions on the limestone plain. In the west of the survey area gilgai structures also occur on the drainage floors of the large depressions within the calcrete Nyanga Plain. Soil heaving associated with wetting and drying cycles of gilgai soils bring limestone rocks to the surface. Limestone debris ranging from coarse fragments to boulders (6–200 cm in diameter) can cover up to 20 per cent of the surface. Soils are cracking clays.

**Physiognomy and composition of vegetation**

GGSL commonly occurs as low shrubs of very scattered (5–10 per cent PFC) *Lycium austral e* (water bush) among dense patches of perennial grass of variable composition. Occasionally, isolated *Eremophila longifolia* (berrigan) or *Pittosporum angustifolium* (native willow) trees are present.

41 perennial species were recorded at the 11 inventory sites, with an average of 13 species per site, two greater than the survey average. 25 annual species were recorded, with an average of nine species per site.

The following species are dominant and/or common:

**Trees:**

Dominant—Nil
Common—Occasionally; *Eremophila longifolia*, *Pittosporum angustifolium* Other—*Acacia papyrocarpa*.

**Tall shrubs:**

Dominant—Not present as a recognisable stratum
Common—*Acacia oswaldii*, *A. tetragonophylla* (KI).

**Mid shrubs:**

Dominant—Not present as a recognisable stratum
Common—*Atriplex nummularia*, *Eremophila maculata*, *Nitraria billardi eri* Others—*Pimelea microcephala*, *Scaevola spinescens*, *Senna artemisioides* subsp. x *artemisioides* (KI), *S. artemisioides* subsp. x *coriacea* (KI).

**Low shrubs:**

Dominant—*Lycium austral e*
Common—*Atriplex vesicaria*, *Chenopodium curvispicatum*, *Enchylaena tomentosa*, *Maireana radiata*, *M. sedifolia* Others—*Atriplex cryptocarpa*, *Zygophyllum aurantiacum*.

**Subshrubs:**

Dominant—Not present as a recognisable stratum
Common—*Atriplex acutibactrea* (KI), *Cullen cinereum*, *Eriochiton sclerolaenoides*, *Sclerolaena diacantha*, *S. obliquicuspis*, *S. patenticuspis*, *Sida spodochroma*, *Solanum ellipticum* Others—*Erodium aureum*, *Maireana trichoptera*, *Sida intricata*, *Swainsona affinis*.

**Perennial grasses:**


**Other plant forms:**

Occasional—*Glycine rubiginosa* (creeper), *Marsdenia australis* (creeper).

Annual species recorded include *Angianthus conocephala*, *Brachyscome sp.*, *Calotis multicaulis*, *Carrichtera annua* (KI), *Centaurium erythraea*, *Chenopodium murale*, *Citrullus lanatus*, *Dysphania*
melanocarpa, Erodium cygnorum, Euphorbia drummondii, Goodenia pinnatifida, Lepidium sp., Lotus cruentus, Malva preissiana, Mesembryanthemum crystallinum (Ki), M. nodiflorum, Nicotiana goodspeedii, N. occidentalis (Ki), Oxalis corniculata, Podolestes canescens, Rhodanthe floribunda (Ki), Salsola tragus (Ki), Sisymbrium erysiioides, Vittadinia sp. and Zygophyllum iodocarpum (Ki).

Ecological disturbance
Due to the landscape position of GGSL as drainage foci and the potential to retain soil moisture for longer periods than the surrounding stony plains, this vegetation association supports an abundance of short-lived species. GGSL is preferentially grazed due to the abundance of palatable grasses it supports, particularly *Eragrostis* species. Under continuous heavy grazing the palatable grasses *Austrodanthonia caespitosa* (wallaby grass), *Eragrostis dielsii* (mallee lovegrass) and *E. setifolia* (neverfail) decline and are replaced by less palatable grasses and annuals. GGSL is also susceptible to invasion by exotic species.

Gradational associations
GGSL grades into *Open bindii grassland* (OBIG), *Mixed shrub bindii grassland* (XSBG) and *Pearl bluebush low shrubland* (PBLS) on the surrounding stony limestone plains.

Land systems
GGSL is a major habitat type on Nurina land system and a minor habitat type on Balgair, Jubilee, Kanandah, Kinclaven, Koonjarra, Nyanga and Seemore land systems.

41. Lignum swamp (LISW)

Sampling
4 inventory sites

General information
LISW was previously described as a minor habitat type in the Sandstone–Yalgoo–Paynes Find survey area (Payne et al. 1998). LISW occurs within areas where water inundation occurs periodically such as in claypans, low-lying areas of karst depressions (‘corridors’ and dongas) and in ancient river courses. These areas sometimes have gilgai structure with *Muehlenbeckia florulenta* (lignum) distributed according to the micro-relief, preferring the raised areas. Soils are calcareous loamy earths and cracking clays where gilgai are present.

LISW occurs occasionally and is found randomly through the survey area dependent on local topography in areas subject to inundation.

Physiognomy and composition of vegetation
LISW is dominated by a very scattered to scattered (5–20 per cent PFC) shrubland of *Muehlenbeckia florulenta*. Species that can cope with temporary inundation such as *Marsilea hirsuta* (Nardoo) and *Rhipogodium ulicina* are common. *Muehlenbeckia florulenta* grows in closed communities with few other plants.

22 perennial species were recorded at the four inventory sites, with an average of seven species per site, four less than the survey average. 15 annual species were recorded, with an average of six species per site.

The following species (by strata) were dominant and/or common:

**Mid shrubs**: Dominant—*Muehlenbeckia florulenta*  Other—*Nitraria billardiarii*.

**Low shrubs**: Dominant—Not present as a recognisable stratum  Common—*Rhipogodium ulicina*  Others—*Atriplex vesicaria*, *Enchylaena tomentosa*, *Lycium australie*, *Maireana sedifolia*, *Rhipogodium crassifolia*.

**Subshrubs**: Dominant—Not present as a recognisable stratum  Common—*Atriplex acutibractea*  Others—*Cullen cinereum*, *Maireana trichoptera*, *Sclerolaena obliquicuspis*, *S. patenticuspis*, *Solanum ellipticum*, *S. nigrum*, *Swainsona affinis*.


**Other plant forms**: Common—*Marsilea hirsuta* (fern).

Annual species recorded include *Carrichtera annua* (Ki), *Centarea melitensis*, *Chenopodium murale*, *Citrullus lanatus*, *Eriachne sp.*, *Goodenia pinnatifida*, *Isolepis congrua*, *Medicago sp.*, *Menkea sp.*, *Mesembryanthemum crystallinum* (Ki), *Nicotiana occidentalis* (Ki), *Rhodanthe floribunda*, *Senecio sp.*, *Sonchus oleraceus* and *Zygophyllum iodocarpum* (Ki).
Ecological disturbance

*Muehlenbeckia florulenta* is rarely eaten and has very low forage value. The palatable grasses *Eragrostis dielsii* (mallee lovegrass) and *E. setifolia* (neverfail) may decline under continuous grazing pressure.

**Gradational association**

LISW has defined boundaries dependent on local topography being confined to areas subject to periodic inundation. It is commonly surrounded by *Pearl bluebush low shrubland* (PBLS) or *Bladder saltbush shrubland* (BSSL).

**Land systems**

LISW is a minor habitat type on Bullseye, Gafa, Kinclaven, Koonjarra and Nyanga land systems.

42. Plain mixed low shrubland (PXLS)

**Sampling**

2 inventory sites, 3 traverse points

**General information**

PXLS occurs in clay depressions to the south of the survey area. Soils are calcareous loamy earths and red/brown non-cracking clays.

**Physiognomy and composition of vegetation**

PXLS comprises scattered (10–15 per cent PFC) mid shrubland dominated by *Eremophila* species.

30 perennial species were recorded at the two inventory sites, with an average of 17 species per site, six greater than the survey average. Six annual species were recorded with an average of three species per site.

The following species (by strata) were dominant and/or common:

**Tall shrubs:**

Dominant—Not present as a recognisable stratum
Common—*Acacia cyclops*, *Geijera linearifolia*
Other—*Exocarpos aphyllus*.

**Mid shrubs:**

Dominant—*Eremophila decipiens* (KI), *E. deserti*
Common—*Atriplex nummularia*, *Nitraria billardieri*
Others—*Leptomemia pachyclada*, *Solanum symonii*.

**Low shrubs:**

Dominant—Occasionally;
*Lawrenzia squamata* (KI)

**Subshrubs:**

Dominant—Not present as a recognisable stratum
Common—*Sclerolaena diacantha* (KD), *Sida spodochroma*
Others—*Hypoxis glabella* var. *glabella*, *Minuria cunninghamii*, *Senecio quadridentatus*, *Solanum nigrum*, *Wahlenbergia communis*, *Wurmbea tenella*.

**Perennial grasses:**

Dominant—*Austrodanthonia caespitosa* (KD), *Austrostipa scabra*
Common—*Austrostipa elegantissima* (KD), *A. platychaeta* (KD).

**Other plant forms:**

Occasional—*Cassytha melantha* (creeper).

Annual species recorded include *Anagallis arvensis*, *Carduus nutans*, *Erodium cicutarium*, *Nicotiana goodspeedii*, *Sonchus oleraceus* and *Xanthium spinosum*.

Ecological disturbance

This vegetation association was insufficiently sampled to obtain detailed quantitative information regarding disturbance characteristics. Overgrazing of PXLS is likely to result in a decline in palatable shrubs such as *Enchylaena tomentosa* (ruby saltbush) and *Sclerolaena diacantha* (grey bindii), and the perennial grasses *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa elegantissima* (feather speargrass) and *A. platychaeta*.

**Gradational associations**

PXLS changes abruptly into the surrounding *Low mallee woodland* (LOMW) and *Eucalypt mixed scrub woodland* (EXSW) at the boundary of the karst depression and the resumption of the stony calcrite plain.

**Land systems**

PXLS is a minor habitat type on Caiguna and Culver land systems.
I. SHRUBLAND AND WOODLAND ON LAKE MARGINS AND SALINE DEPRESSIONS

This group of habitat types is generally confined to the margins of lake beds or occurs in saline low-lying closed or open depressions within undulating plains. Occurring on saline and gypsiferous soils, these habitat types characteristically support halophytic plants, such as species of Tecticornia (samphire) and Frankenia (frankenia). They make up a small proportion of the survey area.

43. Kopi dune woodland (KOPI)

Sampling
2 inventory sites, 8 traverse points

General information
KOPI has previously been described in the north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994) and the Sandstone—Yalgoo—Paynes Find (Payne et al. 1998) survey areas. KOPI occurs on the kopi dunes surrounding Lake Boonderoo, fringing Ponton Creek and salt lakes in the very south-west of the survey area. Kopi dunes form by prevailing winds deflating lake beds and building up powdery dunes of gypsum around the lake margins. The dunes have gently inclined slopes of up to 3 per cent and coarse (2–6 cm) limestone fragments are common on the surface. Soils are calcareous loamy earths.

Physiognomy and composition of vegetation
KOPI occurs as a scattered (10–20 per cent PFC) low shrubland of Tecticornia species (samphire) and Chenopodium curvispicatum. The overstorey consists of very scattered (2.5–5 per cent PFC) Casuarina pauper (black oak). In the south-west of the survey area Eucalyptus species are also present on kopi dunes alongside Casuarina pauper. Around Lake Boonderoo many trees are dead as a result of inundation when the water level increased following Cyclone Bobby in 1995. Areas supporting this vegetation around Lake Boonderoo are now in a state of ecological transition as water levels subside.

31 perennial species were recorded at the two inventory sites, with an average of 16 species per site, five greater than the survey average.

Three annual species were recorded at one site.

The following species (by strata) were dominant and/or common:

- **Trees:**
  - Dominant—Casuarina pauper
  - Common—Myoporum platycarpum, Eucalyptus concinna, E. conglobata.

- **Tall shrubs:**
  - Dominant—Not present as a recognisable stratum
  - Common—Senna arteisioides subsp. x coriacea
  - Others—Acacia ligulata, Geijera linearifolia.

- **Mid shrubs:**
  - Dominant—Not present as a recognisable stratum
  - Common—Atriplex nummularia, Cratylysis conocephala, Eremophila scoparia
  - Others—Acacia nyssophylla, Dodonaeae lobulata.

- **Low shrubs:**
  - Dominant—Chenopodium curvispicatum (KD), Tecticornia doleiformis, Tecticornia sp.
  - Common—Atriplex vesicaria (KD), Disphyma crassifolium, Enchylyena tomentosa (KD), Frankenia densa, Lycium australis, Maireana erioclada, Olearia ramosissima, Rhagodia crassifolia (KD), Zygophyllum aurantiacum.

- **Subshrubs:**
  - Dominant—Not present as a recognisable stratum
  - Common—Maireana trichoptera, Sclerolaena diacantha (KD), S. obliquicuspis, S. patenticuspis.

- **Perennial grasses:**
  - Dominant—Not present as a recognisable stratum
  - Common—Austrodanthonia caespitosa, Austrostipa scabra.

- **Other plant forms:**
  - Occasional—Dianella revoluta (lily).

Annual species recorded include Carrichtera annua, Eriachne sp. and Zygophyllum glaucum.

Ecological disturbance
Inundation due to the associated effects of Cyclone Bobby in 1995 dramatically altered the composition and structure of Lake Boonderoo KOPI. Much of the casuarina woodland surrounding the lake has died and is now in a state of transition as water levels subside. The high soil salinity is influencing the vegetation colonisation sequence.
After infrequent periods of inundation Lake Boonderoo is known to contain fresh water, however during the survey period the water was highly saline due to the concentration of salts through evaporation. Grazing impact will be determined by the quality of nearby drinking water. If the quality of drinking water is fresh then continuous grazing may result and a decline in the palatable shrubs *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush), *Maireana trichoptera* (pink-seeded bluebush), *Rhagodia crassifolia* and *Sclerolaena diacantha* (grey bindii) could be expected. However the absence of these species from an area may be natural rather than as a result of grazing.

**Gradational association**

Sloping down to the margin of Lake Boonderoo, KOPI grades into *Samphire shrubland* (SAMP) and/or *Plain mixed halophyte shrubland* (PXHS) dominated by *Atriplex* and *Tecticornia* species.

**Land systems**

KOPI is a minor habitat type on Boonderoo, Lefroy and Ponton land systems.

44. **Sandy bank lake shrubland (SBLS)**

**Sampling**

2 inventory sites

**General information**

SBLS has been previously described in the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994) and the Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) survey areas. It occurs on sandy banks adjacent to bare lake beds. The formation of the sandy banks is due to a combination of transported sandy sediment via prevailing winds, infrequent lake inundation and by high energy sheet flow from landforms adjacent to and above the sandy slopes. Soils are generally deep red sands.

The banks support two different floristic components: non-halophytic species such as *Acacia* spp., *Casuarina pauper* (black oak), *Eucalyptus* spp. and *Triodia scariosa* (spinifex); and chenopod species such as *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush), *Maireana sedifolia* (pearl bluebush) and *Rhagodia* spp. The morphology of the sandy banks appears to influence the proportion of non-halophytic shrubs to halophytic shrubs occurring adjacent to SBLS on the Boonderoo lake bed. These red, deep sandy soils provide the associated vegetation with increased water availability through enhanced infiltration, deeper storage and reduced evaporation rates.

**Physiognomy and composition of vegetation**

SBLS consists of a non-halophytic component which generally is more prominent on the upper banks. Chenopods become more abundant on the lower banks and bank margins, possibly due to the development of duplex soils and increasing soil salinity associated with the proximity to Lake Boonderoo. This variability is observed in the range of composition and form of this vegetation type.

SBLS occurs as a closed (30–50 per cent PFC) tall shrubland, commonly dominated by species of acacia, such as *Acacia ligulata* (umbrella bush). The tree component is variable, the species composition often reflecting a transition from adjacent habitats. Low shrubs are prominent and perennial grasses such as *Triodia scariosa* (spinifex) vary from common to absent.

21 perennial species were recorded at the two inventory sites.

The following species (by strata) are dominant and/or common:

**Trees:**

Dominant—Not present as a recognisable stratum

Common—*Casuarina pauper*, *Eucalyptus concinna*, *E. sp.*

Fraser Range

Others—*Myoporum platycarpum*, *Psydrax attenuata*.

**Tall shrubs:**

Dominant—*Acacia ligulata*

Common—*Eremophila dempsteri*.

**Mid shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Eremophila latrobei* subsp. *glabra*

Others—*Grevillea sp.*, *Rhagodia preissii* subsp. *preissii* (KD), *Senna* sp.

**Low shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Atriplex vesicaria* (KD), *Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Maireana sedifolia*, *Ptilotus obovatus*, *P. lateralis*.
Rhagodia ulicina (KD), Solanum nummularium.

**Subshrubs:**
Dominant—Not present as a recognisable stratum
Common—Maireana trichoptera.

**Perennial grasses:**
Dominant—Not present as a recognisable stratum
Common—Triodia scariosa.

**Other plant forms:**
Occasional—Marsdenia australis (creeper).

Only one annual (Eriachne sp.) was observed at the time of sampling, however it should be noted that the area was in a dry period.

**Ecological disturbance**
Insufficient information was obtained for a qualitative assessment of disturbance mechanisms. The most noticeable indicators of grazing impact in SBLS would be in the palatable low shrub component where pastures become more saline. Under heavy grazing the palatable shrubs Atriplex vesicaria (bladder saltbush), Chenopodium curvispicatum, Enchylaena tomentosa (ruby saltbush), Maireana trichoptera (pink-seeded bluebush) and Rhagodia spp. may decline. However, the absence of these species may not be as a result of grazing and may reflect natural variability in species composition.

**Gradational associations**
SBLS grades upslope on to calcrete plains overlain by sand supporting Mallee hummock grass (spinifex) woodland (MHGW). The lower slopes of sandy banks are usually clearly defined as the adjacent halophytic plant communities, Plain mixed halophyte shrubland (PXHS), associated with Lake Boonderoo replace the non-halophytic species.

**Land systems**
SBLS is a minor habitat type on Boonderoo and Ponton land systems.

45. Plain mixed halophyte shrubland (PXHS)

**Sampling**
27 inventory sites, 316 traverse points

**General information**
PXHS has previously been described in the north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994), Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) and Pilbara (Van Vreeswyk et al. 2004) survey areas. It was also described in the Murchison survey area (Curry et al. 1994) as Mixed halophyte shrubland (MXHS). PXHS commonly occurs in saline depressions on marginal slopes or within drainage floors and in clay depressions between gently undulating plains. It also occurs on lake beds and margins. Soils are calcareous loamy earths or red/brown non-cracking clays. Where present at lake bed margins soils may be saline wet soils or red deep sands. It is found throughout the survey area.

**Physiognomy and composition of vegetation**
PXHS exists as a scattered to moderately closed (10–25 per cent PFC) low shrubland of Atriplex vesicaria (bladder saltbush), Maireana sedifolia (pearl bluebush) and Tecticornia species (samphire).

68 perennial species were recorded at the 27 inventory sites, with an average of 11 species per site, the survey average. 22 annual species were recorded, with an average of three species per site.

The following species (by strata) were dominant and/or common:

**Trees:**
Dominant—Not present as a recognisable stratum
Others—Acacia papyrocarpa, Eucalyptus gracilis, Melaleuca quadrifaria, Myoporum platycarpum, Pittosporum angustifolium, Santalum acuminatum, Tamarix aphylla.

**Tall shrubs:**
Dominant—Not present as a recognisable stratum
Others—Exocarpus aphyllus, Geijera linearifolia.

**Mid shrubs:**
Dominant—Occasionally: Atriplex nummularia
Common—Cratevulis conocephala, Nitraria billardiarei
Others—Eremophila decipiens (KI), E. deserti, E. scoparia (KI), Scaevola spinescens, Senna artemisioides subsp. x artemisioides (KI), S. artemisioides subsp. x coriacea (KI).

**Low shrubs:**
Dominant—Atriplex vesicaria (KD), Maireana sedifolia, Tecticornia doleiformis, Tecticornia sp.
Common—Atriplex cryptocarpa,
A. stipitata, Enchyelaena tomentosa (KD), Frankenia densa, Gunniopsis calcarea, Lawrenzia squamata, Lycium australae, Maireana erioclada, M. georgei (KD), M. oppositifolia, M. turbinata, Nitraria billardierei
Others—Chenopodium curvispicatum (KD), Cratystylis subsinuata (KD), Disphyma crassifolium, Gunniopsis quadrifida, Olearia calcarea, O. muelleri, Rhagodia crassifolia, R. ulicina, Solanum nummularium, Westringia rigida.

**Ecological disturbance**

The low-lying landscape position can improve growing conditions for plants by providing areas with longer higher soil moisture retention. This can lead to an abundance in subshrubs and annuals, which in turn can lead to preferential grazing by herbivores. If good quality water is available grazing pressure can lead to reductions in palatable plants. Where PXHS has previously been described (Curry et al. 1994; Pringle, Vreeswyk & Gilligan 1994; Payne et al. 1998; Van Vreeswyk et al. 2004) it was found that the most sensitive indicator of grazing impact was the prominence of key decreaser species and, to a lesser extent, increaser species. Under heavy grazing pressure palatable shrubs that tend to decrease include Atriplex vesicaria, Chenopodium curvispicatum, Enchyelaena tomentosa (ruby saltbush), Eriochiton sclerolaenoides (woolly bindii), Maireana tomentosa (felty bluebush), M. trichoptera (pink-seeded bluebush) and Sclerolaena diacantha (grey bindii). With the loss of palatable species Tecticornia spp. (samphire) can become dominant. Other increaser plants include species of Senna and Eremophila. If unpalatable subshrubs such as Atriplex acutibractea (toothed saltbush), Sclerolaena densiflora (grey bindii), S. obliquicuspis (limestone bindii) and S. patenticuspis (spear-fruit copperburr) occur in abundance repeatedly each year then an area is also considered to be in poor condition.

The saline nature of the subsoil makes it susceptible to scald development. As scalds begin to coalesce the capacity of the area to support plant growth is reduced. Loss of perennial species and scald development can result in accelerated soil loss through wind erosion.

The declared weeds Tamarix aphylla (athel pine) and Xanthium spinosum (Bathurst burr) were recorded at this habitat type.

**Gradational associations**

As the subsoil becomes less saline PXHS commonly grades into Bladder saltbush shrubland (BSSL) and Speargrass and wallaby grass open grassland (SWOG). Where kopi or sandy dunes surround Lake Boonderoo and the salt lakes of the Lefroy land system or fringe Ponton Creek, PXHS is bordered by Kopi dune woodland (KOPI) or Sandy bank lake shrubland (SBLS). As eucalypt or myall species start to appear but soils remain saline PXHS grades
into *Eucalypt mixed halophyte shrubland* (EXHS) or *Myall mixed halophyte shrubland* (MHXS). PXHS depressions are commonly surrounded by *Pearl bluebush low shrubland* (PBLS) or less commonly in the south-east by *Myall saltbush shrubland or woodland* (MSAS).

**Land systems**

PXHS is a major habitat type on Boonderoo, Damper, Vanesk and Virginia land systems and a minor habitat on Arubiddy, Caiguna, Chowilla, Nanambinia, Nightshade, Ponton, Reid, Shakehole, Thampanna and Woorlba land systems.

46. **Samphire shrubland (SAMP)**

**Sampling**

5 inventory sites, 29 traverse points

**General information**

SAMP was previously described in the Carnarvon Basin (Payne, Curry & Spencer 1987), north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994), Murchison River catchment (Curry et al. 1994) and Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) surveys. SAMP is associated with highly saline, gypsiferous soils fringing the lake beds in the south-west of the survey area. It is also found on the Roe Plains on the Damper land system and in saline depressions between gentle undulations in the south on the Bunda Plateau. Soils are calcareous shallow loams and loamy earths, and red/brown non-cracking clays.

**Physiognomy and composition of vegetation**

SAMP comprises a low shrubland of very scattered to scattered (5–20 per cent PFC) *Tecticornia* species (samphire).

15 perennial species were recorded at the five inventory sites, with an average of five species per site, six less than the survey average. Five annual species were recorded, with an average of two species per site.

The following species (by strata) are dominant and/or common:

**Mid shrubs:**
- Dominant—Not present as a recognisable stratum
- Other—*Nitraria billardierei*.

**Low shrubs:**
- Dominant—*Tecticornia disarticulata, T. doleiformis*
- Common—*Atriplex vesicaria* (KD), *Lawrencia squamata, Maireana erioclada, M. oppositifolia*
- Others—*Frankenia densa, Guniopsis calcarea, Kippistia suecidifolia*.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Sclerolaena diacantha* (KD)
- Other—*Lawrencia spicata*.

**Perennial grasses:**
- Dominant—Not present as a recognisable stratum
- Others—*Austrostipa scabra*.

**Other plant forms:**
- Occasional—*Carpobrotus modestus* (succulent perennial herb), *C. virescens* (succulent perennial herb).

Annual species recorded include *Brachyscome ciliaris, Lepidium sp., Senecio pinnatifolius, Sonchus oleraceus and Trichanthodium skiriophorum*.

**Ecological disturbance**

Due to the high salt content of most plants, predominantly samphires, the habitat type is resilient to grazing. Pringle, Van Vreeswyk and Gilligan (1994) noted stock preferred other less saline pastures where available, unless nearby water supplies are fresh and there is little else to eat. Some of the more palatable species such as *Atriplex vesicaria* (bladder saltbush) and *Sclerolaena diacantha* (grey bindii), comprising a minor component of this vegetation association, may be removed through grazing, though this is not a reliable indicator of condition as such species can be absent from ungrazed areas.

**Gradational associations**

SAMP populations associated with lake systems in the south-west of the survey area are commonly surrounded by *Kopi dune woodland* (KOPI) or *Sandy bank lake shrubland* (SBLS). Elsewhere SAMP commonly grades upslope to *Speargrass and wallaby grass open grassland* (SWOG) or *Plain mixed chenopod shrubland* (PXCS).

**Land systems**

SAMP is the dominant habitat type on Damper land system and a minor habitat type on Boonderoo, Lefroy and Ponton land systems.
J. COASTAL ZONE SCRUBLAND AND WOODLAND

The habitat types in this group predominantly occur on aeolian sand sheets and dunes, in various stages of stabilisation, along the coastline of the Great Australian Bight in the south of the survey area. These coastal habitats tend to grade inland coastward from eucalyptus–melaleuca woodland into eucalypt mallee woodland and finally develop into scrubland and coastal heath at the coast. This gradational pattern corresponds with increasing depth of sand associated with dune development and structural modifications and adaptations related to coastal influences.

47. Eucalypt, melaleuca mixed chenopod shrubland or woodland (EMCW)

Sampling

9 inventory sites, 8 traverse points

General information

EMCW commonly occurs on the steep stony slope (up to 30 per cent) of the Hampton Scarp. Limestone colluvial debris (2–60 cm) covers up to 90 per cent of the scree slope; up to 50 per cent of the area can have scarp outcrop protruding through it. EMCW also occurs on the Roe Plains where a scattered mantle of mixed-sized calcareous gravel (0.2–6 cm) can cover up to 10 per cent of the surface. Soils are calcareous loamy earths and shallow loams.

Physiognomy and composition of vegetation

EMCW consists of a scattered (10–20 per cent PFC) low woodland or shrubland. The tree stratum is composed of mallee-form eucalypts of variable species but *Eucalyptus brachycalyx* (gilja), *E. gracilis* (yorrell) and *E. oleosa* subsp. *ampliata* dominate. The tall shrub stratum is dominated by *Melaleuca lanceolata* (Rottnest tea-tree), the mid shrub stratum by *Cratystylis conconeaphala* (false bluebush) and the low shrub stratum by *Atriplex vesicaria* (bladder saltbush) and/or *Maireana erioclada*.

58 perennial species were recorded at the nine inventory sites, with an average of 16 perennial species per site, five greater than the survey average. 11 annual species were recorded, with an average of three species per site.

The following species (by stratum) were dominant and/or common:

**Trees:**
- Dominant—Variable; *Eucalyptus brachycalyx* (mallee), *E. gracilis* (mallee), *E. oleosa* subsp. *ampliata* (mallee)
- Common—*Eucalyptus conglobata* (mallee), *E. oleosa* subsp. *oleosa* (mallee), *E. yalatensis* (mallee), *Myoporum platycarpum*
- Others—*Acacia papyrocarpa*, *Eucalyptus discreta* (mallee), *E. diversifolia* (mallee), *Pittosporum angustifolium*, *Santalum spicatum*.

**Tall shrubs:**
- Dominant—*Melaleuca lanceolata*
- Common—*Melaleuca quadrifaria*, *Exocarpos aphyllus*, *Geijera lineatifolia*
- Others—*Eremophila alternifolia* (Templetonia refusa).

**Mid shrubs:**
- Dominant—*Cratystylis conconeaphala*
- Common—*Atriplex nummularia*, *Eremophila glabra*, *Nitraria billardierei*
- Others—*Dodonaea stenozygia*, *Eremophila deserti*, *E. glabra*.

**Low shrubs:**
- Dominant—*Atriplex vesicaria* (KD), *Maireana erioclada*
- Common—*Enchylaena tomentosa*, *Lycium australis*, *Olearia calcarea*, *Rhadodia cressifolia*, *Zygophyllum aurantiacum*
- Others—*Eremophila weldii*, *Frankenia sessilis*, *Maireana georgei* (KD), *M. radiata*, *M. sedifolia*, *Olearia ramosissima*, *Ptilotus obovatus*, *P. symonii*, *Tecticornia sp.*, *Westringia rigida*.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Common—*Maireana tomentosa* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis*, *S. patenticuspis*, *Tetragonia implexicoma*
- Others—*Eriochiton sclerolaenoides* (KD), *Maireana trichoptera* (KD), *Sclerolaena densiflora*, *Zygophyllum apiculatum*.
**Perennial grasses:** Dominant—Not present as a recognisable stratum
Common—Austrostipa platychaeta (KD), A. scabra
Others—Austrodanthonia caespitosa (KD), Austrostipa drummondii, A. elegantissima (KD).

**Other plant forms:** Occasional—Carpobrotus modestus (succulent perennial herb), Dianella revoluta (lily).

Annual species recorded include Asteridea athrixioides, Aristida sp., Brachyscome ciliaris, B. lineariloba, Carrichtera annua, Erodium sp., Euphorbia drummondii, Rostraria pumila, Sonchus oleraceus, Zygophyllum glaucum and Z. ovatum.

**Ecological disturbance**
EMCW commonly occurs adjacent to areas that are actively grazed and are not preferentially sought after. However, heavy grazing will result in a reduction of palatable low shrubs and grasses such as Atriplex vesicaria, Austrostipa platychaeta, A. elegantissima, Austrodanthonia caespitosa, Enchylaena tomentosa, Eriochiton sclerolaenoides, Maireana trichoptera, M. tomentosa and Sclerolaena diacantha.

**Gradational associations**
EMCW grades into Eucalypt melaleuca woodland (EMEW) where the chenopod component becomes sparse and the tree stratum becomes denser and closed. In other areas EMCW tends to have a defined boundary such as where these woodland areas lie adjacent to chenopod shrubland, commonly Plain mixed chenopod shrubland (PXCS), or where stabilised dunes support a heath understorey such as Eucalypt heath woodland (EHEW) or Eucalypt coastal heath woodland (ECHW).

**Land systems**
EMCW is a major habitat type on Roe land system and a minor habitat type on Thampanna and Wurrengoodyea land systems.

**48. Eucalypt, melaleuca woodland (EMEW)**

**Sampling**
20 inventory sites, 81 traverse points

**General information**
EMEW predominantly occurs on the calcarenite Roe Plains. Soils are calcareous loamy earths and calcareous shallow sands. A variable mantle of fine calcareous fragments (2–6 mm) commonly covers less than 10 per cent of the surface, but can cover up to 90 per cent. EMEW is also present in interdune swales of stabilised sand dunes. In the south-east of the survey area EMEW also occurs on residual old dunes now altered to sandy clay and calcarete on the southern edge of the Hampton Tableland behind the Hampton Scarp.

**Physiognomy and composition of vegetation**
EMEW occurs as a scattered to moderately closed (10–30 per cent PFC) low woodland or tall scrubland. The tree stratum is dominated by mallee-form eucalypts of various species and by melaleucas through the tall shrub stratum.

67 perennial species were recorded at the 20 inventory sites, with an average of 11 species per site, the same as the survey average. Seven annual species were recorded with an average of one species per site.

The following species (by strata) were dominant and/or common:

**Trees:**
- Dominant—Variable; Eucalyptus brachycalyx (mallee), E. gracilis (mallee), E. oleosa (mallee), E. oleosa subsp. ampliata (mallee)
- Common—Eucalyptus conglobata (mallee), E. discreta (mallee), E. diversifolia (mallee), E. oleosa subsp. ampiata (mallee), E. urna
- Others—Allocasuarina helmsii, Eucalyptus yalatensis (mallee), Myoporum platycarpum, Santalum acuminatum

**Tall shrubs:**
- Dominant—Melaleuca lanceolata, M. quadrifaria
- Common—Eremophila dempsteri, Exocarpos aphyllus, Geijera linearifolia
- Others—Acacia oswaldii, Templetonia sulcata

**Mid shrubs:**
- Dominant—Occasionally; Cratystylis conexa, Cratystylis conexa, Eremophila dempsteri, Exocarpos aphyllus, Geijera linearifolia
- Others—Acacia oswaldii, A. merrallii, Alyxia buxifolia, Dodonaea bursarifolia
D. stenozyga, Eremophila decipiens, Nitraria billardierei, Scaevola spinescens.

Low shrubs: Dominant—Olearia calcarea
Common—Atriplex vesicaria, Enchylaena tomentosa, Eremophila weldii, Maireana erioclada, Rhagodia crassifolia, Westringia rigida, Zygophyllum aurantiacum
Others—Acacia erinacea, Atriplex isatidea, Eremophila oblonga, E. parvifolia, Frankenia densa, Gunniopsis calcaria, Maireana, Scaevola pauciflora, Tecticornia sp.

Subshrubs: Dominant—Not present as a recognisable stratum
Common—Sclerolaena diacantha
Others—Eriochiton sclerolaenoides, Maireana tomentosa, Sclerolaena obliquicuspis, S. patenticuspis, Threlkeldia diffusa.

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—Austrostipa scabra
Other—Austrostipa platychaeta.

Other plant forms: Occasional—Carphobrotus modestus (succulent perennial herb), Cassytha melantha (creepers), Comesperma volubile (creepers), Dianella revoluta (lily), Gahnia lanigera (perennial sedge).

Annual species recorded include Asteridea athrixoides, Euphorbia drummondii, Oncosiphon suffruticosum, Trichanthodium skirrhophorum, Zygophyllum glaucum, Z. iodocarpum and Z. ovatum.

Gradational associations
EMEW commonly grades into Eucalypt, melaleuca mixed chenopod shrubland or woodland (EMCW) or Eucalypt mixed scrub woodland (EXSW) as the tree stratum becomes scattered and the density of the melaleuca component reduces as chenopods or mixed shrubs begin to dominate the lower shrub stratum. EMEW also grades into Eucalypt heath woodland (EHEW) on stabilised dunes or Coastal shrubland (COAS) as dunes become more mobile. Low mallee woodland (LOMW) replaces EMEW when outcrop starts to occur as calcareous shallow sands disappear and calcareous loamy earths become shallower.

Land systems
EMEW is a major habitat type on Moopina and Roe land systems and a minor habitat type on Caiguna, Culver, Toolinna and Wurrengoodyea land systems.

49. Low mallee woodland (LOMW)

Sampling
11 inventory sites, 80 traverse points

General information
LOMW occurs on limestone and calcrete plains in the south of the survey area. The mantle is variable, becoming stonier coastward. Medium-sized (6–20 mm) angular, calcareous fragments can cover up to 50 per cent of the surface. Indurated calcareous outcrop occurs through 10–50 per cent of habitats depending on the variability of the overlying calcareous shallow loam. On limestone hummocks the outcrop is greater and the surface is commonly pitted due to weathering.

Physiognomy and composition of vegetation
LOMW occurs as scattered (10–20 per cent PFC) low mallee woodland of variable eucalypt species over scattered to moderately closed mixed scrub, sedges and occasionally hummock grasses.

65 perennial species were recorded at the 11 inventory sites, including one priority species, with an average of 13 species per site, two greater than the survey average. One annual species was recorded.

Ecological disturbance
Little is known about the disturbance mechanisms in EMEW in the Nullarbor region. This habitat has limited occurrence within the pastoral leases and is generally unfavoured for grazing owing to the lack of grasses and dominance of unpalatable eucalypts and melaleucas. Where low shrubs and subshrubs occur in any abundance it would be expected palatable species would decline under continuous grazing pressure.
The following species (by strata) are dominant and/or common:

**Trees:**
- **Dominant:** Eucalyptus oleosa subsp. oleosa (mallee) Variable; Eucalyptus brachycalyx (mallee), E. conglobata (mallee), E. cooperiana (mallee), E. gracilis, E. yalatensis (mallee)
- **Common:** Allocasuarina helmsii, Eucalyptus diversifolia (mallee)
- **Other:** Santalum acuminatum.

**Tall shrubs:**
- **Dominant:** Allocasuarina helmsii, Melaleuca lanceolata
- **Common:** Dodonaea stenozyga, Templetonia retusa, Eremophila dempsteri
- **Others:** Acacia cyclops, Allocasuarina scleroclada, Exocarpos aphyllus, E. sparteus, Geijera linearifolia.

**Mid shrubs:**
- **Dominant:** Not present as a recognisable stratum
- **Others:** Acacia cupularis, A. sulcata var. platyphylla, Beyenya lechenaultii, Dodonaea bursarifolia, D. stenozyga, Grevillea sparsiflora, Kunzea pulchella, Lasiopetalum compactum, Leptomeria pachyclada, Melaleuca pentagona var. latifolia, Pultenaea heterochila, Scaevola spinescens, Senna artemisioides subsp. x artemisioides, S. artemisioides subsp. x coriacea.

**Low shrubs:**
- **Dominant:** Not present as a recognisable stratum
- **Common:** Acacia erinacea, Halgania andromedifolia, Olearia calcarea, O. muelleri, Pomaderris myrtilloides, Prostanthera serpyllifolia subsp. serpyllifolia, Pultenaea elachista, Sprydium tricolor, Westringia rigida
- **Others:** Acacia excentrica, Acrotiche cordata, A. patula, Calytrix tetragona, Conostephanium drummondii, Eremophila weldii, Hibbertia nutans, Microcybe multiflora, Olearia picridifolia, Philotheca fitzgeraldii, Pimelea serpyllifolia, Scaevola bursarifolia.

**Subshrubs:**
- **Dominant:** Not present as a recognisable stratum
- **Others:** Goodenia affinis, G. concinna, Lomandra sp., Wahlenbergia communis.

**Perennial grasses:**
- **Dominant:** Not present as a recognisable stratum
- **Common:** Triodia scariosa (hummock grass)
- **Other:** Austrostipa platyphaeta.

**Other plant forms:**
- **Dominant:** Gahnia lanigera (perennial sedge)
- **Common:** Dianella revoluta (lily), Tetraria capillaris (perennial sedge)
- **Others:** Cassytha melantha (creeper), Lepidosperma sp. (perennial sedge), Schoenus subflavus subsp. hispid culms (perennial sedge).

Annual species recorded include Calandrinia sp.

**Ecological disturbance**

This habitat type generally occurs outside of pastoral lease boundaries and little is known about the grazing ecology or other disturbance mechanisms.

**Thysanotus baueri**, a Priority 1 species on the declared rare and priority flora list, was recorded in this habitat and as such the area is of high conservation value.

**Gradational associations**

LOMW commonly grades into *Eucalypt melaleuca woodland* (EMEW) as calcareous loamy earths deepen and calcareous shallow sands cover outcrop. LOMW has a defined boundary against aeolian sand dunes supporting Banksia coastal heath and scrubland (BCHS) behind cliff faces. Also occurring randomly through the LOMW are karst depressions supporting Plain mixed low shrubland (PXLS) or Drainage depression mixed shrub shrubland (DDXS) within the indurated stony calcareous plains and between limestone hummocks.

**Land systems**

LOMW is the dominant habitat type on Toolinna and Culver land systems.
50. Eucalypt heath woodland (EHEW)

**Sampling**

7 inventory sites, 15 traverse points

**General information**

EHEW occurs on partially consolidated, aeolian sand dunes stabilised by vegetation, along the top of the Baxter Cliffs and on the landward side of younger mobile dunes fringing the coastal Israelite and Roe Plains. The dunes generally have gently inclined slopes, though near the Wurrengoodyea Hills they can be steep and up to 90 m. Soils are calcareous deep sands or pale deep sands with a calcrete horizon developed at or near the surface.

**Physiognomy and composition of vegetation**

EHEW comprises scattered to closed (15–50 per cent PFC) low woodland of various eucalypt species in mallee-form over scattered to closed low shrubland of variable heath species.

48 perennial species were recorded at the seven inventory sites with an average of 10 species per site, one less than the survey average. No annual species were recorded.

The following species (by strata) are dominant and/or common:

**Trees:**

Dominant—*Eucalyptus discreta* (mallee), *E. diversifolia* (mallee), *E. incrassata* (mallee)

Common—*Callitris preissii*, *Eucalyptus brachycalyx* (mallee), *E. conglobata* (mallee)

Others—*Allocasuarina helmsii*, *Eucalyptus yalatensis* (mallee).

**Tall shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Exocarpos aphyllus*, *Melaleuca lanceolata*

Others—*Acacia oswaldii*, *Exocarpos sparteus*, *Templetonia retusa*.

**Mid shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Pultenaea heterochila*

Others—*Beaufortia empetrifolia*, *Dodonaea stenozyga*, *Grevillea sparsiflora*, *Hakea nitida*.

**Low shrubs:**

Dominant—*Adenanthis forrestii*

Common—*Acacia cochlearis*, *Beaufortia micrantha*, *Bossiaea leptacantha*, *Conostephium drummondii*, *Pomaderris myrtilloides*


**Subshrubs:**

Dominant—Not present as a recognisable stratum

Other—*Desmocladus myriocladus*.

**Perennial grasses:**

Dominant—Not present as a recognisable stratum

Other—*Austrostipa platychaeta*.

**Other plant forms:**

Common—*Carpobrotus modestus* (succulent perennial herb), *Comesperma volubile* (creeping), *Dianella revoluta* (lily), *Lepidosperma sp. A2 Island Flat* (perennial sedge), *Marianthus bicolor* (creeping)

Others—*Galenia deusta* (perennial sedge), *G. lanigera* (perennial sedge), *Schoenus lanatus* (perennial sedge).

**Ecological disturbance**

This habitat type generally occurs outside of pastoral lease boundaries and little is known about the grazing ecology. Burnt areas show a mosaic pattern, often confined to this habitat type, indicating this woodland is more susceptible to fire than the vegetation associations adjacent to it.

**Gradational associations**

EHEW commonly grades into *Eucalypt, melaleuca woodland* (EMEW) on stabilised dunes and *Eucalypt, melaleuca mixed chenopod/woodland* (EMCW) where calcareous loamy earths and shallow loams become overlain by sandy soils.

**Land systems**

EHEW is a major habitat type on Wurrengoodyea land system.
51. Eucalypt coastal heath woodland (ECHW)

**Sampling**

3 inventory sites

**General information**

ECHW occurs where coastal aeolian sand dunes have accumulated. This predominantly occurs on the Roe Plains but there are also aeolian sand deposits at the edge of the Hampton Range and Baxter Cliffs. These sandy deposits occur as sand sheets and coastal dunes in the south of the survey area near the coast. Where dunes occur they are gently sloping (up to 6 per cent). Soils vary from calcareous deep sands to pale deep sands.

**Physiognomy and composition of vegetation**

ECHW consists of a scattered to moderately closed (15–30 per cent PFC) low woodland of mallee-form eucalypts. Scattered (10–15 per cent PFC) mixed shrubs form the understorey. 38 species were recorded at the three inventory sites, with an average of 15 species per site, four greater than the survey average. No annual species were recorded.

The following species were dominant and/or common:

**Trees:**

Dominant—Variable; *Eucalyptus discreta* (mallee), *E. gracilis*, *E. incrassata* (mallee)

Common—*Callitris preissii*

Other—*Eucalyptus cooperiana* (mallee).

**Tall shrubs:**

Dominant—Variable; *Melaleuca lanceolata*

Common—*Callitris preissii*

Others—*Exocarpos aphyllus*, *Rhagodia preissii*, *Templetonia retusa*.

**Mid shrubs:**

Dominant—Variable; *Beaufortia empetrifolia*, *Hakea nitida*

Others—*Adenanthes cuneatus*, *Dodonaea amblyophylla*, *Pultenaea heterochila*, *Styphelia hainesii*.

**Low shrubs:**

Dominant—Not present as a recognisable stratum

Common—*Pimelea serpyllifolia*, *Spyridium microcephalum*, *Synaphea oligantha*.

**Subshrubs:**

Dominant—Not present as a recognisable stratum

Others—*Harperia eyreana*, *Lomandra sp.*

**Other plant forms:**


**Ecological disturbance**

The disturbance mechanisms of this habitat have not been investigated in any significant detail in this region. Disturbance by vehicles and/or fire may result in wind erosion of the dunes.

**Gradational associations**

ECHW commonly grades into Coastal shrubland (COAS) as dune development becomes unconsolidated. ECHW has a defined boundary where the stabilised sand dunes overlie calcareous loamy earths and shallow loams that support *Eucalypt, melaleuca mixed chenopod shrubland or woodland (EMCW).*

**Land systems**

ECHW is a minor habitat type of Toolinna and Wurrengoodyea land systems.

52. Banksia coastal heath and scrubland (BCHS)

**Sampling**

3 inventory sites

**General information**

BCHS is a unique vegetation association. It occurs on stabilised sand dune deposits on the Israelite Plain, above the Baxter Cliffs and Wylie Scarp. Sand dunes have developed between the Wylie Scarp and the landward side of mobile coastal dunes on the Israelite Plain.
These older dunes are likely to have formed during a sea regression, forming beaches at the base of the cliff. Winds built sand ramps and transported large amounts of sand to the clifftops (Jennings 1968). Later sea level increases have removed some dune ramps but aeolian clifftop deposits have remained above the Baxter Cliffs and Wylie Scarp. BCHS is largely restricted to these aeolian sand deposits.

Along the edge of the Baxter Cliffs the BCHS vegetation association is present in a dwarfed form due to wind exposure causing high evapotranspiration and wind-borne salt spray causing leaf tip necrosis and asymmetric growth forms (Parsons 1970). The banksia population found above Toolinna Cove is the most easterly population of a Western Australian banksia species (Nelson 1974).

Physiognomy and composition of vegetation

BCHS comprises closed (30–50 per cent) thickets of banksia, eucalyptus and melaleuca, except along the cliff edge where BCHS is a dwarfed closed low heathland. The lower shrub stratum is variable and can be dominated by Beaufortia micrantha or Pomaderris forestiana.

36 perennial species were recorded at the three inventory sites, with an average of 10 species per site, one less than the survey average. No annual species were recorded.

The following species were dominant and/or common:

**Tall shrubs:**
- Dominant—Banksia media, Eucalyptus incrassata, Melaleuca pentagona var. latifolia
- Others—Allocasuarina helmsii, Banksia speciosa, Calothamnus gracilis, Eucalyptus diversifolia, Melaleuca lanceolata.

**Mid shrubs:**
- Dominant—Occasionally Melaleuca quadrifaria
- Common—Pultenaea heterochila
- Others—Adenanthis cuneatus, Grevillea sparsiflora, Hakea cinerea, H. nitida, Isopogon trilobus, Melaleuca pulchella, Petrophile teretifolia.

**Low shrubs:**
- Dominant—Occasionally Beaufortia micrantha, Pomaderris forestiana
- Common—Adenanthis forrestii, Boronia crassifolia, Conostephus drummondii
- Others—Acrotiriche patula, Bossiaea leptacantha, Grevillea nudiflora, Hibbertia nutans, Stirlingia anethifolia, Verticordia sieberi.

**Subshrubs:**
- Dominant—Not present as a recognisable stratum
- Others—Desmocladus myriocladus, Euphorbia sp.

**Other plant forms:**
- Occasional—Cassitha melantha (creep), Dianella revoluta (lily), Lepidosperma sp.
- A2 Island Flat (perennial sedge), Schoenus caespititus (perennial sedge), S. Ianatus (perennial sedge), Tetraria capellaris (perennial sedge).

**Ecological disturbance**

The mechanisms of disturbance in BCHS have not been investigated in any significant detail. Dune erosion has resulted when disturbance caused by vehicles and/or fire has damaged or removed stabilising vegetation.

**Gradational associations**

BCHS commonly grades into scattered Low mallee woodland (LOMW) or Eucalypt mixed scrub woodland (EXSW). Coastward as the stabilised colluvial dune apron becomes less consolidated and foredunes and swales develop BCHS is replaced by Coastal shrubland (COAS).

**Land systems**

BCHS is the dominant habitat type on the Baxter and Wylie land systems.

53. Coastal shrubland (COAS)

**Sampling**

7 inventory sites, 2 traverse points

**General information**

COAS occurs on recently mobile or fixed dunes fringing the Israelite and Roe coastal plains. In places dunes form large masses such as the Bilbunya Dunes near Point Culver and the Delisser Sandhills near Eucla. Foredunes are usually 3–10 m high with gently inclined slopes to 8 per cent, though at the Bilbunya Dunes they are more steeply inclined, with relief up to 90 m. Soils are deep calcareous sands.
Physiognomy and composition of vegetation

COAS commonly occurs as a mid to low shrubland of varying composition. It ranges from supporting isolated shrubs (0–2.5 per cent PFC) to closed (30–50 per cent PFC) shrubland. Vegetation characteristic to coastal areas such as *Euphorbia paralias* (sea spurge), *Ficinia nodosa* (knotted club rush), *Leucophyta brownii* and *Scaevola crassifolia* (thick-leaved fan-flower) are common.

29 perennial species were recorded at the seven inventory sites with an average of seven species per site, four less than the survey average. Two annual species were recorded.

The following species were dominant and/or common to this vegetation association:

**Tall shrubs:**
- Dominant—Occasionally: *Acacia cyclops*, *Eucalyptus conglobata* (mallee), *Melaleuca lanceolata*
- Others—*Myoporum platycarpum*, *Olearia axillaris*.

**Mid shrubs:**
- Dominant—*Acacia aniceps*
- Others—*Atriplex isatidea*, *Nitraria billardierei*, *Pultenaea heterocha.*

**Low shrubs:**
- Dominant—Occasionally: *Leucophyta brownii*, *Scaevola crassifolia*
- Common—*Olearia axillaris*, *Rhagodia crassifolia*, *Westringia sessilis*, *Zygophyllum apiculatum*, *Z. billardierei*.
- Others—*Acacia cochlearis*, *Atriplex cinerea*, *Darwinia diosmoides*, *Pimelea ferruginea*, *Tecticornia sp.*

**Subshrubs:**
- Dominant—*Threlkeldia diffusa*
- Others—*Euphorbia paralias*, *Senecio spanomerus*, *Tetragonia implexicoma*, *Zygophyllum cuneatum*, *Z. billardierei*.

**Perennial grasses:**
- Dominant—Not present as a recognisable stratum
- Common—*Spinifex hirsutus*.

**Other plant forms:**
- Common—*Carpobrotus modestus* (succulent perennial herb), *C. virescens* (succulent perennial herb), *Ficinia nodosa* (perennial sedge).

Annual species recorded include *Cakile maritima* and *Senecio pinnatifolius*.

Ecological disturbance

This habitat is susceptible to dune erosion when coastal vegetation is damaged or removed. Common disturbance mechanisms causing dune instability include vehicle impact and fire.

Gradational associations

COAS commonly grades into *Samphire shrubland* (SAMP) growing in lagoonal habitats immediately between or behind recent coastal dunes. As unconsolidated dunes become increasingly stabilised COAS grades into *Banksia coastal heath and scrubland* (BCHS), *Eucalypt coastal heath woodland* (ECHW) or *Eucalypt, melaleuca woodland* (EMEW).

Land systems

COAS is the dominant habitat type on the Bilbunya and Delisser land systems.

References

Atkins, KJ 2006, *Declared Rare and Priority Flora List for Western Australia*, Dept of Conservation and Land Management, Western Australia.

Beard, JS 1975, *Vegetation survey of Western Australia, 1:1 000 000 Vegetation Series*, Explanatory notes to sheet 4, University of Western Australia Press, Perth.


Mitchell, AA, McCarthy, RC & Hacker, RB 1979, A range inventory and condition survey of part of the Western Australian Nullarbor Plain, 1974, Western Australian Department of Agriculture, Technical Bulletin No. 47.

Mitchell, AA & Wilcox, DG 1994, Arid shrubland plants of Western Australia, revised edition, University of Western Australia Press, Perth.


Payne, AL, Curry, PJ & Spencer, GF 1987, An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia, Western Australian Department of Agriculture, Technical Bulletin No. 73.

Payne, AL, Van Vreeswyk, AME, Pringle, HJR, Leighton, KA & Hennig, P 1998, An inventory and condition survey of rangelands in the Sandstone-Yalgoo-Paynes Find area, Western Australia, Agriculture Western Australia, Technical Bulletin No. 90.

Pringle, HJ., Van Vreeswyk, AME & Gilligan, SA 1994, An inventory and condition survey of the north-eastern Goldfields, Western Australia, Western Australian Department of Agriculture, Technical Bulletin No. 87.


Land systems

PA Waddell

Within the survey area 54 land systems have been identified, 34 of which are described for the first time and the other 20 previously described in adjacent surveys. The land systems are derived from aerial photography and descriptions are built up using field data collected during traversing and at inventory sites. With improved aerial photography and the benefit of LANDSAT imagery the land systems identified in the eastern part of the Western Australian Nullarbor Plain during the 1974 survey (Mitchell, McCarthy & Hacker 1979) have been reassessed and in some cases boundaries have been modified. Four land systems from the 1974 survey were extensively modified resulting in one system being renamed and three systems incorporated into others.

Land systems are grouped into land types according to a combination of landforms, soils, vegetation and drainage patterns. Table 19 shows the land types and their component land systems. This amalgamation of the 54 land systems into 15 land types provides information at a more appropriate level for use when considering a regional scale, and provides a simpler way to colour code regional scale maps.

The location of each inventory site, with the site number and a code for the land unit on which it occurred, is shown on pastoral lease maps. Table 20 provides a list of land units with the codes used on the maps.

Land systems are described in alphabetical order in this chapter. A summary description of each system’s major features is followed by more detailed accounts of the units that comprise each system. The format used for the summary description is:

- land system name, area and percentage of the survey area
- reference to any previous description
- brief descriptive statement of dominant landform(s) and vegetation
- land type (refer to Table 19)
- major geological formation or land surface types
- geomorphology overview

- brief description of land management considerations such as susceptibility to soil erosion
- traverse condition summary
- locality map showing the distribution of the land system
- plan showing the physical features of the system, and with each land unit identified
- list of land units, normally in order of highest to lowest position in the landscape, with the number of sampling points. Not all units in each land system are shown in diagrams or described in tables. Minor units that were encountered very occasionally whilst traversing the land system are listed as ‘other’ in the summary table.

On each opposing page a summary of the biophysical components for each land unit provides additional detail:

- unit area, estimated from aerial photograph interpretation and field observation, is presented as a percentage of the total land system area
- landform—lists each land unit with a description of the landform
- soils—generalised description with reference to the appropriate soil groupings (refer to the Soils chapter)
- vegetation—the vegetation is described in three parts: foliar cover (refer to Table 8 of the Methodology chapter); formation (refer to the Vegetation chapter) and dominant species, e.g. ‘Pearl bluebush low shrubland (PBLs)’. The four-letter code for the habitat type (refer to the Habitat type ecology chapter) is also listed.
<table>
<thead>
<tr>
<th>Land type</th>
<th>Description and land systems</th>
</tr>
</thead>
</table>
| 1         | Calcrite plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses  
Land system—Zanthus |
| 2         | Calcrite plains with eucalypt woodland and mixed scrub understorey  
Land systems—Caiguna and Gumbelt |
| 3         | Calcrite plains with myall woodland and mixed shrubland  
Land systems—Colville and Nyanga |
| 4         | Calcrite plains with sparse myall and bindii grassland or chenopod shrubland  
Land systems—Carlisle, Haig, Jubilee, Kyarra and Rabbit |
| 5         | Large depressions within calcrite plains with chenopod shrubland or bindii grassland  
Land systems—Koonjarra and Woortba |
| 6         | Low granite outcrop protruding through calcrite plains with fringing acacia–dodonaea–eremophila shrubland  
Land system—Balladonia |
| 7         | Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland  
Land systems—Moodini, Moopina, Thampanna and Weebubbie |
| 8         | Undulating calcareous plains with eucalypt woodland, mixed scrub and heathland  
Land systems—Culver and Toolinna |
| 9         | Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland  
Land systems—Kanandah, Lowry and Virginia |
| 10        | Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland  
Land systems—Chowilla, Seemore, Shakehole and Vanesk |
| 11        | Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland  
Land systems—Arubiddy, Balgair, Gafa, Kitchener, Kybo, Moonera, Morris, Nanambinia, Naretha, Nightshade, Pondana, Reid and Skink |
| 12        | Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland  
Land systems—Bullseye, Kinclaven, Nurina and Oasis |
| 13        | Level calcarenite coastal plains with eucalypt–melaleuca–myall woodland and mixed shrubland  
Land systems—Mundrabilla and Roe |
| 14        | Coastal plains, cliffs, dunes, lagoonal deposits and beaches; varied vegetation  
Land systems—Baxter, Bilbunya, Delisser, Wurrengoodyea and Wylie |
| 15        | Salt lakes and fringing saline plains with halophytic shrubland  
Land systems—Boonderoo, Damper, Lefroy and Ponton |

These are modified land types taken from the Department of Agriculture and Food, WA State Land Type list.
### Table 20 Land units and their codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Land unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAS</td>
<td>Sandy bank</td>
</tr>
<tr>
<td>BEA</td>
<td>Beach</td>
</tr>
<tr>
<td>BRX</td>
<td>Breakaway</td>
</tr>
<tr>
<td>CLA</td>
<td>Claypan</td>
</tr>
<tr>
<td>CLD</td>
<td>Clay depression</td>
</tr>
<tr>
<td>CLP</td>
<td>Clay plain</td>
</tr>
<tr>
<td>DFL</td>
<td>Drainage floor</td>
</tr>
<tr>
<td>DON</td>
<td>Donga (karst depression)</td>
</tr>
<tr>
<td>DRF</td>
<td>Drainage focus</td>
</tr>
<tr>
<td>DRN</td>
<td>Narrow drainage floor (&lt; 0.5 km)</td>
</tr>
<tr>
<td>DRT</td>
<td>Drainage tract (ancient river course)</td>
</tr>
<tr>
<td>DUN</td>
<td>Dune</td>
</tr>
<tr>
<td>FOL</td>
<td>Lower footslope – concave</td>
</tr>
<tr>
<td>FOR</td>
<td>Foredune</td>
</tr>
<tr>
<td>GIL</td>
<td>Gilgaied depression</td>
</tr>
<tr>
<td>KOP</td>
<td>Kopi dune</td>
</tr>
<tr>
<td>KPL</td>
<td>Calcrete plain overlain by calcareous loam of varying depth</td>
</tr>
<tr>
<td>KRL</td>
<td>Calcrete (residual) rise overlain by calcareous loam of varying depth</td>
</tr>
<tr>
<td>KSP</td>
<td>Calcrete stony plain</td>
</tr>
<tr>
<td>LAK</td>
<td>Lake bed including playa lake</td>
</tr>
<tr>
<td>LAM</td>
<td>Lake margin</td>
</tr>
<tr>
<td>LGR</td>
<td>Low granite rise</td>
</tr>
<tr>
<td>MDF</td>
<td>Marginal slope to drainage floor</td>
</tr>
<tr>
<td>PCL</td>
<td>Calcarenite plain overlain by calcareous loam</td>
</tr>
<tr>
<td>PGR</td>
<td>Gritty-surfaced plain with shallow soil on granite</td>
</tr>
<tr>
<td>PGY</td>
<td>Gypsiferous plain</td>
</tr>
<tr>
<td>PKE</td>
<td>Calcareous loam plain overlain by shallow aeolian sand</td>
</tr>
<tr>
<td>PLS</td>
<td>Highly saline depression</td>
</tr>
<tr>
<td>LHR</td>
<td>Limestone hummock (low rise)</td>
</tr>
<tr>
<td>SCF</td>
<td>Scarp face</td>
</tr>
<tr>
<td>SLP</td>
<td>Stony limestone plain</td>
</tr>
<tr>
<td>SWA</td>
<td>Swale</td>
</tr>
<tr>
<td>SWP</td>
<td>Swamp</td>
</tr>
</tbody>
</table>
## Sampling intensity

Table 21 indicates the area and intensity of sampling on each system in the survey area.

### Table 21 Land system areas and sampling intensity

<table>
<thead>
<tr>
<th>Land system</th>
<th>Area (km²)</th>
<th>% of total survey area</th>
<th>No. of inventory sites</th>
<th>Traverse sampling intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of assessments</td>
</tr>
<tr>
<td>Arubiddy</td>
<td>2 046</td>
<td>1.7</td>
<td>5</td>
<td>210</td>
</tr>
<tr>
<td>Balgair</td>
<td>1 937</td>
<td>1.6</td>
<td>4</td>
<td>196</td>
</tr>
<tr>
<td>Ballardonia</td>
<td>145</td>
<td>0.1</td>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>Baxter</td>
<td>285</td>
<td>0.2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Bilbunya</td>
<td>47</td>
<td>&lt; 0.1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Boonderoo</td>
<td>83</td>
<td>0.1</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Bullseye</td>
<td>8 817</td>
<td>7.4</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Caiguna</td>
<td>7 066</td>
<td>6.0</td>
<td>16</td>
<td>201</td>
</tr>
<tr>
<td>Carlisle</td>
<td>2 066</td>
<td>1.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chowilla</td>
<td>1 532</td>
<td>1.3</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Colville</td>
<td>421</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Culver</td>
<td>1 707</td>
<td>1.4</td>
<td>9</td>
<td>48</td>
</tr>
<tr>
<td>Damper</td>
<td>390</td>
<td>0.3</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>Delisser</td>
<td>150</td>
<td>0.1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Gafa</td>
<td>8 501</td>
<td>7.2</td>
<td>5</td>
<td>138</td>
</tr>
<tr>
<td>Gumbelt</td>
<td>5 053</td>
<td>4.3</td>
<td>12</td>
<td>381</td>
</tr>
<tr>
<td>Haig</td>
<td>552</td>
<td>0.5</td>
<td>7</td>
<td>115</td>
</tr>
<tr>
<td>Jubilee</td>
<td>934</td>
<td>0.8</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Kanandah</td>
<td>1 641</td>
<td>1.4</td>
<td>10</td>
<td>223</td>
</tr>
<tr>
<td>Kinclaven</td>
<td>4 790</td>
<td>4.0</td>
<td>14</td>
<td>542</td>
</tr>
<tr>
<td>Kitchener</td>
<td>405</td>
<td>0.3</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td>Koonjarra</td>
<td>1 067</td>
<td>0.9</td>
<td>14</td>
<td>186</td>
</tr>
<tr>
<td>Kyarra</td>
<td>2 099</td>
<td>1.8</td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>Kybo</td>
<td>1 289</td>
<td>1.1</td>
<td>12</td>
<td>174</td>
</tr>
<tr>
<td>Lefroy</td>
<td>9</td>
<td>&lt; 0.1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Lowry</td>
<td>65</td>
<td>0.1</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Moodini</td>
<td>123</td>
<td>0.1</td>
<td>7</td>
<td>51</td>
</tr>
<tr>
<td>Moonera</td>
<td>4 234</td>
<td>3.6</td>
<td>10</td>
<td>319</td>
</tr>
<tr>
<td>Moopina</td>
<td>107</td>
<td>0.1</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Morris</td>
<td>3 323</td>
<td>2.8</td>
<td>0</td>
<td>49</td>
</tr>
<tr>
<td>Mundrabilla</td>
<td>1 688</td>
<td>1.4</td>
<td>19</td>
<td>127</td>
</tr>
<tr>
<td>Nanambinia</td>
<td>570</td>
<td>0.5</td>
<td>5</td>
<td>114</td>
</tr>
<tr>
<td>Naretha</td>
<td>1 547</td>
<td>1.3</td>
<td>7</td>
<td>139</td>
</tr>
<tr>
<td>Nightshade</td>
<td>3 373</td>
<td>2.8</td>
<td>7</td>
<td>286</td>
</tr>
<tr>
<td>Nurina</td>
<td>2 247</td>
<td>1.9</td>
<td>9</td>
<td>204</td>
</tr>
<tr>
<td>Nyanga</td>
<td>12 990</td>
<td>11.0</td>
<td>38</td>
<td>1 045</td>
</tr>
<tr>
<td>Oasis</td>
<td>4 180</td>
<td>3.5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pondana</td>
<td>1 649</td>
<td>1.4</td>
<td>6</td>
<td>188</td>
</tr>
<tr>
<td>Ponton</td>
<td>23</td>
<td>&lt; 0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rabbit</td>
<td>350</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reid</td>
<td>3 998</td>
<td>3.4</td>
<td>1</td>
<td>38</td>
</tr>
<tr>
<td>Roe</td>
<td>2 853</td>
<td>2.4</td>
<td>20</td>
<td>64</td>
</tr>
<tr>
<td>Seemore</td>
<td>415</td>
<td>0.4</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Shakehole</td>
<td>4 045</td>
<td>3.4</td>
<td>11</td>
<td>355</td>
</tr>
<tr>
<td>Skink</td>
<td>4 000</td>
<td>3.4</td>
<td>2</td>
<td>85</td>
</tr>
<tr>
<td>Thampanna</td>
<td>5 284</td>
<td>4.5</td>
<td>36</td>
<td>723</td>
</tr>
<tr>
<td>Toolinna</td>
<td>1 879</td>
<td>1.6</td>
<td>9</td>
<td>55</td>
</tr>
<tr>
<td>Vanesk</td>
<td>1 107</td>
<td>0.9</td>
<td>6</td>
<td>64</td>
</tr>
<tr>
<td>Virginia</td>
<td>1 689</td>
<td>1.4</td>
<td>4</td>
<td>144</td>
</tr>
<tr>
<td>Weebubbe</td>
<td>416</td>
<td>0.4</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Woorba</td>
<td>554</td>
<td>0.5</td>
<td>10</td>
<td>163</td>
</tr>
<tr>
<td>Wurrengooyea</td>
<td>1 946</td>
<td>1.6</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Wyile</td>
<td>52</td>
<td>&lt; 0.1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Zanthus</td>
<td>619</td>
<td>0.5</td>
<td>6</td>
<td>49</td>
</tr>
</tbody>
</table>

* Density index: measure of sampling intensity relative to the mean of the survey area (16.9 km² per assessment)