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Floristic communities of the Ravensthorpe Range, Western Australia

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ABSTRACT

The Ravensthorpe Range consists of a series of ridges and peaks located in the greater Fitzgerald Biosphere reserve, in south-west Western Australia near the township of Ravensthorpe. A floristic classification of the vegetation of the range is described and compared to recent vegetation mapping undertaken in the area. The floristic classification was derived from an analysis of 580 taxa from 265 plots that were located to cover the topographic and geographic extent of the range. Twenty-one communities are described, and these show broad agreement with the recent detailed mapping, except for one widespread upland unit that was floristically heterogeneous. The floristic communities correlated with site physical attributes, notably topographic position, substrate and altitude. In addition to the high beta diversity, the Ravensthorpe Range has a large number of geographically restricted species, species listed as threatened and species being considered for listing. Despite the high conservation values of the range, reservation is limited to two small A-class nature reserves off the main range. These reserves are not representative of the full diversity of flora and communities on the range. Mineral exploration and mining are currently active or proposed for parts of the range, and mining tenements cover most of the area of the range. The impacts of exploration, mining and *Phytophthora* present significant challenges to managing this major biodiversity hotspot.

Keywords: endemic, threatened taxa, beta diversity, classification

INTRODUCTION

The Yilgarn Craton of Western Australia is composed of ancient granitoid gneisses, within which are inter-bedded extensive belts of metamorphosed sedimentary and volcanic rocks. These are referred to locally as ‘greenstone’ belts, which manifest as hills and ranges when exposed above the surrounding plains. Recent surveys of these landforms have found them to be repositories of endemic and rare plant taxa (Gibson et al. 2007, 2010, 2011), and short range endemic invertebrate species (i.e. species with total range of less than 10,000 km²; Harvey 2002; Edward & Harvey 2010). They also support floristic communities which differ in composition to both the surrounding lowlands and adjacent ranges (Gibson et al. 2007, 2010, 2011).

The Ravensthorpe Range is one such greenstone landform located on the Yilgarn Craton, in the far south-western corner of Western Australia (Fig. 1) and within the South West Australian Floristic Region (SWAFR, sensu Hopper & Gioia 2004). This region is known for its exceptional biological diversity, and is considered to be one of 34 global biodiversity hotspots because of a

combination of high species richness, endemism and habitat loss (Myers et al. 2000; Myers 2003). The Ravensthorpe Range occurs within a node of high species diversity and endemism within the SWAFR (Hopper & Gioia 2004), and is part of the United Nations Educational, Scientific and Cultural Organisation’s Fitzgerald River Biosphere Reserve (Chapman & Newbey 1995). Because of its location, the Ravensthorpe Range is recognised as a significant biological corridor between the Fitzgerald River National Park and the Great Western Woodlands (Chapman & Newbey 1995; Watson 1991; Watson & Wilkins 1999). The range is noted for its high biodiversity values (Craig et al. 2008; Moir et al. 2009; Edward & Harvey 2010; McDonald 2010), including being important habitat for several threatened species of vertebrates (Chapman & Newbey 1995; Harris et al. 2008). The most recent census of vascular plants recorded 1324 native species (Craig 2008) from Beard’s Ravensthorpe vegetation system (Beard 1972, 1973), which covers both the range and areas of mafic geology immediately to the south-west. At least 58 taxa are endemic to, or largely restricted to, this vegetation system (Craig 2008; Kern et al. 2008; the Western Australian Herbarium 1998–). Some 76 taxa in the Ravensthorpe vegetation system are listed as being of conservation significance

(Craig 2008; Smith 2010), and 60 of these are known to occur on the range (Harris et al. 2008; Western Australian Herbarium 1998–). Five ecological communities of conservation significance are listed for the range (Craig et al. 2008; Kern et al. 2008; Department of Environment and Conservation 2010). Like many greenstone ranges on the Yilgarn Craton, the Ravensthorpe Range is rich in mineral resources and of interest to the resources sector (Witt 1998).

STUDY SITE

The Ravensthorpe Range is an extensive outcropping of greenstone bedrock located 550 km south-east of Perth, Western Australia. The main range is a narrow, linear feature c. 50 km in length trending north-west to south-east, and up to 7 km wide. The centre of the range is 7 km east of the town of Ravensthorpe and the southern edge 25 km from the coastal township of Hopetoun. There are six peaks named on the main range; Mt Short is the highest peak (453 m), followed by Mt Benson (404 m),

Mt Desmond (340 m), Mt Chester (300m), Mt McMahon (274 m) and Overshot Hill (377 m; Fig. 1). Immediately east of the main ridges are a series of low, undulating pediments and hills. Isolated from the main range, Bandalup Hill (228 m) is a prominent feature 34 km east of Ravensthorpe township and on the eastern margin of the survey area (Fig. 1). The main range is relatively low in elevation, being only, at the most, c. 150 m above the surrounding plains. Numerous drainage lines and several ephemeral creeks drain from the ranges into the Steere and Jerdacuttup Rivers, which incise the central and southern portion of the range. These two main rivers are saline and flow only after winter rainfall, contracting to a series of permanent pools during the summer months.

Climate

The Ravensthorpe Range is located near the edge of the transitional rainfall zone of the SWAFR, and the area has a warm Mediterranean climate, with cool and wet winters and warm to hot summers (Harris et al. 2008; Beard 1990). The climate is moderated by proximity to the

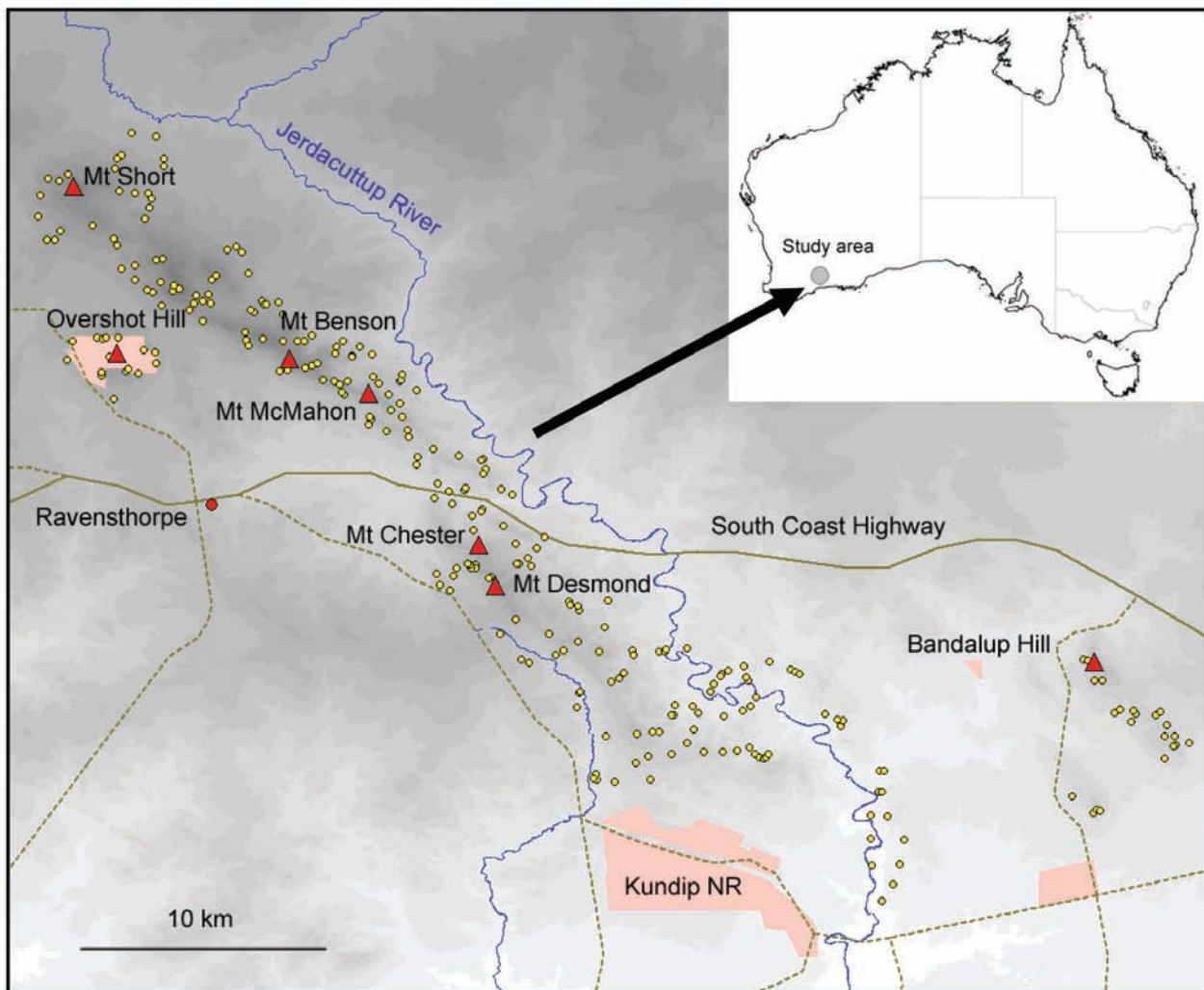


Figure 1. Ravensthorpe Range survey area showing major landmarks and the locations of the 266 permanent plots. Darker shading indicates upland areas.

Southern Ocean, and rainfall is predominately derived from southerly fronts that occur during the winter months (Craig et al. 2008; Chapman & Newbey 1995). However, summer rainfall can originate from the north as remnants of tropical cyclones. On very rare occasions snowfalls have been reported on the range (Chapman & Newbey 1995). The nearest meteorological station is Ravensthorpe township (1901–2007), which has an annual average rainfall of 426 mm (Bureau of Meteorology 1908–). Data from average annual rainfall grids indicate that rainfall across the range declines from 523 to 391 mm with distance from the coastline (Harris et al. 2008).

Geology

The Ravensthorpe Range is essentially a linear outcropping of a complex of Archean (c. 3 Ga) metavolcanic (mafic and ultramafic) and metasedimentary bedrock, which is inter-bedded within the granitoid gneiss of the southern Yilgarn Craton (Witt 1997, 1998). These metasediments and metavolcanics are faulted and folded to produce a sharp ridge and peaks, the uplands of which are covered by an undulating upland of Quaternary laterites or silcretes, produced from in situ weathering. The eroding margins of this caprock give way to colluvial slopes with some outcropping bedrock and deep valleys incised into steep slopes. Surrounding the Ravensthorpe Range are Tertiary sediments, colluvium and sand that overlie the Archean granitoid gneiss, forming extensive, low-lying plains and alluvial flats interrupted by outcrops and hills. The nearest significant granite–quartzite hills are associated with the Barren and Eyre Ranges, the closest peaks being 25–40 km south of Ravensthorpe.

The geology of the Ravensthorpe greenstone belt and associated Ravensthorpe Range has been described and mapped at a scale of 1:100,000 (Witt 1996). Witt (1996, 1997) described three geological terranes that cover the Ravensthorpe Range survey area, of which the Carlingup Terrane is the main tectonic unit. The Ravensthorpe Terrane abuts onto the western margin of the Carlingup Terrane, and the Cocanarup greenstones underlie part of Mt Short. The Carlingup Terrane is composed of four main stratigraphic units: the Bandalup Ultramafics, the Chester Formation, Maydon Basalt and the Hatfield Formation. The Bandalup Ultramafics (metamorphosed undivided ultramafic rocks) occur on lower slopes and undulating low hills, while the Maydon Basalt (metamorphosed undivided mafic rocks) dominates low hills between the main range and Bandalup Hill. The Hatfield Formation (pelite, psammite, metamorphic and felsic volcanic rocks) lies on the eastern margin of main ridge. It is the durable, erosion-resistant Chester Formation (pelite, psammite and metamorphosed sedimentary rocks) which forms the main ridges of the range (Witt 1996, 1997).

Soils of the Ravensthorpe Range reflect underlying lithology and topography, with skeletal to shallow soils being formed in situ on upland laterites and bedrock, colluvium being deposited on hill slopes and foot slopes, and alluvial deposits accumulating in drainage features and

alluvial flats at the base of the range. Associated with the mafic and ultramafic lithologies are mineral-rich clays (Beard 1973; Bennett 1987; Chapman & Newbey 1995).

Vegetation

The Ravensthorpe Range is situated within the Esperance Plains Bioregion (Department of Environment and Water Resources 2007). The vegetation was first described by Beard (1972, 1973) as part of a wider survey of the Ravensthorpe region. According to these publications, three vegetation systems occur on the range (Ravensthorpe, Oldfield and Esperance Systems). The Ravensthorpe System covers most of the range and wider surrounds to the south-west and east. Beard recognised eight physiognomic communities on the range. These communities are associated with the topographic and soil catenary sequence on the range and fall into three categories: ‘Thickets’ on summit ridges; ‘Mallee’ on pediments and low hills; and ‘Sclerophyll Woodland’ in deep, broad valleys. Bennett (1987) and Chapman and Newbey (1995) subsequently focussed on sections of the range, providing greater floristic and structural detail for these sections and describing their associations with edaphic and topographic factors. Targeted surveys on other parts of the range have been undertaken for environment impact assessments (e.g. Cockerton & Craig 2000; Craig 1999, 2004, 2005). More recently, detailed vegetation mapping of the main range between Mt Short and Kundip has described 70 vegetation units based on structure and composition (Craig et al. 2008).

Land use

Over the past century the Ravensthorpe region has been an agricultural and mining centre, and these activities have had impacts upon the vegetation of the range. The region lies in the south-east of the wheatbelt agricultural zone, and a significant proportion of the woodlands around the range have been cleared or cut-over. Wheatfields abut the base of the northern and western foothills, taking advantage of the heavy, rich soils derived from the mafic bedrock (Beard 1973).

The Ravensthorpe greenstone belt is highly prospective for minerals, and has a long history of exploration and mining for base and precious minerals, notably gold, copper, nickel and silver (Witt 1998). The original mining centre was established in the 1890s at the now abandoned township of Kundip, and several open pits and tailings dumps remain in the southern section of the range from these and more recent mining activities (Harris et al. 2008). Major operations to exploit significant nickel laterite and magnesite deposits at Bandalup Hill commenced in January 2008, and a lithium/tantalum mine immediately north of Ravensthorpe township (Mt Cattlin) was approved in 2009. Exploration activities are in progress at various locations over the range, and active or pending mining tenements cover almost the entire extent (Harris et al. 2008). Although not in the tenure of the Department of Environment and Conservation (DEC),

the Department manages these areas and conducts prescribed burns and feral animal baiting programs. Most of the range is Unallocated Crown Land, with the Overshot Hill and Kundip Nature Reserves being the only parts of the range within the conservation estate (both A-class nature reserves; Fig. 1).

Objectives

The aim of this study was to produce a classification of the vegetation communities on the Ravensthorpe Range based on floristic composition, in order to allow the regional context of proposed developments to be determined in a consistent and repeatable manner. These data were also used to examine compositional heterogeneity in some of the 70 mapping units that cover the northern sections of the range (Craig et al. 2008) and to assess the relationship between the vegetation mapping and the floristic classification.

METHODS

Two hundred permanently marked, georeferenced plots were established by a team of consultants (Western Botanical Pty. Ltd.) and rescored over a period of several months in 2007. A further 66 plots were established by the DEC in the following late spring and summer of 2008–09 (Fig. 1). Plots were placed to cover the geographical and topographical extent of the range in order to capture the widest range of floristic variation. No recently burnt vegetation was sampled in order to minimise the inclusion of fire ephemerals in the dataset. For each plot, location (to within an accuracy of 4 m) and altitude were determined using a GPS (Garmin, GPS76). The occurrence of all vascular species was recorded in each 10 × 10 m plot. Each of these plots was nested within a larger 20 × 20 m plot that was used to record canopy species (trees, mallee shrubs >3 m). Plot size was based on species-area curves from Bennett (1987) and sampling methodology follows Gibson et al. (2004). Taxa occurring within and adjacent to plots were collected for identification at the Western Australian Herbarium (PERTH), where over 1500 voucher specimens have been lodged. Further information on taxa was obtained from online records of the Western Australian Herbarium (1998–).

Data analyses were performed using routines available in PRIMER-E and PERMANOVA+ (PRIMER version 6, Clarke & Gorley 2006). Presence/absence data were analysed using Bray & Curtis association measures. This measure has proved extremely robust in the analysis of ecological data (Faith et al. 1987). Classifications of both the plots and species were performed using UPGMA clustering (Sneath & Sokal 1973). Similarity profiles (SIMPROF) and indicator species analysis (INDVAL) were used to examine the classification structure (Dufrene & Legendre 1997; Clarke et al. 2008). Floristic nomenclature follows that of the Western Australian Herbarium (1998–).

A preliminary analysis was undertaken on 593 taxa

identified from within the 266 plots. The subsequent analysis was performed on 580 taxa from 265 plots, after one outlying plot and its singleton taxa were omitted. Hybrid taxa were also omitted and several closely-related or intergrading pairs of taxa were amalgamated at a higher taxonomic level, mostly from lower ranks to species level (*Hybanthus floribundus*, *Hakea pandanica*, *Eucalyptus astringens*, *Melaleuca pentagona*, *Acacia sulcata*, *Pultenaea indira* and *Schoenus subclaxus*) or a species complex later resolved to be separate taxa (*Leucopogon* sp. Coujinup [MA Burgman 1085] and *Leucopogon* sp. Newdegate [M Hislop 3585], and *Lysinema ciliatum* and *Lysinema pentapetalum*). Preliminary analyses showed that these amalgamations had little effect on the classifications.

For each community a list of diagnostic, common, short-range endemic and conservation taxa was compiled and a photograph of a plot representative of each community is provided. These photos were taken along plot diagonals. Diagnostic taxa indicative of a community type were identified using indicator species analysis (INDVAL), implemented in PC-ORD (Dufrene & Legendre 1997; McCune & Mefford 1999). Indicator values were derived from species fidelity and constancy within each community, where a value of 100 indicated that a species was present in all plots of a community and absent from all other plots. Diagnostic species were defined as those with INDVAL values 14 or greater. Common taxa were those that occurred at frequencies of ≥25% of plots in a community. Short-range endemic (SRE) taxa were defined as those that had a total range of less than 10,000 km². Four categories are listed: 1, taxa with ranges <10 km²; 2, taxa with ranges 10–100 km²; 3, taxa with ranges 100–1,000 km²; 4, taxa with ranges 1,000–10,000 km². Convex hulls were calculated from distributional data downloaded from the Western Australian Herbarium, which include our vouchers (accessed 22nd November 2010). Conservation taxa listing follows Smith (2010) and recent updates as shown on Florabase (Western Australian Herbarium 1998–): R = threatened taxa formally listed under Western Australian legislation; P1–P4 = taxa being considered for listing (codes follow Smith 2010).

Typical soils (McDonald et al. 1998) and the number of plots in each of the vegetation map units of Craig et al. (2008) were also listed for each community. Vegetation map units were determined by intersecting the vegetation map with plot location. Some 166 of the 266 plots fell within the mapped area; seven of these were in mosaic units that were not included in the community descriptions. Plots were located in 40 of the 70 vegetation units recognized by Craig et al. (2008), with frequencies ranging from 1 to 44 plots per vegetation unit.

RESULTS

Flora

A total of 697 taxa (species, subspecies and varieties, including putative new taxa and nine new putative hybrid

or intergrade taxa) were recorded within and adjacent to the 266 plots (Appendix 1). Of these, six are listed as rare and 37 are on DEC's priority list (Appendix 1). Six species are naturalised herbaceous weed taxa (*Asphodelus fistulosus*, *Avena fatua*, *Lepidium africanum*, *Sonchus oleraceus*, *Lolium perenne* and *Asparagus asparagoides*). The highest species numbers were from Myrtaceae (136 taxa), Fabaceae (112; 64 Papilionoidea), Proteaceae (69), Cyperaceae (53), Ericaceae (28) and Goodeniaceae (23). The most species-rich genera were *Eucalyptus* (45 taxa and 8 hybrids), *Acacia* (46), *Melaleuca* (35), *Lepidosperma* (33), *Hakea* (19), *Grevillea* (17), *Daviesia* (14 and 1 hybrid), *Boronia* (13), *Schoenus* (14) and *Hibbertia* (11).

Craig (2008) listed 55 taxa believed to be endemic (99–100% of known populations) or almost endemic (80–99% of known populations) to Beard's (1972, 1973) Ravensthorpe vegetation system that covers most of the range as well as extensive areas to the south-west. These definitions are somewhat arbitrary and rely on boundaries defined at 1:250,000-scale mapping. In contrast, we defined short-range endemic taxa as those taxa recorded

in our survey that had a total range of less than 10,000 km², following definitions used for invertebrate taxa (Harvey 2002). Some very restricted taxa fall outside this definition, for example taxa with a small fragmented population restricted to rare habitats but with a total range of >10,000 km² (e.g. *Tetratheca applanata*—total range 10,072.5 km²). Sixty-four SREs were found, four restricted to a range of less than 10 km², and a further seven with ranges of less than 100 km². These taxa were not restricted to particular families but primarily represented shrubs, with a minor occurrence of eucalypt mallees, trees and mallets (Table 1).

Classification

All but two of the 265 plots were classified into 21 groups (subsequently referred to as communities; Fig. 2). Groups have been resolved at variable similarity levels, and decisions on selecting groups at particular levels have been based on branch support from SIMPER analysis, from patterns in the sorted data table (Appendix 2), from indicator species analysis (Appendix 3) and from field

Table 1

Short-range endemic taxa (SRE) recorded on the Ravensthorpe Range. SRE were defined as those taxa that had a total range less than 10,000 km². Four categories are listed: 1 = taxa with ranges <10 km²; 2 = taxa with ranges 10–100 km²; 3 = taxa with ranges 100–1000 km²; and 4 = taxa with ranges 1000–10,000 km².

Family	Taxon	SRE code	Family	Taxon	SRE code
Casuarinaceae	<i>Allocasuarina hystricosa</i>	4		<i>Eucalyptus gardneri</i> subsp. <i>ravensthorpensis</i>	3
Dilleniaceae	<i>Hibbertia abyssa</i>	1		<i>Eucalyptus megacornuta</i>	4
	<i>Hibbertia atrichosepala</i>	1		<i>Eucalyptus oleosa</i> subsp. <i>corvina</i>	4
Droseraceae	<i>Drosera grievei</i>	4		<i>Eucalyptus purpurata</i>	2
Ericaceae	<i>Acrotriche orbicularis</i>	1		<i>Eucalyptus stoatei</i>	4
	<i>Leucopogon infuscatus</i>	3		<i>Eucalyptus</i> x <i>bennettiae</i>	3
	<i>Lissanthe pleurandroides</i>	4		<i>Kunzea cincinnata</i>	3
Euphorbiaceae	<i>Beyeria cockertonii</i>	2		<i>Kunzea similis</i> subsp. <i>mediterranea</i>	1
	<i>Beyeria villosa</i>	3		<i>Leptospermum</i> sp. Bandalup Hill (G Cockerton 11001)	4
Fabaceae	<i>Acacia bifaria</i>	4		<i>Melaleuca penicula</i>	4
	<i>Acacia disticha</i>	4		<i>Melaleuca pomphostoma</i>	4
	<i>Acacia durabilis</i>	4		<i>Melaleuca stramentosa</i>	3
	<i>Acacia heterochroa</i> subsp. <i>heterochroa</i>	4		<i>Melaleuca ulicoides</i>	3
	<i>Acacia larcina</i> var. <i>crassifolia</i>	4		<i>Micromyrtus navicularis</i>	4
	<i>Acacia ophiolithica</i>	4	Pittosporaceae	<i>Marianthus mollis</i>	3
	<i>Acacia pinguiculosa</i> subsp. <i>pinguiculosa</i>	4	Proteaceae	<i>Adenanthos glabrescens</i> subsp. <i>exasperatus</i>	4
	<i>Acacia pusilla</i>	4		<i>Banksia corvijuga</i>	2
	<i>Acacia</i> sp. Ravensthorpe Range (BR Maslin 5463)	3		<i>Banksia foliosissima</i>	4
	<i>Daviesia megacalyx</i>	2		<i>Banksia laevigata</i> subsp. <i>laevigata</i>	4
	<i>Pultenaea calycina</i> subsp. <i>proxena</i>	3		<i>Grevillea fulgens</i>	4
	<i>Pultenaea craigiana</i>	3		<i>Grevillea patentiloba</i> subsp. <i>platypoda</i>	4
	<i>Pultenaea indira</i> subsp. <i>monstrosita</i>	4		<i>Grevillea punctata</i>	3
<i>Pultenaea wudjariensis</i>	2		<i>Grevillea rigida</i> subsp. <i>distans</i>	4	
Goodeniaceae	<i>Dampiera deltoidea</i>	4		<i>Grevillea sulcata</i>	3
	<i>Goodenia phillipsiae</i>	3		<i>Isopogon</i> sp. Ravensthorpe (DB Foreman 1207)	3
	<i>Goodenia stenophylla</i>	3	Rhamnaceae	<i>Spyridium glaucum</i>	3
Lamiaceae	<i>Microcorys pimeleoides</i>	3	Rutaceae	<i>Boronia oxyantha</i> var. <i>brevicalyx</i>	4
Malvaceae	<i>Guichenotia anota</i>	3		<i>Boronia ternata</i> var. <i>elongata</i>	4
	<i>Guichenotia apetala</i>	3		<i>Microcybe pauciflora</i> subsp. <i>grandis</i>	2
Myrtaceae	<i>Calothamnus roseus</i>	2	Sapindaceae	<i>Dodonaea trifida</i>	4
	<i>Eucalyptus cernua</i>	4	Scrophulariaceae	<i>Eremophila densifolia</i> subsp. <i>erecta</i>	4
	<i>Eucalyptus desmondensis</i>	3	Thymelaeaceae	<i>Pimelea physodes</i>	4

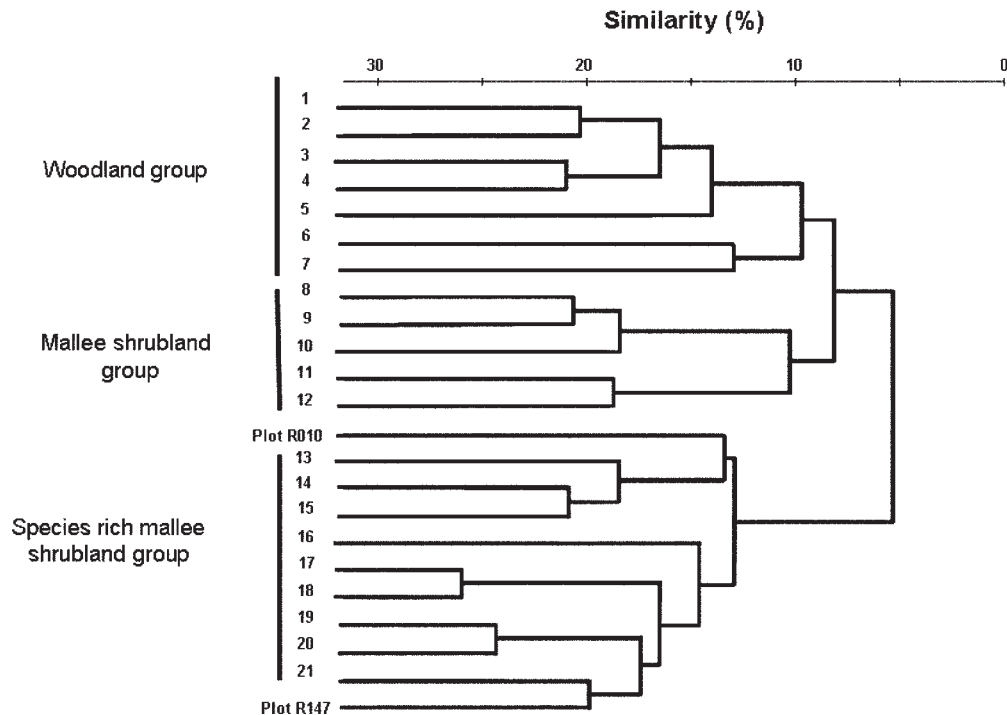


Figure 2. Summary dendrogram of the 21 communities found on the Ravensthorpe Range, derived from the classification of presence/absence data of 580 taxa from 265 plots. Three major groups and the two unallocated plots are shown.

observations. At the highest level in the dendrogram, three broad groups were recognised (Fig. 2). The first group (communities 1–7) are predominately woodlands with average species richness per community of 10–27.8 taxa per plot, generally occurring lower in the landscape. The second group (communities 8–12) are mostly mallee shrublands with moderate levels of species richness (14.8–24.5 taxa per plot), found across the landscape; while the third group (communities 13–21) are species-rich mallee shrublands (16.7–42.7 taxa per plot) generally found high in the landscape. Detailed descriptions of each community are given below.

Woodlands group

Community 1: Lowland *Eucalyptus flocktoniae*/*E. phenax*/*E. calycogona* woodlands.

Map unit(s): Eflo/Ephe (4), Egar (2).

This community consisted of woodlands of mallee and mallots, typically dominated by *Eucalyptus flocktoniae* subsp. *flocktoniae*, *E. phenax* subsp. *phenax* and *E. calycogona* subsp. *calycogona*, but also with *E. gardneri* subsp. *ravensthorpensis* and *E. oleosa* subsp. *corvina* as co-dominant canopy species at some sites. The understorey was usually a sparse assemblage of shrubs, grasses and herbs. This community was found around Overshot Hill and in the central part of the range, usually on the gently- to moderately-inclined lower hillslopes of the range.

Soils: dark red-brown clay loam, no exposed bedrock.

No. plots 8; Taxa/plot (SD) 20.4 ± 2.9; Altitude 202–284 m.

Diagnostic taxa (INDVAL): Trees *Eucalyptus phenax* subsp. *phenax* (19). Shrubs *Acacia* sp. Ravensthorpe Range [BR Maslin

5463] (22), *Enchylaena tomentosa* var. *tomentosa* (16), *Grevillea patentiloba* subsp. *platypoda* (22). Herbs *Austrodanthonia setacea* (17), *Austrostipa acrocliata* (21), *A. hemipogon* (22), *A. sp. Carlingup Rd [S Kern & R Jasper 184959]* (43), *Daucus glochidiatus* (22), *Oxalis perennans* (50), *Ptilotus holosericeus* (63), *Sonchus oleraceus* (20), *Vittadinia gracilis* (25).

Most common taxa (% frequency): Trees *Eucalyptus flocktoniae* subsp. *flocktoniae* (100), *E. phenax* subsp. *phenax* (100), *E. calycogona* subsp. *calycogona* (50), *E. gardneri* subsp. *ravensthorpensis* (25), *E. oleosa* subsp. *corvina* (25), Shrubs *Senna artemisioides* subsp. *x artemisioides* (75), *Acacia glaucoptera* (63), *A. erinacea* (50), *Gastrolobium parviflorum* (50), *Grevillea patentiloba* subsp. *platypoda* (50), *Enchylaena tomentosa* var. *tomentosa* (38), *Exocarpos aphyllus* (38), *Grevillea huegelii* (38), *Lasiopetalum compactum* (38), *Olearia muelleri* (38), *Acacia* sp. Ravensthorpe Range [BR Maslin 5463] (25), *Acrotriche ramiflora* (25), *Boronia inornata* subsp. *inornata* (25), *Dodonaea pinifolia* (25), *Hakea commutata* (25), *Hibbertia psilocarpa* (25), *Melaleuca hamata* (25), *Santalum acuminatum* (25), *Sclerolaena diacantha* (25). Herbs *Austrodanthonia setacea* (63), *Austrostipa hemipogon* (63), *A. sp. Carlingup Rd [S Kern & R Jasper 184959]* (63), *Ptilotus holosericeus* (63), *Oxalis perennans* (50), *Austrostipa acrocliata* (38), *A. elegantissima* (38), *Billardiera fusiformis* (25), *Daucus glochidiatus* (25), *Lepidosperma* sp. Saltbush Hill [KR Newbey 4118] (25), *Platysace maxwellii* (25), *Sonchus oleraceus* (25), *Vittadinia gracilis* (25).

Short range endemics

100–1000 km²: *Acacia* sp. Ravensthorpe Range (BR Maslin 5463), *Eucalyptus gardneri* subsp. *ravensthorpensis*, *Melaleuca ulicoides*.

1000–10,000 km²: *Acacia bifaria*, *A. pusilla*, *Eucalyptus oleosa* subsp. *corvina*, *Grevillea patentiloba* subsp. *platypoda*.

Conservation taxa: *Acacia bifaria* (P3), *A. sp.* Ravensthorpe Range [BR Maslin 5463] (P1).



Figure 3. Community 1, mallee woodland with sparse understorey (survey plot R216).

Community 2: *Eucalyptus salmonophloia* woodlands on lower hillslopes.

Map unit(s): Esal (3), Eflo/Esug (1), Egar (1).

Community 2 typically consisted of *Eucalyptus salmonophloia* tall open forest and woodlands, sometimes co-occurring with *E. gardneri* subsp. *ravensthorpensis* or other eucalypt taxa (*E. phenax*, *E. flocktoniae*) and overtops an open to sparse shrubland. This community type was found on Ravensthorpe Range, near the confluence of the Jerdacuttup River and Cordingup Creek where a fault bisects the Range.

Soils: generally red-brown sandy loams of varying depth, with limited exposure of outcropping bedrock.

No. plots 5; Taxa/plot (SD) 21.2 ± 2.4 ; Altitude 157–204 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus salmonophloia* (80). **Shrubs** *Olearia muelleri* (53), *Acacia crinacca* (41), *Rhagodia crassifolia* (31), *Acacia glaucoptera* (24), *Wilsonia humilis* (19). **Herbs** *Lepidosperma* sp. Mt Chester [S Kern et al. LCH 16596] (58), *Dianella brevicaulis* (50), *Austrostipa pycnostachya* (54), *A. elegantissima* (33), *A. hemipogon* (20).

Most common taxa (% frequency): **Trees** *Eucalyptus salmonophloia* (80), *E. phenax* subsp. *phenax* (40). **Shrubs** *Acacia crinacca* (100), *A. glaucoptera* (100), *Olearia muelleri* (100), *Rhagodia crassifolia* (60), *Wilsonia humilis* (60), *Daviesia nematophylla* (40), *Grevillea pectinata* (40), *Melaleuca hamata* (40), *Santalum acuminatum* (40), *Senna artemisioides* subsp. *x artemisioides* (40). **Herbs** *Austrostipa elegantissima* (80),

Lepidosperma sp. Mt Chester [S. Kern et al. LCH 16596] (80), *Austrostipa hemipogon* (60), *A. pycnostachya* (60), *Dianella brevicaulis* (60), *Austrodanthonia setacea* (40), *Cassytha melanantha* (40), *Dianella revoluta* var. *revoluta* (40), *Gahnia ancistrophylla* (40), *Neurachne alopecuroidea* (40).

Short range endemics

100–1000 km²: *Eucalyptus gardneri* subsp. *ravensthorpensis*.

Conservation taxa: *Cassinia arcuata* (P2).

Community 3: *Eucalyptus flocktoniae*/*E. phenax*/*E. calycogona*/*E. cernua* woodlands over *Melaleuca* spp.

Map unit(s): Eflo/Ephe (5), Eflo/Mgor (3), Edie (1), Eext (1), Eind/Mpau (1), Epil/Edep (1), Mosaic Mallee/Mund & Mspp (1).

This community type was widespread and typically consisted of tall mallee shrublands and mallet woodlands dominated by mixed eucalypts, notably *Eucalyptus flocktoniae* subsp. *flocktoniae*, *E. phenax* subsp. *phenax* and *E. calycogona* subsp. *calycogona*, also with *E. pileata*, *E. cernua* and *E. platypus* as less common canopy eucalypt species. It had a rich assemblage of *Melaleuca* species (*M. cucullata*, *M. pauperiflora*, *M. cliffortioides*, *M. lateriflora* subsp. *lateriflora*) associated with it, and often one or several species would form a dense shrub mid-stratum. There was some suggestion of internal structure within this community and further sampling may resolve subgroups. Community 3 was found on gently- to moderately-inclined hillslopes, from lower to upper slopes but predominantly on midslopes across the range. There was a tendency for the *M. hamata* dominated sites to occur on mid to upper slopes.



Figure 4. Community 2, tall salmon gum woodland (survey plot R196).

Soils: predominantly red-brown to brown clays, with some clay loams; exposed shale bedrock was rare.

No. plots 34; Taxa/plot (SD) 19.0 ± 0.8 ; Altitude 75–334 m

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus calycogona* subsp. *calycogona* (16), *E. phenax* subsp. *phenax* (14). **Shrubs** *Melaleuca ulicooides* (20), *Acacia binata* (18), *Pultenaea purpurea* (15). **Herbs** *Lepidosperma fimbriatum* (15).

Most common taxa (% frequency): **Trees** *Eucalyptus flocktoniae* subsp. *flocktoniae* (91), *E. phenax* subsp. *phenax* (88), *E. calycogona* subsp. *calycogona* (53), *E. cernua* (32). **Shrubs** *Melaleuca ulicooides* (68), *Pultenaea purpurea* (53), *Acacia glaucoptera* (50), *Hakea commutata* (44), *Acacia binata* (41), *Exocarpos aphyllus* (41), *Dodonaea concinna* (38), *Acacia ingrata* (35), *Daviesia nematophylla* (35), *Melaleuca cucullata* (35), *Boronia inornata* subsp. *leptophylla* (29), *Hibbertia psilocarpa* (26), *Melaleuca torquata* (26). **Herbs** *Cassytha melantha* (65), *Lepidosperma fimbriatum* (50), *Lepidosperma gahnioides* (26).

Short range endemics

10–100 km²: *Eucalyptus purpurata*.

100–1000 km²: *Acacia* sp. Ravensthorpe Range (B.R. Maslin 5463), *Eucalyptus gardneri* subsp. *ravensthorpensis*, *Grevillea punctata*, *G. sulcata*, *Melaleuca ulicooides*, *Spyridium glaucum*.

1000–10,000 km²: *Acacia ophiolithica*, *A. pusilla*, *Dodonaea trifida*, *Eucalyptus cernua*, *E. oleosa* subsp. *corvina*, *Melaleuca pomphostoma*.

Conservation taxa: *Acacia* sp. Ravensthorpe Range [BR Maslin 5463] (P1), *Eucalyptus purpurata* (R), *Grevillea fastigiata* (P4), *G. punctata* (P3), *G. sulcata* (P1).

Community 4: *Eucalyptus tenera*/*E. flocktoniae*/*E. pileata* tall mallee shrublands over *Melaleuca* spp.

Map unit(s): Epil/Edep/Mspp (2), Epil/Edep (1), Eunc/Espp (1).

Note: Since vegetation mapping was undertaken many Ravensthorpe Range collections of *Eucalyptus depauperata* have been redetermined as *Eucalyptus tenera*.

Community 4 was described from five plots, and consisted of tall mallee shrublands comprised of a number of eucalypt species, most commonly *E. tenera*, *E. flocktoniae*, *E. pileata* and *E. phaenophylla*. Unlike community 3, *E. phenax* was notably absent from this community. A variety of species of *Melaleuca* was found in the tall shrub stratum, many of these common to, or characteristic of, the community type. All sites were located in the northern section of the range, on the gently inclined, lower slopes around Mt Short and Overshot Hill.

Soils: red-brown to brown coloured, light to heavy clays and clay loams, relatively deep with no exposed bedrock.

No. plots 5; Taxa/plot (SD) 25.2 ± 2.4 ; Altitude 285–308 m

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus tenera* (67), *E. pileata*



Figure 5. Community 3, typical mallee woodland over dense *Melaleuca* shrubland (survey plot R140).



Figure 6. Community 4, tall mallee shrubland (survey plot R107) on north end of the range.

(29), *E. flocktoniae* subsp. *flocktoniae* (16). **Shrubs** *Melaleuca societatis* (60), *M. undulata* (57), *M. teuthidooides* (45), *M. johnsonii* (40), *M. coronicarpa* (30), *Daviesia benthamii* (24), *Melaleuca torquata* (24), *Microcybe albiiflora* (24), *Pultenaea purpurea* (19), *Grevillea pectinata* (18), *Melaleuca acuminata* subsp. *acuminata* (18), *Thomasia microphylla* (17). **Herbs** *Lepidosperma* sp. [GF Craig 8243] (23), *L. sp.* Maydon [S Kern et al. LCH 17844] (22), *Cassytha melantha* (17).

Most common taxa (% frequency): **Trees** *Eucalyptus flocktoniae* subsp. *flocktoniae* (100), *E. tenera* (80), *E. pilcata* (80), *E. phaenophylla* (60), *E. calycogona* subsp. *calycogona* (40). **Shrubs** *Exocarpos aphyllus* (60), *Grevillea pectinata* (60), *Hibbertia psilocarpa* (60), *Melaleuca societatis* (60), *M. teuthidooides* (60), *M. torquata* (60), *M. undulata* (60), *Pultenaea purpurea* (60), *Spyridium cordatum* (60), *Boronia inconspicua* (40), *B. inornata* subsp. *leptophylla* (40), *Cooperookia strophiolata* (40), *Daviesia benthamii* (40), *Gastrolobium parviflorum* (40), *Hakea commutata* (40), *Hibbertia pungens* (40), *Melaleuca acuminata* subsp. *acuminata* (40), *M. coronicarpa* (40), *M. cucullata* (40), *M. glaberrima* (40), *M. hamata* (40), *M. johnsonii* (40), *M. lateriflora* subsp. *lateriflora* (40), *M. pauperiflora* subsp. *pauperiflora* (40), *Microcybe albiiflora* (40), *Thomasia microphylla* (40), *Wilsonia humilis* (40). **Herbs** *Cassytha melantha* (80), *Gahnia ancistrophylla* (40), *Lepidosperma* sp. Bandalup Scabrid [N Eveleigh 10798] (40), *L. sp.* [GF Craig 8243] (40), *L. sp.* Maydon [S Kern et al. LCH 17844] (40).

Short range endemics

1000–10,000 km²: *Acacia pusilla*.

Conservation taxa: none recorded.

Community 5: *Eucalyptus clivicola*/*E. extensa*/*E. platypus* woodlands and open forest.

Map unit(s): Ecli (2), Ecer (1), Eext (1), Epla (1), Epla/Mcuc (1), Esab (1).

Community 5 consisted of woodlands and open forests most commonly dominated by mixtures of *Eucalyptus clivicola*, *E. extensa*, *E. platypus*, *E. flocktoniae* and/or *E. pilcata*. Many of the dominant tree species were mallots. The understorey shrub stratum was typically sparse and the diversity of taxa in the understorey was low. Community 5 was present across most of the range except for the area around Bandalup Hill on gently to moderately inclined, lower to middle hill slopes.

Soils: clay and clay loams to sandy clays with no exposed bedrock.

No. plots 12; Taxa/plot (SD) 11.8 ± 1.5; Altitude 102–369 m

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus platypus* (33), *E. extensa* (31), *E. clivicola* (21).

Most common taxa (% frequency): **Trees** *Eucalyptus clivicola* (67), *E. extensa* (58), *E. flocktoniae* subsp. *flocktoniae* (58), *E. pilcata* (50), *E. platypus* (50). **Shrubs** *Exocarpos aphyllus* (50), *Acacia glaucoptera* (42), *Melaleuca torquata* (42), *Lasiopetalum compactum* (33), *Melaleuca cucullata* (33), *Boronia inornata* subsp. *leptophylla* (25), *Grevillea patentiloba* subsp. *patentiloba* (25), *G. pectinata* (25), *Hibbertia psilocarpa* (25), *Melaleuca hamata* (25), *Microcybe albiiflora* (25), *Olearia muelleri* (25). **Herbs** *Lepidosperma* sp. Bandalup Scabrid [N Eveleigh 10798] (25), *L. sp.* Ravensthorpe [GF Craig 5188] (25).



Figure 7. Community 5, often a mallet woodland over a sparse understorey (survey plot R198).

Short range endemics

100–1000 km²: *Melaleuca ulicoides*, *Pultenaca craigiana*.

1000–10,000 km²: *Eucalyptus cernua*, *E. oleosa* subsp. *corvina*.

Conservation taxa: *Pultenaca craigiana* (P3).

Community 6: *Eucalyptus gardneri* subsp. *ravensthorpensis* woodlands and tall open forest.

Map unit(s): Egar (2), Emeg (1).

This community consisted of woodlands and tall open forests of *Eucalyptus gardneri* subsp. *ravensthorpensis*, often with the co-occurrence of both *E. cernua* and *E. phenax*, and *E. megacornuta* on occasion. The associated understorey was usually sparse; it occurred on moderately to steeply inclined upper hill slopes. Plots of this community type were located along the main ridges in the central region of the main range and also on Overshot Hill.

Soils: red-brown clay loam soils with minimal or no exposure of bedrock.

No. plots 5; Taxa/plot (SD) 9.8 ± 1.3; Altitude 178–321 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus gardneri* subsp. *ravensthorpensis* (53), *E. cernua* (25). **Shrubs** *Boronia oxyantha* var. *brevicalyx* (26), *Spyridium glaucum* (24), *Gastrolobium parviflorum* (14).

Most common taxa (% frequency): **Trees** *Eucalyptus gardneri* subsp. *ravensthorpensis* (100), *E. cernua* (60), *E. phenax* subsp. *phenax* (60). **Shrubs** *Boronia oxyantha* var. *brevicalyx* (80), *Gastrolobium parviflorum* (80), *Spyridium glaucum* (60), *Acacia erinacea* (40), *Beyeria sulcata* var. *brevipes* (40), *Exocarpos aphyllus* (40), *Persoonia teretifolia* (40).

Short range endemics

100–1000 km²: *Eucalyptus gardneri* subsp. *ravensthorpensis*, *Spyridium glaucum*.

1000–10,000 km²: *Boronia oxyantha* var. *brevicalyx*, *Eucalyptus cernua*, *E. megacornuta*.

Conservation taxa: none recorded.

Community 7: *Eucalyptus astringens*/*E. clivicola* woodlands.

Map unit(s): East (1), Epla (1).

Community 7 was variable, typically dominated by woodlands of *Eucalyptus astringens* and *E. clivicola*. However, one site was an *E. leptocalyx*/*E. flocktoniae*/*E. phaenophylla* open mallee shrubland over dense *Melaleuca stramentosa* shrubland. These woodlands occurred both in the north and south of the range, were typically species poor and usually recorded on gently to moderately inclined midslopes.

Soils: grey to grey-brown sandy clay loams with no exposed bedrock.



Figure 8. Community 6, forming open woodlands along the range crest (survey plot R095).



Figure 9. Community 7, typically open woodlands (survey plot R171), but mallee shrublands were also encountered.

No. plots 4; Taxa/plot (SD) 12.8 ± 1.9 ; Altitude 129–335 m.

Diagnostic taxa (INDVAL): Trees *Eucalyptus astringens* (75), *E. clivicola* (26). Shrubs *Melaleuca stramentosa* (48), *Dodonaea trifida* (47), *Boronia oxyantha* var. *brevicalyx* (23). Herbs *Lepidosperma* sp. [GF Craig 8249] (22).

Most common taxa (% frequency): Trees *Eucalyptus astringens* (75), *E. clivicola* (75), *E. flocktoniae* subsp. *flocktoniae* (50), *E. falcata* subsp. *falcata* (25), *E. incrassata* (25), *E. leptocalyx* (25), *E. phaenophylla* (25), *E. suggrandis* subsp. *suggrandis* (25). Shrubs *Boronia oxyantha* var. *brevicalyx* (75), *Melaleuca stramentosa* (75), *Baeckea corynophylla* (50), *Dodonaea trifida* (50), *Exocarpos aphyllus* (50), *Melaleuca hamata* (50), *Acacia gonophylla* (25), *A. patagiata* (25), *Acrotriche parviflora* (25), *Boronia inconspicua* (25), *Chorizema trigonum* (25), *Daviesia articulata* (25), *D. lancifolia* (25), *Dodonaea amblyophylla* (25), *Gastrolobium parviflorum* (25), *Gompholobium confertum* (25), *Grevillea patentiloba* subsp. *patentiloba* (25), *Hakea laurina* (25), *Hibbertia psilocarpa* (25), *Lasiopetalum compactum* (25), *Melaleuca bracteosa* (25), *Nematolepis phebaloides* (25), *Rinzia communis* (25), *Siegfriedia darwinoides* (25), *Spyridium glaucum* (25), *Templetonia retusa* (25), *Thomasia microphylla* (25). Herbs *Lepidosperma* sp. [GF Craig 8249] (25), *L.* sp. Mt Chester [S Kern et al. LCH 16596] (25), *L.* sp. Ravensthorpe [GF Craig 5188] (25).

Short range endemics

100–1000 km²: *Melaleuca stramentosa*, *Spyridium glaucum*.

1000–10,000 km²: *Boronia oxyantha* var. *brevicalyx*, *Dodonaea trifida*.

Conservation taxa: *Acrotriche parviflora* (P4).

Mallee shrubland group

Community 8: *Eucalyptus* sp. Ravensthorpe (AS George 616) tall mallee shrubland or *Allocasuarina*/*Melaleuca* shrublands.

Map unit(s): Edes/Alca (1), Epro/Mspp (1), EspR/Mcli (1).

This community was structurally heterogeneous, typically being *Eucalyptus* sp. Ravensthorpe (AS George 616) tall mallee shrubland. Less frequent canopy eucalypt species included *E. flocktoniae*, *E. phenax*, *E. proxima* and *E. brachycalyx*, while *Allocasuarina* (*A. campestris* or *A. hystricosa*) and *Melaleuca* formed the dominant canopy stratum at some sites. All plots classified as this community were located in the south-eastern region of the Ravensthorpe Range, on gently undulating, hilly terrain east of the main ridges. Sites were generally gently to moderately inclined hillslopes, occurring from lower slopes to hillcrests.

Soils: typically red-brown clays with occasional metavolcanic outcropping.

No. plots 12; Taxa/plot (SD) 23.0 ± 2.0 ; Altitude 84–190 m.

Diagnostic taxa (INDVAL): Trees *Eucalyptus* sp. Ravensthorpe [AS George 616] (20). Shrubs *Calytrix tetragona* (48), *Grevillea fastigiata* (39), *Cryptandra myriantha* (33), *Styphelia pulchella* (25), *Dodonaea pinifolia* (22), *Hibbertia rostellata* (19), *Calothamnus quadrifidus* (18), *Hybanthus floribundus* subsp. *adpressus* (17). Herbs *Stackhousia monogyna* (34), *Lepidosperma diurnum* (32), *Neurachne alopecuroidea* (16), *Wurmbea cernua* (15).

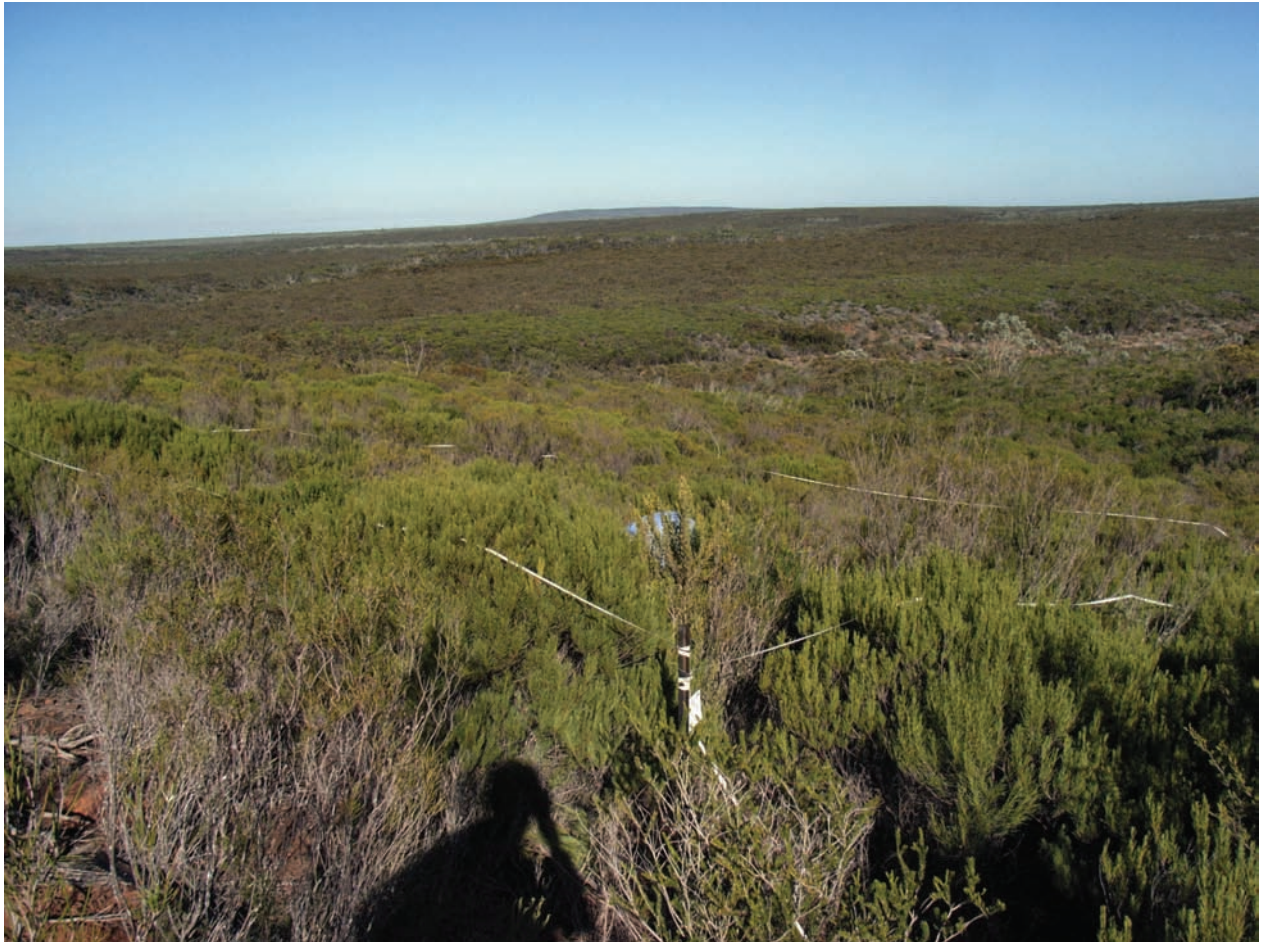


Figure 10. Community 8, forming dense tall shrublands (survey plot R047) on the south-eastern section of the range.

Most common taxa (% frequency): **Trees** *Eucalyptus* sp. Ravensthorpe [AS George 616] (58). **Shrubs** *Dodonaea pinifolia* (92), *Hakea verrucosa* (75), *Hibbertia pungens* (75), *Calothamnus quadrifidus* (67), *Calytrix tetragona* (67), *Melaleuca hamata* (67), *Hybanthus floribundus* subsp. *adpressus* (58), *Acacia ophiolithica* (50), *Daviesia anceps* (50), *Astroloma epacridis* (42), *Grevillea fastigiata* (42), *Melaleuca cliffortioides* (42), *Stryphelia pulchella* (42), *Astroloma serratifolium* (33), *Cryptandra myriantha* (33), *Hibbertia rostellata* (33), *Acacia glaucoptera* (25), *Allocasuarina campestris* (25), *A. hystricosa* (25), *Grevillea oligantha* (25), *Halgania andromedifolia* (25), *Petrophile fastigiata* (25), *Verticordia acerosa* var. *preissii* (25). **Herbs** *Neurachne alopecuroidea* (83), *Lepidosperma diurnum* (75), *Stackhousia monogyna* (50), *Cassylia glabella* (42), *Dianella revoluta* var. *revoluta* (42), *Dampiera lavandulacea* (33), *Wurmbea cernua* (33), *Gahnia ancistrophylla* (25), *Spartochloa scirpoides* (25).

Short range endemics

100–1000 km²: *Kunzea cincinnata*, *Pultenaea calycina* subsp. *proxena*.

1000–10,000 km²: *Acacia ophiolithica*, *Allocasuarina hystricosa*.

Conservation taxa: *Allocasuarina hystricosa* (P4), *Grevillea fastigiata* (P4), *Pultenaea calycina* subsp. *proxena* (P4).

Community 9: *Eucalyptus phenax*/*E. cernua* over *Melaleuca cliffortioides* and *Acacia ophiolithica*.

Map unit(s): EspR/Mcl1 (1).

Community 9 generally consisted of tall mallee shrubland dominated by *Eucalyptus phenax* and/or *E. cernua*, also with *E. leptocalyx* or *E. calycogona* as less common canopy species. The shrub stratum ranged from mid-dense to dense in structure. Significant indicator species included the vulnerable, DRF-listed *Beyeria cockertonii*. This community generally occurred on gently to moderately inclined hill slopes, on the lower to mid slopes of low, undulating hills on the eastern side of the main range and on Bandalup Hill.

Soils: rocky grey-brown medium to heavy clays, with no exposed bedrock.

No. plots 5; Taxa/plot (SD) 22.8 ± 4.6; Altitude 123–231 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus leptocalyx* (19). **Shrubs** *Beyeria cockertonii* (60), *Grevillea oligantha* (28), *Melaleuca pomphostoma* (24), *Hakea verrucosa* (23), *Pultenaea rotundifolia* (23), *Melaleuca cliffortioides* (21), *Acacia ophiolithica* (17), *Dodonaea pinifolia* (16), *Melaleuca ulicoides* (16), *Acacia glaucoptera* (15). **Herbs** *Wurmbea cernua* (22).

Most common taxa (% frequency): **Trees** *Eucalyptus phenax* subsp. *phenax* (80), *E. leptocalyx* (60), *E. cernua* (40), *E. uncinata* (40). **Shrubs** *Hakea verrucosa* (100), *Acacia glaucoptera* (80), *Dodonaea pinifolia* (80), *Grevillea oligantha* (80), *Acacia ophiolithica* (60), *Beyeria cockertonii* (60), *Daviesia anceps* (60), *Hibbertia psilocarpa* (60), *Melaleuca cliffortioides* (60), *Melaleuca ulicoides* (60), *Acrotriche cordata* (40), *Cryptandra wilsonii* (40), *Hakea commutata* (40), *Halgania andromedifolia* (40), *Hybanthus floribundus* subsp. *adpressus* (40), *Logania buxifolia* (40), *Melaleuca lateriflora* subsp. *lateriflora* (40), *M. pomphostoma* (40), *Nematolepis phebalioides*



Figure 11. Community 9 was found scattered along the range and most often formed tall open mallees over a dense understorey (survey plot R092).



Figure 12. Community 10, dense *Melaleuca pomphostoma* shrubland on skeletal soils, apparently restricted to Overshot Hill (survey plot R205).

(40), *Pomaderris brevifolia* (40), *Pultenaea rotundifolia* (40), *Santalum acuminatum* (40). **Herbs** *Gahnia aristata* (40), *Lepidosperma diurnum* (40), *Wurmbea cernua* (40).

Short range endemics

10–100 km²: *Beyeria cockertonii*, *Pultenaea wudjariensis*.

100–1000 km²: *Leucopogon infuscatus*, *Melaleuca ulicoides*, *Pultenaea calycina* subsp. *proxena*.

1000–10,000 km²: *Acacia ophiolithica*, *Eucalyptus cernua*, *Melaleuca pomphostoma*.

Conservation taxa: *Beyeria cockertonii* (R), *Pultenaea calycina* subsp. *proxena* (P4), *P. wudjariensis* (P1)

Community 10: *Melaleuca pomphostoma* heaths on skeletal soils on outcrops.

Map unit(s): not mapped.

This community was found at only two sites, both of which occurred on Overshot Hill Nature Reserve. Structurally, it formed a dense shrubland dominated by a variety of taxa, notably *Melaleuca pomphostoma* and *Hakea verrucosa*. Over this dense shrubland were emergent tall shrubs and mallets of *Eucalyptus cernua* that appear to be outliers from the adjacent mallet woodlands. *Allocasuarina huegeliana* was an additional emergent tree in the site near the crest of Mt Short. This community was found on both crests and lower down the slope in gently inclined, shallow valleys eroded into the hillside.

Soils: skeletal to shallow red-brown sandy clay loams with significant exposure of the metavolcanic bedrock.

No. plots 2; Taxa/plot (SD) 21.0 ± 2.0; Altitude 326–372 m.

Diagnostic taxa: insufficient plots.

Most common taxa: insufficient plots.

Short range endemics

1000–10,000 km²: *Eucalyptus cernua*, *Melaleuca pomphostoma*.

Conservation taxa: none recorded.

Community 11: *Eucalyptus brachycalyx*/*E. indurata* tall, open mallee shrublands.

Map unit(s): Ebra (1), Eind/Mpau (1), Eole/Mpau (1).

Community 11 typically consisted of tall, open mallee shrublands typically dominated by *Eucalyptus brachycalyx* and *E. indurata*, but also having *E. purpurata* or *E. sp.* Ravensthorpe (AS George 616) as dominant species at some sites. The shrub understorey tended to be structurally dominated by a few main taxa, a number of which (*Leptomeria pachyclada*, *Pultenaea calycina* subsp. *proxena*), are restricted to the south-eastern part of the range, and some species (*E. purpurata* and *Acrotriche orbicularis*) are restricted to Bandalup Hill. Community 11 occurred on the gently inclined mid to upper slopes of low, undulating hills on the eastern side of the main range and on Bandalup Hill.



Figure 13. Community 11 was structurally variable, here forming a low open woodland (survey plot R086) on the south-eastern side of the main range and Bandalup Hill.

Soils: generally rocky brown silty loams – silty clay loams with some magnesite from weathered ultramafics. There was limited magnesite outcrop.

No. plots 15; Taxa/plot (SD) 16.4 ± 2.1 ; Altitude 106–244 m.

Diagnostic taxa (INDVAL): Trees *Eucalyptus indurata* (56), *E. brachycalyx* (38). Shrubs *Beyeria villosa* (53), *Pultenaca calycina* subsp. *proxena* (42), *Melaleuca pauperiflora* subsp. *pauperiflora* (35), *Leptomeria pachyclada* (20), *Melaleuca brevifolia* (20), *Acacia ingrata* (19), *A. mutabilis* subsp. *mutabilis* (19), *Boronia inornata* subsp. *inornata* (17), *Halgania andromedifolia* (14).

Most common taxa (% frequency): Trees *Eucalyptus brachycalyx* (87), *E. indurata* (80). Shrubs *Acacia ingrata* (80), *Melaleuca pauperiflora* subsp. *pauperiflora* (80), *Boronia inornata* subsp. *inornata* (67), *Pultenaca calycina* subsp. *proxena* (67), *Halgania andromedifolia* (60), *Beyeria villosa* (53), *Hakea verrucosa* (47), *Pomaderris brevifolia* (47), *Dodonaea concinna* (40), *Leptomeria pachyclada* (40), *Westringia dampieri* (40), *Daviesia anceps* (33), *Nematolepis phebalioides* (33), *Acacia mutabilis* subsp. *mutabilis* (27), *Exocarpos sparteus* (27), *Hibbertia rostellata* (27), *Melaleuca cliffortioides* (27). Herbs *Cassytha glabella* (33), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (27).

Short range endemics

0–10 km²: *Acrotriche orbicularis*.

10–100 km²: *Eucalyptus purpurata*.

100–1000 km²: *Beyeria villosa*, *Melaleuca ulicoides*, *Pultenaca calycina* subsp. *proxena*.

1000–10,000 km²: *Acacia ophiolithica*, *Eucalyptus oleosa* subsp. *corvina*.

Conservation taxa: *Acrotriche orbicularis*, *Beyeria villosa* (P4), *Eucalyptus purpurata* (R), *Pultenaca calycina* subsp. *proxena* (P4).

Community 12: *Eucalyptus oleosa* subsp. *corvina* tall, open mallee shrubland and open forest.

Map unit(s): Eole (2), EspR/Mcli (1).

A small, structurally heterogeneous group closely allied to community 11, community 12 consisted of tall, open mallee shrubland and open forest dominated by *Eucalyptus oleosa* subsp. *corvina*, co-occurring with other eucalypt species (*E. brachycalyx*, *E. calycogona*, *E. myriadena* subsp. *myriadena*). The shrub understorey was structurally sparse. Sites of this community were located on the on slopes east of the main range in the central to south-east part of the range on lower to upper slopes. The sites varied from gentle to steep.

Soils: typically brown to grey clay loams and clays, sometimes with komatiite and magnesite outcropping. Soils and surface shale, komatiite and magnesite were derived from underlying mafic and ultramafic substrates.

No. plots 4; Taxa/plot (SD) 13.8 ± 0.8 ; Altitude 102–214 m.

Diagnostic taxa (INDVAL): Trees *Eucalyptus oleosa* subsp. *corvina* (65), *E. celastroides* subsp. *virella* (22). Shrubs *Boronia inornata*



Figure 14. Community 12 was also structurally variable here forming a tall mallee shrubland (survey plot R028) was also found on the eastern side of main range.

subsp. *inornata* (38), *Rhagodia crassifolia* (21), *Senna artemisioides* subsp. *x artemisioides* (21).

Most common taxa (% frequency): Trees *Eucalyptus oleosa* subsp. *corvina* (100), *E. brachycalyx* (50), *E. cclastroides* subsp. *virella* (25), *E. clivicola* (25), *E. extensa* (25), *E. incurata* (25), *E. myriadena* subsp. *myriadena* (25), *E. phenax* subsp. *phenax* (25), *E. pileata* (25). **Shrubs** *Boronia inornata* subsp. *inornata* (100), *Senna artemisioides* subsp. *x artemisioides* (75), *Acacia glaucoptera* (50), *A. ingrata* (50), *Exocarpos aphyllus* (50), *Hovea acanthoclada* (50), *Lasiopetalum compactum* (50), *Rhagodia crassifolia* (50), *Santalum acuminatum* (50), *Acacia cyclops* (25), *A. erinacca* (25), *Atriplex semibaccata* (25), *Dodonaea concinna* (25), *Enchylaena tomentosa* var. *tomentosa* (25), *Exocarpos sparteus* (25), *Halgania andromedifolia* (25), *Hibbertia psilocarpa* (25), *Melaleuca acuminata* subsp. *acuminata* (25), *M. pauperiflora* subsp. *pauperiflora* (25), *Nematolepis phebalioides* (25), *Olcara muelleri* (25), *Phyllanthus scaber* (25), *Pultenaca purpurea* (25), *Westringia dampieri* (25). **Herbs** *Austrostipa elegantissima* (50), *A. exilis* (25), *Lepidosperma fimbriatum* (25), *L. sp.* Saltbush Hill [KR Newbey 4118] (25), *Platysacc maxwellii* (25).

Short range endemics

1000–10,000 km²: *Eucalyptus oleosa* subsp. *corvina*.

Conservation taxa: none recorded.

Species-rich mallee shrubland group

Community 13: Upper slope *Eucalyptus gardneri* subsp. *ravensthorpensis*/*E. clivicola*/*E. falcata* woodlands/mallee shrublands.

Map unit(s): Ecli (5), Egar (5), Efal (3), Efal/Eple (2), Mham (2), Efal/Alca (1), Emeg (1).

Community 13 usually consisted of woodlands and mallee shrublands dominated by *Eucalyptus gardneri* subsp. *ravensthorpensis* and *E. falcata* subsp. *falcata*, but *E. clivicola* was also a frequent canopy species. The understorey was typically an open shrubland composed commonly of the taller shrubland species. *Melaleuca thapsina* is a distinctive tall shrub that was found at some sites as dense stands within a distinctive belt on the upper slopes of the range. At some sites, it formed thickets under very sparse stands of *E. pleurocarpa* and/or *E. falcata* mallee shrubs. As with other woodland communities, species richness was relatively low. This community was mostly found in the central part of the range typically on mid to upper hillslopes, where the slope varies from gentle to steep.

Soils: rocky red-brown to dark brown clay loams and clay loam sands. Exposed bedrock included massive gossan.

No. plots 23; Taxa/plot (SD) 16.5 ± 1.1; Altitude 119–339 m.



Figure 15. Community 13 was one of the most structurally variable communities, here forming an open woodland (survey plot R261).

Diagnostic taxa (INDVAL): Shrubs *Phebalium tuberculatum* (48), *Trymalium clachophyllum* (16).

Most common taxa (% frequency): Trees *Eucalyptus falcata* subsp. *falcata* (74), *E. clivicola* (39), *E. gardneri* subsp. *ravensthorpensis* (39). Shrubs *Gastrolobium parviflorum* (74), *Melaleuca hamata* (65), *Phebalium tuberculatum* (65), *Dodonaea pinifolia* (43), *Hibbertia pungens* (43), *Lasiopetalum compactum* (43), *Santalum acuminatum* (43), *Beyeria sulcata* var. *brevipes* (39), *Labichea lanceolata* subsp. *brevifolia* (30), *Acacia* sp. Ravensthorpe [RS Cowan & BR Maslin RSC A-760] (26), *Hakea laurina* (26), *Philotheca gardneri* subsp. *gardneri* (26), *Trymalium clachophyllum* (26). Herbs *Platysace maxwellii* (61), *Austrodanthonia setacea* (39), *Austrostipa hemipogon* (30), *Stylidium albomontis* (30), *Lepidosperma* sp. Cordingup [GF Craig 6138] (26), *Thysanotus patersonii* (26).

Short range endemics

100–1000 km²: *Eucalyptus gardneri* subsp. *ravensthorpensis*, *Isopogon* sp. Ravensthorpe (DB Foreman 1207), *Kunzea cincinnata*, *Spyridium glaucum*.

1000–10,000 km²: *Acacia durabilis*, *A. pusilla*, *Boronia oxyantha* var. *brevicalyx*, *B. ternata* var. *elongata*, *Eucalyptus megacornuta*, *Grevillea patentiloba* subsp. *platypoda*.

Community 14: Upland *Eucalyptus falcata*, *E. pleurocarpa*, *Beaufortia orbifolia*, *Banksia* spp. mallee shrublands.

Map unit(s): Efal/Eple (13), Blac/Borb (3), Ecli (1), Efal (1), Efal/Alca (1), Eunc/Espp (1).

Community 14 consisted of upland *Eucalyptus falcata*/*E. pleurocarpa* mallee shrublands that occur on the lateritic duricrust that covers the ridges of the main range. This community was structurally heterogeneous. These shrub mallees overtopped a tall, mid-dense to dense shrub stratum. On occasion, this upper shrub stratum was dominated by stands of *Allocasuarina acutivalvis* subsp. *acutivalvis* or *A. campestris*. Most collections of the relatively uncommon and endemic species, *Hibbertia atrichosepala* were from this community type. Community 14 was located across the north–south extent of the range, mostly on the gently to moderately inclined mid to upper hillslopes and extending up onto crests. These are areas of the range where laterite has formed from in situ weathering.

Soils: stony brown sandy loams, with infrequent outcropping of bedrock—usually laterite and occasionally some metavolcanics/gossan.

No. plots 26; Taxa/plot (SD) 24.9 ± 1.7; Altitude 119–447 m.

Diagnostic taxa (INDVAL): Trees *Eucalyptus falcata* subsp. *falcata* (17), *E. pleurocarpa* (14). Shrubs *Philotheca gardneri* subsp. *gardneri* (34), *Brachyloma geissoloma* subsp. *geissoloma* (29), *Beaufortia orbifolia* (27), *Acacia* sp. Ravensthorpe [RS Cowan & BR Maslin RSC A-760] (18), *Banksia laevigata* subsp. *laevigata* (18), *Boronia ternata* var. *elongata* (18), *Hakea multilineata* (17), *Isopogon* sp. Ravensthorpe [DB Foreman 1207] (15), *Hakea obtusa* (14).

Most common taxa (% frequency): Trees *Eucalyptus falcata* subsp. *falcata* (92), *E. pleurocarpa* (85), *E. uncinata* (31). Shrubs *Beaufortia orbifolia* (69), *Hakea obtusa* (65), *Melaleuca hamata* (65), *Gastrolobium parviflorum* (62), *Philotheca gardneri* subsp. *gardneri* (62), *Acacia* sp. Ravensthorpe [RS Cowan & BR Maslin RSC A-



Figure 16. Community 14, open mallee shrubland on the lateritic ridges along main range (survey plot R250).

760] (54), *Santalum acuminatum* (50), *Hibbertia gracilipes* (46), *Isopogon* sp. Ravensthorpe [DB Foreman 1207] (46), *Brachyloma geissoloma* subsp. *geissoloma* (38), *Lasiopetalum compactum* (38), *Acrotriche ramiflora* (35), *Beyeria sulcata* var. *brevipes* (35), *Goodenia pinifolia* (35), *Leucopogon cuneifolius* (35), *Banksia laevigata* subsp. *laevigata* (31), *Calothamnus quadrifidus* (31), *Hakea verrucosa* (31), *Rhadinanthus rudis* subsp. *amblycarpus* (31), *Boronia ternata* var. *elongata* (27), *Persoonia teretifolia* (27). **Herbs** *Stylidium albomontis* (65), *Lepidosperma* sp. [RL Barrett 3553] (46), *L. sp.* Cordingup [GF Craig 6138] (42), *Platysace maxwellii* (31), *Dampiera angulata* subsp. *angulata* (27).

Short range endemics

0–10 km²: *Hibbertia atrichosepala*.

100–1000 km²: *Guichenotia anota*, *G. apetalata*, *Isopogon* sp. Ravensthorpe (DB Foreman 1207), *Kunzea cincinnata*, *Marianthus mollis*, *Micromyrtus navicularis*, *Spyridium glaucum*

1000–10,000 km²: *Acacia heterochroa* subsp. *heterochroa*, *A. ophiolithica*, *A. pinguiculosa* subsp. *pinguiculosa*, *Banksia laevigata* subsp. *laevigata*, *Boronia ternata* var. *elongata*, *Grevillea patentiloba* subsp. *platypoda*, *Leptospermum* sp. Bandalup Hill (G Cockerton 11001), *Melaleuca pomphostoma*.

Conservation taxa: *Banksia laevigata* subsp. *laevigata* (P4), *Guichenotia anota* (P1), *G. apetalata* (P1), *Hibbertia atrichosepala* (P1), *Marianthus mollis* (R), *Micromyrtus navicularis* (P3), *Pterostylis* sp. Ongerup [KR Newbey 4874] (P4).

Community 15: *Eucalyptus* spp/*Banksia lehmanniana*/*B. heliantha* mallee shrublands.

Map unit(s): Dque (1), Efal/Eple (1), Mstr (1).

Community 15 has close floristic affinities to community 14. This community consisted of mixed *Eucalyptus* mallee shrublands, where

a variety of combinations of *Eucalyptus* species were co-dominant, including *E. pleurocarpa*, *E. falcata* subsp. *falcata*, *E. uncinata*, *E. preissiana* subsp. *preissiana* and *E. lehmannii* subsp. *parallela* over a tall shrubland. *Lepidosperma* sp. (AS George 9935) was a common understorey sedge on the slopes of Bandalup Hill. Community 15 was located on the crest of Bandalup Hill, and around Mt Desmond and Mt Chester on the southern parts of the main range ridge. This community was typically associated with moderately-inclined hill slopes, generally on upper slopes but ranging from lower slopes to crests.

Soils: variable in texture from brown to grey sandy loams, to clays and clay sands.

No. plots 6; Taxa/plot (SD) 32.5 ± 1.2; Altitude 165–315 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus preissiana* subsp. *preissiana* (34), *E. lehmannii* subsp. *parallela* (32). **Shrubs** *Banksia heliantha* (36), *Grevillea concinna* subsp. *lehmanniana* (33), *Hakea obtusa* (33), *Andersonia* aff. *lehmanniana* [S Kern & R Jasper LCH 17769] (31), *Beaufortia orbifolia* (25), *Boronia subsessilis* (24), *Daviesia mollis* (23), *Grevillea nudiflora* (19), *Leucopogon carinatus* (19), *L. infuscatus* (19), *Boronia oxyantha* var. *brevicalyx* (18), *Spyridium majoranifolium* (18), *Chorizema trigonum* (17), *Taxandria spathulata* (17), *Hovea acanthoclada* (16). **Herbs** *Stylidium albomontis* (19), *Lepidosperma* sp. Cordingup [GF Craig 6138] (18).

Most common taxa (% frequency): **Trees** *Eucalyptus pleurocarpa* (67), *E. uncinata* (67), *E. preissiana* subsp. *preissiana* (50), *E. lehmannii* subsp. *parallela* (50), *E. falcata* subsp. *falcata* (33), *E. incrassata* (33), *E. pluricaulis* subsp. *pluricaulis* (33). **Shrubs** *Hakea obtusa* (100), *Banksia heliantha* (83), *Beaufortia orbifolia* (67), *Boronia oxyantha* var. *brevicalyx* (67), *Gastrolobium parviflorum* (67), *Hibbertia pungens* (67), *Hovea acanthoclada* (67), *Taxandria spathulata* (67), *Acrotriche cordata* (50), *A. ramiflora* (50), *Banksia*

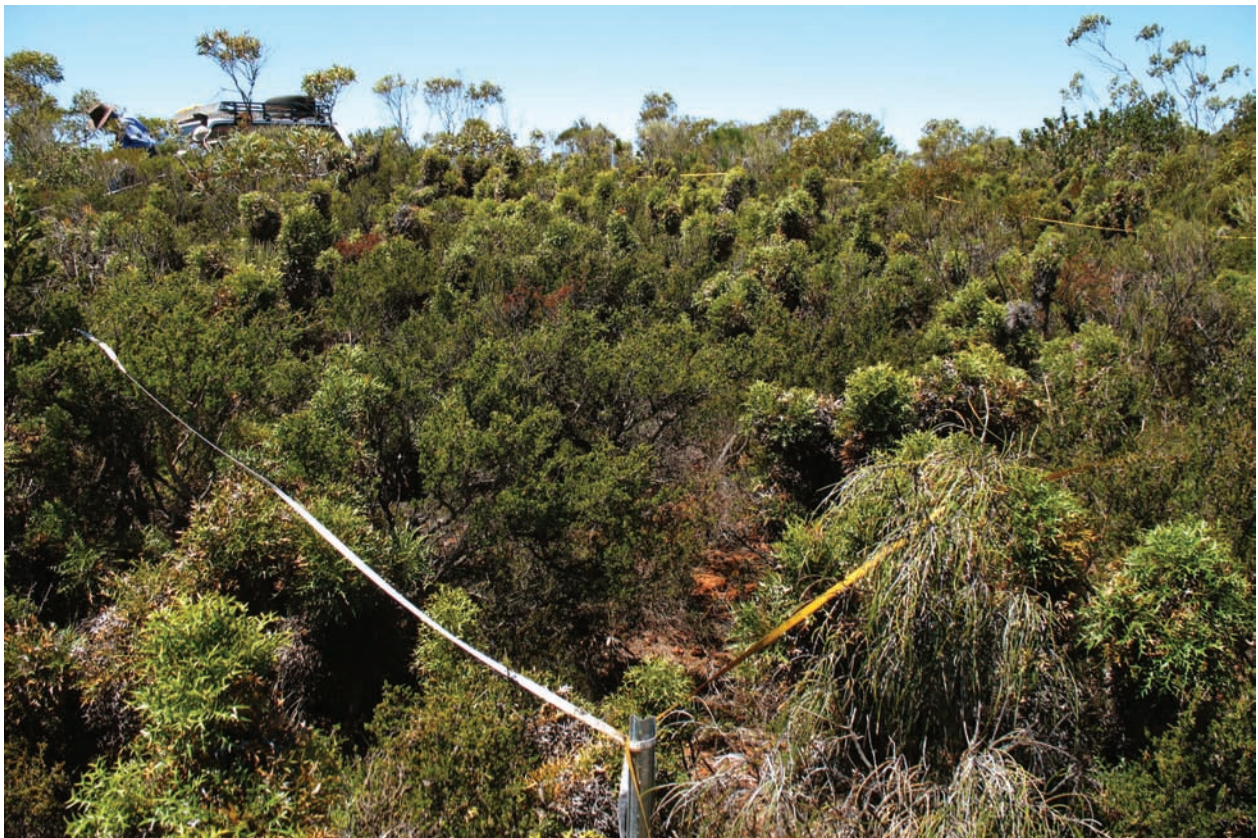


Figure 17. Community 15, species-rich shrublands on the lateritic ridges in the south of the study area (survey plot R002).

lemniana (50), *Beaufortia schaueri* (50), *Boronia inconspicua* (50), *Chorizema trigonum* (50), *Leucopogon carinatus* (50), *L. infuscatus* (50), *Melaleuca hamata* (50), *Acacia heterochroa* subsp. *heterochroa* (33), *Andersonia* aff. *lemniana* [S Kern & R Jasper LCH 17769] (33), *Banksia cirsioides* (33), *Boronia crassifolia* (33), *B. subsessilis* (33), *Daviesia mollis* (33), *Grevillea concinna* subsp. *lemniana* (33), *G. nudiflora* (33), *Isopogon* sp. Ravensthorpe [DB Foreman 1207] (33), *Lasiopetalum compactum* (33), *Leptospermum* sp. Bandalup Hill [G Cockerton 11001] (33), *Melaleuca pentagona* (33), *M. rigidifolia* (33), *M. stramentosa* (33), *Petrophile glauca* (33), *Rhadinothamnus rudis* subsp. *amblycarpus* (33), *Siegfriedia darwinoides* (33), *Spyridium majoranifolium* (33). **Herbs** *Styloidium albomontis* (83), *Lepidosperma* sp. Cordingup [GF Craig 6138] (67), *L. sp.* Saltbush Hill [KR Newbey 4118] (50), *Lomandra mucronata* (50), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (50), *Cassytha glabella* (33), *C. melantha* (33), *Lepidosperma* sp. [AS George 9935] (33), *L. sp.* Mt Short [S Kern et al. LCH 17510] (33), *Lomandra micrantha* subsp. *teretifolia* (33).

Short range endemics

0–10 km²: *Hibbertia abyssa*.

100–1000 km²: *Guichenotia apetala*, *Isopogon* sp. Ravensthorpe (DB Foreman 1207), *Leucopogon infuscatus*, *Marianthus mollis*, *Melaleuca stramentosa*, *Spyridium glaucum*.

1000–10,000 km²: *Acacia disticha*, *A. durabilis*, *A. heterochroa* subsp. *heterochroa*, *A. laricina* var. *crassifolia*, *Boronia oxyantha* var. *brevicalyx*, *Grevillea patentiloba* subsp. *platypoda*, *Leptospermum* sp. Bandalup Hill (G Cockerton 11001).

Conservation taxa: *Guichenotia apetala* (P1), *Hibbertia abyssa* (R), *Marianthus mollis* (R).

Community 16: *Eucalyptus falcata* subsp. *falcata*/*E. spp.* mallee shrublands.

Map unit(s): Ecli (2), East (1), Efal/Eple (1).

Common canopy species of community 16 included *Eucalyptus falcata* subsp. *falcata* and *E. pleurocarpa*, although *E. megacornuta* occurred as the dominant stratum in open forest at one site with exposed gossaniferous bedrock. This community had only half the species richness of related communities (17–21). Community 16 occurred on the steep mid to upper slopes and gently inclined hillcrests of Mt Desmond and Mt Chester, on the southern main ridges of the range.

Soils: typically dark loamy sands or sandy loams, some gossan outcrop.

No. plots 4; Taxa/plot (SD) 18.0 ± 2.4; Altitude 152–318 m.

Diagnostic taxa (INDVAL): **Shrubs** *Labichea lanceolata* subsp. *brevifolia* (48), *Hibbertia mucronata* (45), *Hovea acanthoclada* (35), *Lasiopetalum rosmarinifolium* (30), *Melaleuca pentagona* (26). **Herbs** *Lomandra mucronata* (16).

Most common taxa (% frequency): **Trees** *Eucalyptus falcata* subsp. *falcata* (75), *E. pleurocarpa* (75), *E. incrassata* (25), *E. megacornuta* (25), *E. thamnoides* subsp. *megista* (25). **Shrubs** *Hovea acanthoclada* (100), *Labichea lanceolata* subsp. *brevifolia* (75), *Lasiopetalum rosmarinifolium* (75), *Calothamnus quadrifidus* (50), *Hibbertia mucronata* (50), *Melaleuca pentagona* (50), *Acacia gonophylla* (25), *A. subcaerulea* (25), *Acrotriche ramiflora* (25), *Allocasuarina acutivalvis* subsp. *acutivalvis* (25), *A. humilis* (25),



Figure 18. *Eucalyptus megacornuta* open forest was an unusual structural unit in Community 16 (survey plot R045).

Astroloma serratifolium (25), *Banksia heliantha* (25), *B. lemanniana* (25), *Beyeria brevifolia* (25), *Calothamnus pinifolius* (25), *C. roseus* (25), *Chorizema trigonum* (25), *Grevillea patentiloba* subsp. *platypoda* (25), *Hakea laurina* (25), *H. lissocarpa* (25), *H. obtusa* (25), *H. verrucosa* (25), *Hibbertia atrichosepala* (25), *Leucopogon carinatus* (25), *L. sp. Coujinup/sp. Newdegate* (25), *Spyridium majoranifolium* (25), *Taxandria spathulata* (25). **Herbs** *Lomandra mucronata* (100), *Lepidosperma* sp. Saltbush Hill [KR Newbey 4118] (50), *Platysace maxwellii* (50), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (50), *Amphipogon turbinatus* (25), *Austrodanthonia setacea* (25), *Billardiera coriacea* (25), *Cassytha glabella* (25), *Conostylis argentea* (25), *Dampiera lavandulacea* (25), *Dianella revoluta* var. *revoluta* (25), *Lepidosperma* sp. Bandalup Scabrid [N Eveleigh 10798] (25), *L. sp. Cordingup* [GF Craig 6138] (25), *L. sp. [AS George 9935]* (25), *L. sp. [RL Barrett 3553]* (25), *Lomandra micrantha* subsp. *teretifolia* (25), *Marianthus bicolor* (25), *Neurachne alopecuroidea* (25), *Stylidium albomontis* (25).

Short range endemics

0–10 km²: *Hibbertia atrichosepala*.

10–100 km²: *Calothamnus roseus*.

1000–10,000 km²: *Eucalyptus megacornuta*, *Grevillea patentiloba* subsp. *platypoda*.

Conservation taxa: *Calothamnus roseus* (P1), *Hibbertia atrichosepala* (P1).

Community 17: Northern lateritic *Eucalyptus pleurocarpa*/*E. falcata* subsp. *falcata*/*E. spp.* mallee shrublands.

Map unit(s): Efal/Eple (17), Dcir (8), Dfol (2), Mosaic Efal/Eple & Eunc/Einc (2), Blac/Borb (1), Eunc/Espp (2), Mosaic Blac/Borb & Efal/Eple (1).

This community typically consisted of an overstorey of sparse mallees

dominated by *Eucalyptus pleurocarpa* and by other eucalypt species, including *E. falcata* subsp. *falcata*, *E. uncinata* and, less frequently, *E. incrassata*. The mid stratum of mid-dense to dense shrubland was very species rich and was dominated by a diverse array of Proteaceous and Myrtaceous taxa, and some sites were dominated by *Banksia cirsioides* and *B. pallida*, while a few others were dominated by dense stands of *B. foliosissima*. Community 17 was found on gently to moderately inclined hillslopes, generally ranging from the midslopes to ridge crests, occurring from the central to the northern extent of the main ridges of the Ravensthorpe Range.

Soils: rocky, sandy loams with an abundance of surface ferruginous pe gravel with limited exposure of lateritic bedrock.

No. plots 33; Taxa/plot (SD) 41.8 ± 1.5; Altitude 237–438 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus pleurocarpa* (17). **Shrubs** *Banksia pallida* (61), *Melaleuca villosisepala* (54), *Banksia cirsioides* (42), *Leptospermum* sp. Bandalup Hill [G Cockerton 11001] (35), *Adenanthos flavidiflorus* (33), *Beaufortia micrantha* var. *micrantha* (33), *Daviesia coryloba* (30), *Hakea cygna* subsp. *cygna* (30), *Petrophile glauca* (30), *Jacksonia viscosa* (29), *Boronia crassifolia* (28), *Astroloma prostratum* (27), *Guichenotia anota* (27), *Hemigenia teretiuscula* (27), *Lysinema pentapetalum* (27), *Allocasuarina humilis* (26), *Persoonia striata* (26), *Goodenia pinifolia* (25), *Stachystemon brachyphyllus* (24), *Beaufortia schaueri* (22), *Banksia corviflora* (21), *Leucopogon cuneifolius* (21), *Hibbertia gracilipes* (20), *Banksia foliosissima* (18), *Hakea subsulcata* (18), *Isopogon* sp. Ravensthorpe [DB Foreman 1207] (16), *Petrophile seminuda* (15). **Herbs** *Dampiera juncea* (60), *Lepidosperma* sp. [RL Barrett 3570] (41), *Schoenus brevisetis* (36), *Drosera grievii* (33), *Cassytha pomiformis* (26), *Mesomelaena stygia* subsp. *stygia* (20), *Lepidobolus chaetocephalus* (18), *Amphipogon turbinatus* (14), *Conostylis argentea* (14).

Most common taxa (% frequency): **Trees** *Eucalyptus pleurocarpa* (94), *E. falcata* subsp. *falcata* (70), *E. uncinata* (48), *E. incrassata*



Figure 19. Community 17 typically occurred as species-rich mallee shrubland (survey plot R242) and was largely restricted to laterite ridges in the north of the study area.

(39). **Shrubs** *Hibbertia gracilipes* (85), *Melaleuca villosispala* (85), *Leptospermum* sp. Bandalup Hill [G Cockerton 11001] (79), *Beaufortia schaueri* (76), *Allocasuarina humilis* (73), *Banksia cirsioides* (73), *Boronia crassifolia* (70), *Banksia pallida* (61), *Lysinema pentapetalum* (61), *Banksia lemmaniana* (58), *Beaufortia micrantha* var. *micrantha* (58), *Goodenia pinifolia* (55), *Petrophile glauca* (55), *Leucopogon cuneifolius* (52), *Isopogon* sp. Ravensthorpe [D.B. Foreman 1207] (48), *Jacksonia viscosa* (48), *Hakea obtusa* (45), *Taxandria spathulata* (45), *Persoonia striata* (42), *Petrophile seminuda* (39), *Leucopogon* sp. Coujinup/sp. Newdegate (36), *Acacia* sp. Ravensthorpe [RS Cowan & BR Maslin RSC A-760] (33), *Adenanthos flavidiflorus* (33), *Leucopogon concinnus* (33), *Persoonia helix* (33), *Acacia heterochroa* subsp. *heterochroa* (30), *Daviesia coryloba* (30), *Guichenotia anota* (30), *Hakea cygna* subsp. *cygna* (30), *Hemigenia teretiuscula* (30), *Leptospermum spinescens* (30), *Spyridium cordatum* (30), *Astroloma prostratum* (27), *Gompholobium knightianum* (27). **Herbs** *Lomandra mucronata* (70), *Dampiera juncea* (67), *Mesomelaena stygia* subsp. *stygia* (64), *Neurachne alopecuroidea* (64), *Amphipogon turbinatus* (61), *Lepidosperma* sp. [RL Barrett 3570] (61), *Conostylis argentea* (58), *Gahnia ancistrophylla* (42), *Cassytha glabella* (39), *Stylidium albomontis* (39), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (39), *Cassytha pomiformis* (36), *Schoenus brevisetis* (36), *Billardiera venusta* (33), *Drosera grieviei* (33), *Lepidosperma* sp. Mt Burdett [MA Burgman & C Layman MAB 3287] (27), *Lomandra micrantha* subsp. *teretifolia* (27).

Short range endemics

10–100 km²: *Banksia corvujuga*, *Daviesia megacalyx*.

100–1000 km²: *Guichenotia anota*, *Isopogon* sp. Ravensthorpe (DB Foreman 1207), *Kunzea cincinnata*, *Leucopogon infuscatus*, *Micromyrtus navicularis*, *Spyridium glaucum*.

1000–10,000 km²: *Acacia heterochroa* subsp. *heterochroa*, *A. laricina* var. *crassifolia*, *Banksia foliosissima*, *B. laevigata* subsp. *laevigata*, *Boronia oxyantha* var. *brevicalyx*, *B. ternata* var. *elongata*, *Drosera grieviei*, *Leptospermum* sp. Bandalup Hill (G Cockerton 11001), *Microcorys pimeleoides*.

Conservation taxa: *Banksia corvujuga* (P3), *B. foliosissima* (P4), *B. laevigata* subsp. *laevigata* (P4), *Chorizema ulotropis* (P4), *Daviesia megacalyx* (R), *Drosera grieviei* (P1), *Guichenotia anota* (P1), *Micromyrtus navicularis* (P3), *Synaphea drummondii* (P3)

Community 18: Southern lateritic *Eucalyptus pleurocarpa*/E. *falcata* subsp. *falcata* mallee shrublands.

Map unit(s): Efal/Eple (4), Dque (1), Eple/Bmed (1).

Community 18 appeared to be a southern variant of community 17. This community typically consisted of tall, open mallee shrublands dominated by *Eucalyptus pleurocarpa*, *E. falcata* subsp. *falcata* and *E. incrassata*, over a mid-dense to dense, species-rich shrubland of *Banksia lemmaniana*, *Taxandria spathulata*, *Banksia heliantha*, *Allocasuarina humilis* and *Leucopogon* sp. Coujinup/sp. Newdegate. Sites of this community were located on the south-eastern half of the Ravensthorpe Range, notably around Kundip and on Bandalup Hill. Sites generally occurred on gently to moderately inclined hillslopes, ranging from lower slopes to hillcrests.

Soils: grey-brown sandy loams, clay sands and loamy sands. Outcropping bedrock was infrequent, and varied.

No. plots 17; Taxa/plot (SD) 38.6 ± 1.7; Altitude 110–280 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus pleurocarpa* (19), *E. incrassata* (16), *E. falcata* subsp. *falcata* (14). **Shrubs** *Xanthorrhoea platyphylla* (53), *Petrophile squamata* subsp. northern [J Monks 40] (38), *Banksia heliantha* (35), *Allocasuarina humilis* (33), *Lysinema pentapetalum* (31), *Taxandria spathulata* (31), *Pultenaca indira* (30), *Jacksonia elongata* (28), *Calothamnus gracilis* (27), *Isopogon trilobus* (27), *Leucopogon* sp. Coujinup/sp. Newdegate (26), *Chorizema*

uncinatum (24), *Gompholobium viscidulum* (24), *Stachystemon virgatus* (23), *Adenanthos oreophilus* (21), *Calothamnus pinifolius* (21), *Banksia lemmaniana* (19), *Hakea pandanicarpa* (19), *Isopogon* sp. Fitzgerald River [DB Foreman 813] (19), *Boronia crassifolia* (16), *Hibbertia gracilipes* (16), *Leptospermum* sp. Bandalup Hill [G Cockerton 11001] (16). **Herbs** *Schoenus subclaxus* (37), *Mesomelaena stygia* subsp. *stygia* (33), *Amphipogon turbinatus* (22), *Conostylis bealiana* (21), *Lomandra mucronata* (20), *Argentipallium niveum* (19), *Dampiera fasciculata* (19), *Lepidosperma* sp. Mt Burdett [MA Burgman & C Layman MAB 3287] (19).

Most common taxa (% frequency): **Trees** *Eucalyptus pleurocarpa* (100), *E. falcata* subsp. *falcata* (82), *E. incrassata* (71), *E. uncinata* (29). **Shrubs** *Taxandria spathulata* (88), *Allocasuarina humilis* (82), *Banksia heliantha* (82), *Hibbertia gracilipes* (76), *Leucopogon* sp. Coujinup/sp. Newdegate (76), *Banksia lemmaniana* (71), *Lysinema pentapetalum/ciliatum* (65), *Boronia crassifolia* (53), *Leptospermum* sp. Bandalup Hill [G Cockerton 11001] (53), *Petrophile squamata* subsp. northern [J. Monks 40] (53), *Xanthorrhoea platyphylla* (53), *Acacia gonophylla* (41), *Beaufortia schaueri* (41), *Chamelaucium ciliatum* (41), *Jacksonia elongata* (41), *Leucopogon carinatus* (41), *Stachystemon virgatus* (41), *Adenanthos oreophilus* (35), *Calothamnus pinifolius* (35), *Daviesia teretifolia* (35), *Hakea pandanicarpa* (35), *Melaleuca rigidifolia* (35), *Petrophile seminuda* (35), *Pultenaca indira* (35), *Acacia heterochroa* subsp. *heterochroa* (29), *Beaufortia micrantha* var. *micrantha* (29), *Beyeria brevifolia* (29), *Calothamnus gracilis* (29), *Chorizema trigonum* (29), *Hakea laurina* (29), *Isopogon trilobus* (29), *Lasiopetalum rosmarinifolium* (29), *Leptospermum spinescens* (29). **Herbs** *Lomandra mucronata* (88), *Mesomelaena stygia* subsp. *stygia* (82), *Amphipogon turbinatus* (76), *Cassytha glabella* (59), *Lepidosperma* sp. Mt Burdett [MA Burgman & C Layman MAB 3287] (53), *Schoenus subclaxus* (53), *Dampiera lavandulacea* (41), *Lomandra micrantha* subsp. *teretifolia* (41), *Conostylis bealiana* (29), *Dampiera fasciculata* (29), *Gahnia ancistrophylla* (29), *Pterostylis vittata* (29).

Short range endemics

0–10 km²: *Kunzea similis* subsp. *mediterranea*.

10–100 km²: *Calothamnus roseus*.

100–1000 km²: *Isopogon* sp. Ravensthorpe (DB Foreman 1207), *Spyridium glaucum*.

1000–10,000 km²: *Acacia heterochroa* subsp. *heterochroa*, *A. pinguiculosa* subsp. *pinguiculosa*, *Boronia oxyantha* var. *brevicalyx*, *Grevillea rigida* subsp. *distans*, *Leptospermum* sp. Bandalup Hill (G Cockerton 11001).

Conservation taxa: *Calothamnus roseus* (P1), *Kunzea similis* subsp. *mediterranea* (R).

Community 19: Mixed *Eucalyptus flocktoniae*/E. *leptocalyx*/E. spp mallee shrubland.

Map unit(s): Eflo/Esug (1).

A range of canopy eucalypt species were recorded for this community type, notably mixed stands of tall, open mallee, including *Eucalyptus suggrandis* subsp. *suggrandis*, *E. leptocalyx*, *E. phaenophylla*, *E. uncinata* and *E. flocktoniae*. Common taxa in the taller understorey included *Hakea verrucosa*, *Banksia media*, and *Melaleuca hamata*. Community 19 was also species-rich and was located on the south-eastern half of the range, on an area of low, undulating hills east of the main ridge. It occurred on hillslopes with low gradients, from the lower to upper slopes of these hills.

Soils: rocky brown clay loams with no exposed bedrock.

No. plots 7; Taxa/plot (SD) 35.0 ± 3.0; Altitude 58–192 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus kessellii* subsp. *eugnota* (38), *E. leptocalyx* (26), *E. suggrandis* subsp. *suggrandis* (22). **Shrubs** *Coopernookia polygalacea* (41), *Styphelia intertexta*

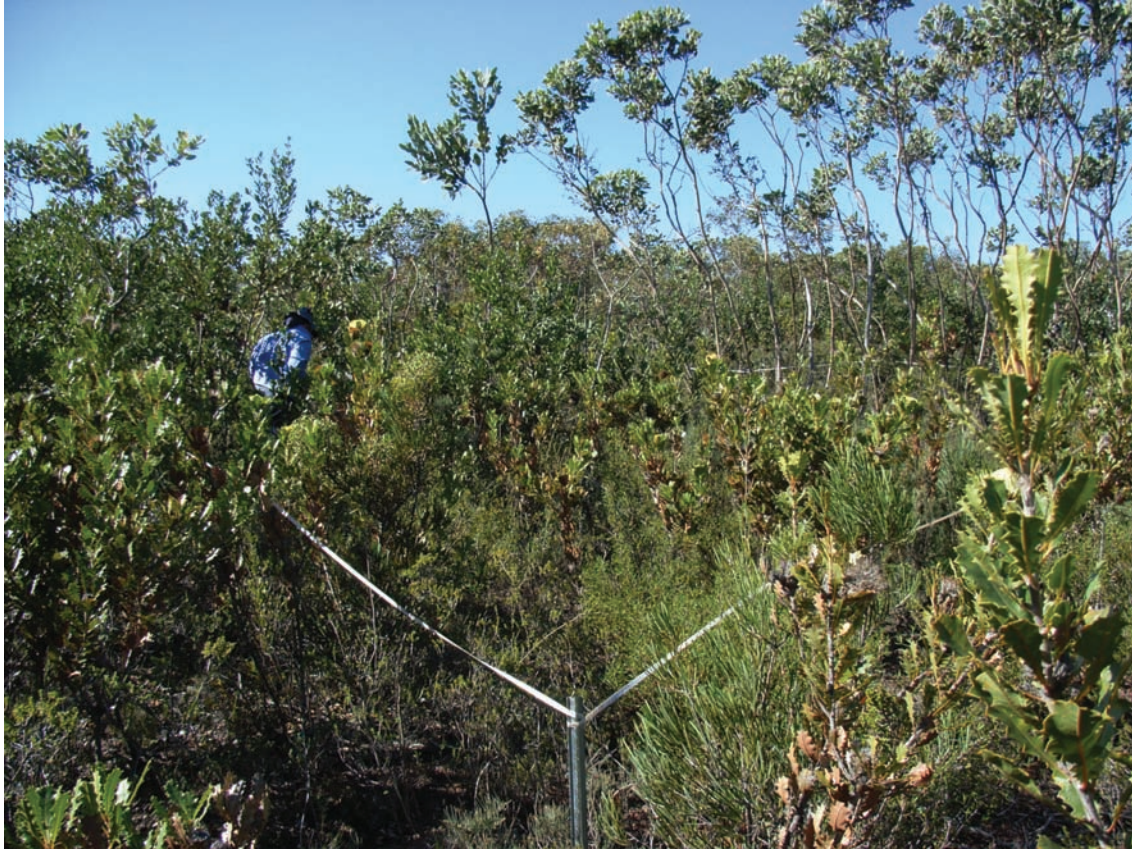


Figure 20. Related to community 17, community 18 was generally species-rich mallee shrublands (survey plot R050) found on laterite ridges in the south of the study area.



Figure 21. Community 19, a species-rich mallee shrubland (survey plot R053) restricted to the south-eastern end of the range.

(40), *Hibbertia exasperata* (39), *Comesperma spinosum* (37), *Boronia inornata* subsp. *leptophylla* (32), *Acacia ingrata* (30), *Banksia media* (29), *Spyridium cordatum* (26), *Pomaderris brevifolia* (24), *Daviesia anceps* (21), *D. articulata* (20), *Melaleuca subfalcata* (20), *Acrotriche cordata* (18), *Grevillea pectinata* (17), *Acacia ophiolithica* (16), *Grevillea oligantha* (15), *Leucopogon infuscatus* (14), *Melaleuca ulicoides* (14). **Herbs** *Cassytha melantha* (14).

Most common taxa (% frequency): **Trees** *Eucalyptus flocktoniae* subsp. *flocktoniae* (86), *E. leptocalyx* (71), *E. suggrandis* subsp. *suggrandis* (71), *E. uncinata* (71), *E. phaenophylla* (57), *E. kessellii* subsp. *eugnota* (43), *E. phenax* subsp. *phenax* (43), *E. pleurocarpa* (29), *E. sp.* Ravensthorpe [AS George 616] (29). **Shrubs** *Acacia ingrata* (100), *Boronia inornata* subsp. *leptophylla* (86), *Daviesia anceps* (86), *Melaleuca hamata* (86), *Spyridium cordatum* (86), *Acrotriche cordata* (71), *Hakea verrucosa* (71), *Lasiopetalum compactum* (71), *Pomaderris brevifolia* (71), *Acacia ophiolithica* (57), *Cooperookia polygalacea* (57), *Daviesia articulata* (57), *Grevillea oligantha* (57), *G. pectinata* (57), *Hakea laurina* (57), *Hibbertia psilocarpa* (57), *Melaleuca ulicoides* (57), *Banksia media* (43), *Comesperma spinosum* (43), *Halgania andromedifolia* (43), *Hibbertia exasperata* (43), *H. pungens* (43), *Leucopogon infuscatus* (43), *Styphelia intertexta* (43), *Boronia inconspicua* (29), *Dodonaea pinifolia* (29), *Exocarpos aphyllus* (29), *Grevillea huegelii* (29), *G. patentiloba* subsp. *patentiloba* (29), *Logania buxifolia* (29), *Melaleuca lateriflora* subsp. *lateriflora* (29), *M. subfalcata* (29), *Microcorys glabra* (29), *Pultenaea purpurea* (29), *Siegfriedia darwinoides* (29), *Templetonia retusa* (29), *Wilsonia humilis* (29). **Herbs** *Cassytha melantha* (71), *Gahnia ancistrophylla* (57), *Lomandra micrantha* subsp. *teretifolia* (57), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (57), *Dianella revoluta* var. *revoluta* (43), *Lepidosperma gahnioides* (43), *Cassytha glabella* (29), *Gahnia aristata* (29), *Marianthus bicolor* (29).

Short range endemics

100–1000 km²: *Leucopogon infuscatus*, *Melaleuca ulicoides*.

1000–10,000 km²: *Acacia durabilis*, *Acacia ophiolithica*, *Melaleuca pomphostoma*.

Conservation taxa: none recorded.

Community 20: *Eucalyptus uncinata*/*E. incrassata*/*E. spp.* mallee shrublands.

Map unit(s): Eunc/Espp (6), Efal/Eple (5), Mallee/Mspp (3), Mosaic Efal/Eple & Eunc/Einc (3), Esug/Mspp (2), Eunc/Einc (2), Efal/Alca (1), Epro/Mspp (1).

This was a widespread, structurally heterogeneous unit that was closely allied to community 19. It typically consisted of species-rich mallee shrublands dominated by mixtures of *Eucalyptus* species, most commonly including *E. uncinata*, *E. incrassata*, *E. pleurocarpa*, *E. flocktoniae* subsp. *flocktoniae*, *E. phenax* subsp. *phenax* and *E. phaenophylla*. Other eucalypt taxa that were common in the south-eastern sites included *E. pluricaulis* subsp. *pluricaulis*, *E. proxima* and *E. suggrandis* subsp. *suggrandis*. *Hakea laurina* was a common tall shrub and significant indicator species of this community. There was some suggestion of further internal structure associated with a gradation in species composition from southern to northern sites, which could be resolved with further sampling. Community 20 generally occurred on gently inclined slopes, sometimes in minor gullies or minor dry creek lines ranging from lower to upper hillslopes, and was distributed across the north–south extent of the main range and on Bandalup Hill.

Soils: rocky grey-brown soils of a variety of soil textures, from sandy loams, clay sands, to clay loams and clays, with limited outcropping of laterite or metasedimentary bedrock.

No. plots 32; Taxa/plot (SD) 39.1 ± 1.1; Altitude 91–383 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus incrassata* (18), *E. uncinata* (16). **Shrubs** *Eutaxia cuneata* (25), *Hakea lissocarpa* (19), *Melaleuca rigidifolia* (16), *Hakea laurina* (15). **Herbs** *Harperia lateriflora* (19), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (17), *Gahnia ancistrophylla* (14).

Most common taxa (% frequency): **Trees** *Eucalyptus uncinata* (84), *E. incrassata* (75), *E. phaenophylla* (59), *E. pleurocarpa* (50), *E. suggrandis* subsp. *suggrandis* (41), *E. falcata* subsp. *falcata* (34), *E. flocktoniae* subsp. *flocktoniae* (34). **Shrubs** *Melaleuca hamata* (94), *Hakea laurina* (69), *Hibbertia pungens* (69), *Hakea lissocarpa* (66), *Daviesia anceps* (56), *Melaleuca rigidifolia* (56), *Baeckea corynophylla* (50), *Eutaxia cuneata* (47), *Spyridium cordatum* (47), *Acacia ingrata* (44), *Hibbertia gracilipes* (44), *Lasiopetalum rosmarinifolium* (44), *Leucopogon* sp. Coujinup/sp. Newdegate (44), *Melaleuca glaberrima* (44), *Acacia gonophylla* (41), *Gompholobium confertum* (41), *Beaufortia schaueri* (38), *Calothamnus quadrifidus* (38), *Boronia inconspicua* (31), *Calytrix leschenaultii* (28), *Rinzia communis* (28), *Acrotriche cordata* (25), *Banksia lemniata* (25), *Lasiopetalum compactum* (25). **Herbs** *Gahnia ancistrophylla* (81), *Tetraria* sp. Mt Madden [CD Turley 40 BP/897] (78), *Neurachne alopecuroidea* (75), *Lomandra micrantha* subsp. *teretifolia* (53), *Cassytha glabella* (44), *Dianella revoluta* var. *revoluta* (44), *Lomandra mucronata* (44), *Stygidium albomontis* (44), *Lepidosperma* sp. Bandalup Scabrid [N Eveleigh 10798] (41), *Platysace maxwellii* (41), *Lepidosperma* sp. Saltbush Hill [KR Newbey 4118] (38), *Marianthus bicolor* (38), *Schoenus racemosus* (38), *Amphipogon turbinatus* (31), *Conostylis argentea* (31), *Billardiera venusta* (25), *Dampiera lavandulacea* (25).

Short range endemics

10–100 km²: *Microcybe pauciflora* subsp. *grandis*.

100–1000 km²: *Goodenia phillipsiae*, *Guichenotia apetala*, *Isopogon* sp. Ravensthorpe (DB Foreman 1207), *Kunzea cincinnata*, *Leucopogon infuscatus*, *Marianthus mollis*, *Melaleuca stramentosa*, *Micromyrtus navicularis*, *Pultenaea calycina* subsp. *proxena*, *Spyridium glaucum*.

1000–10,000 km²: *Acacia heterochroa* subsp. *heterochroa*, *A. laricina* var. *crassifolia*, *A. ophiolithica*, *A. pinguiculosa* subsp. *pinguiculosa*, *A. pusilla*, *Banksia foliosissima*, *Boronia oxyantha* var. *brevicalyx*, *Eucalyptus cernua*, *Grevillea patentiloba* subsp. *platypoda*, *Leptospermum* sp. Bandalup Hill (G Cockerton 11001), *Melaleuca pomphostoma*, *Microcorys pimeleoides*.

Conservation taxa: *Banksia foliosissima* (P4), *Goodenia phillipsiae* (P4), *Guichenotia apetala* (P1), *Marianthus mollis* (R), *Microcybe pauciflora* subsp. *grandis* (P3), *Micromyrtus navicularis* (P3), *Pultenaea calycina* subsp. *proxena* (P4), *P. indira* subsp. *monstrosita* (P3), *Stachystemon vinosus* (P4).

Community 21: *Eucalyptus desmondensis*/*Allocasuarina* spp. tall mallee shrubland.

Map unit(s): Alac (1), Alhu (1), Epro/Mspp (1), Esug/Mspp (1).

Community 21 had some affinities to Communities 19 and 20. This community generally consisted of *Eucalyptus desmondensis* tall mallee shrubland with *Allocasuarina* spp. and *Melaleuca hamata*. This community was found west of the main ridges and with most plots (3) in the southern half of the range. Topographic position ranged from lower to upper hill slopes, on gentle to moderate gradients.

Soils: generally grey-brown to red-brown clay loams, sandy loams and clay sand, exposed bedrock rare.

No. plots 4; Taxa/plot (SD) 30.3 ± 2.5; Altitude 211–404 m.

Diagnostic taxa (INDVAL): **Trees** *Eucalyptus desmondensis* (75). **Shrubs** *Acacia mimica* var. *angusta* (72), *Grevillea dolichopoda* (70), *Gompholobium marginatum* (60), *Baeckea crispiflora* (50), *Leucopogon concinnus* (46), *Melaleuca carrii* (42), *Calytrix*



Figure 22. Community 20, a very species-rich mallee shrubland (survey plot R259) that contained large numbers of short-range endemic species. It was more widespread than the related community 19.



Figure 23. Community 21, *Eucalyptus desmondensis* – *Allocasuarina* tall mallee shrubland (survey plot R074).

leschenaultii (38), *Daviesia pachyphylla* (37), *Chorizema aciculare* subsp. *aciculare* (29), *Allocasuarina campestris* (25), *Hakea lissocarpha* (24), *Logania tortuosa* (22), *Hibbertia pungens* (20), *Astroloma serratifolium* (17). **Herbs** *Schoenus sesquispiculus* (62), *Conostylis argentea* (42), *Lepidobolus preissianus* (35), *Haemodorum discolor* (18), *Schoenus racemosus* (18).

Most common taxa (% frequency): **Trees** *Eucalyptus desmondensis* (75), *E. uncinata* (50), *Allocasuarina huegeliana* (25), *E. phenax* subsp. *phenax* (25), *E. pluricaulis* subsp. *pluricaulis* (25). **Shrubs** *Grevillea dolichopoda* (100), *Hibbertia pungens* (100), *Melaleuca hamata* (100), *Acacia mimica* var. *angusta* (75), *Calytrix leschenaultii* (75), *Gompholobium marginatum* (75), *Hakea lissocarpha* (75), *Leucopogon concinnus* (75), *Allocasuarina campestris* (50), *Astroloma epacridis* (50), *A. serratifolium* (50), *Baeckea crispiflora* (50), *Chorizema aciculare* subsp. *aciculare* (50), *Daviesia pachyphylla* (50), *Dodonaea pinifolia* (50), *Hibbertia gracilipes* (50), *Melaleuca carrii* (50), *Acacia sulcata* (25), *Allocasuarina acutivalvis* subsp. *acutivalvis* (25), *A. hystricosa* (25), *Beaufortia schaueri* (25), *Calothamnus quadrifidus* (25), *Calytrix tetragona* (25), *Daviesia aniceps* (25), *D. teretifolia* (25), *Goodenia pinifolia* (25), *Hakea incrassata* (25), *H. marginata* (25), *Halgania anagalloides* var. *Southern* [AE Orchard 1609] (25), *Kunzea strigosa* (25), *Leucopogon* sp. *Coujilup*/sp. *Newdegate* (25), *Logania tortuosa* (25), *Melaleuca elliptica* (25), *M. glaberrima* (25), *M. rigidifolia* (25), *M. villosisepala* (25), *Mirbelia multicaulis* (25), *Persoonia helix* (25), *Petrophile fastigiata* (25), *P. seminuda* (25), *Stachystemon virgatus* (25), *Verticordia acerosa* var. *preissii* (25). **Herbs** *Conostylis argentea* (100), *Gahnia ancistrophylla* (75), *Neurachne alopecuroidea* (75), *Schoenus sesquispiculus* (75), *Amphipogon turbinatus* (50), *Lepidobolus preissianus* (50), *Lepidosperma* sp. [RL Barrett 3553] (50), *Mesomelaena stygia* subsp. *stygia* (50), *Schoenus racemosus* (50), *Agrostocrinum scabrum* subsp. *scabrum* (25), *Austrodanthonia setacea* (25), *Cassytha glabella* (25), *Dampiera lavandulacea* (25), *Dianella revoluta* var. *revoluta* (25), *Eriochilus dilatatus* subsp. *undulatus* (25), *Haemodorum discolor* (25), *Lepidosperma* sp. *Archer Drive* [S Kern & R Jasper LCH 18300] (25), *L. sp. Bandalup Scabrid* [N Eveleigh 10798] (25), *L. sp. Cordingup* [GF Craig 6138] (25), *L. sp. Elverdton* [R Jasper et al. LCH 16844] (25), *L. sp.* [RL Barrett 2770] (25), *L. sp. Maydon* [S Kern et al. LCH 17844] (25), *Lomandra mucronata* (25), *Pterochaeta paniculata* (25), *Spartochloa scirpoidea* (25), *Stylidium dichotomum* (25), *S. piliferum* (25), *Stypantra glauca* (25), *Thysanotus patersonii* (25).

Short range endemics

100–1000 km²: *Eucalyptus desmondensis*.

1000–10,000 km²: *Allocasuarina hystricosa*.

Conservation taxa: *Allocasuarina hystricosa* (P4), *Eucalyptus desmondensis* (P4).

Unallocated plots

Three plots were not allocated to a community from this analysis. One plot was found to be an outlier in preliminary analyses and was omitted from subsequent analyses. That plot sampled a swamp yate (*Eucalyptus occidentalis*) tall open forest over *Acacia verrucula* and *Acacia saligna* subsp. *lindleyi* tall shrubland over *Gahnia ancistrophylla*, *Lomandra effusa* and *Lepidosperma* sp. Hopetoun Road (S Kern et al. LCH 16552) open sedgeland. Seven species in this plot were not recorded in the other 265 plots. This plot appears to represent a distinct swamp yate community that occurs on the alluvial flats around Jerdacuttup Creek.

Two other plots retained in the final analyses did not cluster with other community types (Fig. 2). One plot sampled a *Eucalyptus megacornuta* woodland (plot R010) on outcropping gossan over a very sparse shrub layer

dominated by *Gastrolobium parviflorum* and *Siegfriedia darwinioides*. This plot was species poor (9 taxa) but most closely allied to community 13. The second plot (R147) sampled an *Acacia pinguiculosa* subsp. *pinguiculosa*, *Kunzea affinis* tall shrubland over *Lepidosperma* sp. (RL Barrett 3553) open sedgeland. Floristically, this site was closest in composition to community 21, but relatively species poor (20 taxa per plot) in comparison. The low species richness found in these plots may have influenced their placement in the analysis.

Correlation with vegetation mapping

There was broad agreement between our communities defined by composition and the vegetation mapping undertaken by Craig et al. (2008; Table 2). Craig et al. (2008) arranged their vegetation mapping units under a soil–landscape classification (Department of Agriculture and Food 2006) and at this level there is good correlation between groups of our communities and the mapping units of the broad soil–landscape classification. Communities 17, 14, 18 and 15 largely correspond to seven vegetation units in the Ravensthorpe System laterite and colluvium group (Table 2). Similarly communities 6, 13, 1, 16, 3, 19, 20, 4 and 2 correspond broadly to the 12 vegetation units in the Ravensthorpe System sedimentary and colluvium group (Table 2). At a finer scale the correspondence is less clear cut.

One vegetation unit (Efal/Eple) covers 28.3% of the mapped area, while the next largest vegetation unit covers just 5% and many are less than 1% (Craig et al. 2008). The large unit was described as heterogeneous and our analysis confirmed this. Most plots in this unit belong to community 17 (18 plots) or community 14 (13 plots), with plots from five other communities being recorded from this unit. While 18 plots of community 17 were mapped as Efal/Eple, a further eight plots were mapped as the Dcir unit of the Kybulup System sandplains (Table 2), suggesting that the Dcir unit does not differ significantly (in terms of composition) from many of our plots in the Efal/Eple unit. Where sufficient replication exists, a number of the vegetation units are split between several of our communities, suggesting that structural–dominance factors contribute significantly to the identification of the mapping units (e.g. Egar, Ecil, Eflo/Ephe; Table 2).

Correlation with PEC mapping

Five Priority Ecological Communities (PECs) have been listed for the Ravensthorpe Range (Department of Environment and Conservation 2010), all of which are listed as Priority 1 PECs (Table 3). These have been described from dominant plant taxa and vegetation structure, and Craig et al. (2008) mapped four of these units in their study area. Our sampling did not include any of the ‘*Melaleuca* sp. Kundip Heath’ (Mx map unit). Three plots from community 14 and one plot from community 17 fell within ‘*Banksia laevigata* – *B. lemanniana* proteaceous thicket’ (Blae/Bor map unit). The

‘*Eucalyptus megacornuta* mallet woodland’ (Emeg map unit) was found to be floristically heterogeneous, including plots from two different community types and one of our ungrouped plots (R010, Table 3).

No plots were established in the ‘Heath on Komatite at Bandalup Hill’ (Acop map unit) in the northern part of the range mapped by Craig et al. (2008), but one plot occurred in the mapped area of this community at Bandalup Hill (spatial data supplied by DEC’s Species and Communities Unit). This plot was classified as community 9 but the general description of this community outlined in Craig et al. (2008) suggests that a number of our plots in community 8 could also fall within that type.

Three plots that fell within the DEC mapping of the ‘*Eucalyptus purpurata* woodlands (Bandalup Hill)’ community were classified as community 11. These plots form a small cluster within a more broadly-defined floristic unit, with *Eucalyptus purpurata* occurring in only 20% of our plots of this community type, which were more typically open mallee shrubland rather than eucalypt woodland.

DISCUSSION

Recent surveys addressing the biological diversity on the Ravensthorpe Range have demonstrated this region’s significance as more than a northern buffer of the Fitzgerald River Biosphere Reserve (Deegan 2006, in Harris et al. 2008), because of the high conservation values specific to the range. It supports a large and diverse array of vascular plant taxa (Craig 2008), a high number of priority and short-range endemic plant species (Kern et al. 2008; this survey), a wide range of vegetation communities (Craig et al. 2008; this survey), and a high number of significant fauna species (Chapman & Newbey 1995; Edward & Harvey 2010). A large proportion of this diversity can be attributed to the location of this landform within the transitional rainfall zone of the SWAFR (Hopper & Gioia 2004) and at a convergence zone of different ecological regions (Beard 1990).

At a finer scale, the patterns of species and communities on the range are strongly correlated with landform, soils and edaphic variables. The Ravensthorpe Range is relatively low in altitude compared with other ranges in the wider region, such as the Stirling Ranges, where there is a clear montane vegetation belt (Pignatti et al. 1993). Nonetheless, the range shows high turnover of edaphic factors and habitats within a small area, due to the interactions of topography and a complex geology. Both this study and previous surveys (Bennett 1987; Chapman & Newbey 1995; Craig et al. 2008) have shown that the floristic communities are closely associated with site physical parameters—notably landform element, geology and soil depth and texture. This is a common pattern found among floristic communities on greenstone and BIF ranges on the Yilgarn Craton (Gibson et al. 2010, 2011), particularly the major floristic segregation between upland and lowland sites (e.g. Markey & Dillon 2008).

The closest upland shrubland communities to the Ravensthorpe Range occur on the Mt Barren quartzites, and while these share conspicuous elements (e.g. *Eucalyptus pleurocarpa*, *E. incrassata*, *E. preissiana*, *E. lehmannii*, *Banksia heliantha*, *Hakea pandanicarpa*, *Banksia lehmanniana*, *Calothamnus pinifolius*, *Allocasuarina humilis* and *Melaleuca pentagona*) there are a number of restricted taxa that clearly distinguish these mallee shrubland communities (e.g. *Banksia foliosissima*, *Acacia ophiolithica*, *Acacia* sp. Ravensthorpe Range [BR Maslin 5463], *Allocasuarina hystricosa*, *Spyridium glaucum* and *Guichenotia anota*). Beard (1972, 1973) recognized these two ranges in different vegetation systems and our data supports this interpretation.

At a more detailed scale our survey showed significant turnover in species composition within upland communities along the range, in particular resolving both a northern and southern laterite shrubland community (communities 17 and 18). There were also indications of an eastern set of floristic communities that were associated with different geological substrates, including weathered ultramafics (communities 8 and 9). This high turnover of floristic communities within and between disjunct ranges of greenstone and banded iron formation has been documented elsewhere in the Yilgarn (Gibson et al. 2007, 2010, 2011).

The unique feature of the Ravensthorpe Range is the extraordinary high number of SREs found on the range, being some six times the number of endemics recorded for the Hatter Hill – Ironcap Range (Gibson 2004) and the Bungalbin Hill area (Gibson et al. 2010). Current analysis of the SREs on the Ravensthorpe Range does not include the very complex *Lepidosperma* group (Barrett et al. 2009) and numbers could be expected to further increase when the taxonomy of this group is resolved.

Vegetation mapping

Despite the very different approaches inherent in plot-based survey and field-based vegetation mapping, a reasonable degree of concordance was seen between the two classifications. The correlation was better at a broader scale but with a few exceptions (primarily the heterogeneous Efal/Eple unit); reasonable correlation can also be seen at a finer scale. Given the complex nature of the vegetation and the small median size of the vegetation polygons (1.4 ha) some of the mismatch between the classifications may be related to boundary placement. No firm conclusion can be reached on the correlation of many of the vegetation units and our communities due to low sampling density; indeed only 40 of the 70 units were sampled. Current available mapping of the PECs suggests that they are variable in terms of floristic composition, with the exception of the ‘*Eucalyptus purpurata* woodlands (Bandalup Hill)’, which form a subset within our community 11.

Conservation and threats

The Ravensthorpe Range has high conservation values of

Table 2

Comparison between the vegetation mapping units of Craig et al. (2008) and the communities determined in this study. In all, 166 plots fell within the area mapped by Craig et al. (2008). Seven plots that fell into mosaic units, and one plot not included in compositional analysis, were excluded from the comparison. Vegetation units are grouped by a soil–landscape classification (Department of Agriculture and Food 2006). Figures indicate the number of plots in each mapped vegetation unit – current community classification combination. A perfect match between vegetation mapping units and communities defined from our current classification would show all plots along the diagonal.

SOIL–LANDSCAPE CLASSIFICATION		Vegetation unit	CURRENT COMMUNITY CLASSIFICATION																			
			17	14	18	15	6	13	1	16	3	19	20	4	2	11	12	21	8	9	5	7
RAVENSTHORPE SYSTEM																						
<i>Laterite & Colluvium</i>																						
Crests & upper slopes		01	Efal/Eple	18	13	4	1		2		1			5								
		03	Efal		1				3													
		04	Efal/Alca		1				1				1									
		05	Dfol	2																		
		06	Dque			1	1															
		07	Blae/Borb	1	3																	
		10	Alac																1			
<i>Metasedimentary rock & colluvium</i>																						
Crests, upper- & mid-slopes		12	Emeg					1	1													
		13	Egar					2	5	2					1							
		14	Ecli		1				5		2											2
Mid- & lower slopes		15	Eflo/Ephe							4		5				1						1
		16	Eflo/Esug																			
		18	Eunc/Einc												2							
		19	Eunc/Espp	1	1										7							1
		20	Mallee/Mspp												3							
		22	Mham						2													
Lower slopes		24	Epil/Edep									1										1
		25	Epil/Edep/Mspp																			2
Valleys		26	Esal																			3

Table 3

Comparison of the potentially threatened Priority Ecological Communities (DEC 2010) with the vegetation mapping unit (Craig et al. 2008) and the community determined by current classification. For each plot occurring in the PEC the community type is indicated.

Priority Ecological Community	Craig et al. 2008 map unit	Current classification
<i>Melaleuca</i> sp. Kundip Heath ¹	Mx	Not sampled
<i>Banksia laevigata</i> – <i>Banksia lemniiana</i> proteaceous thicket	Blae/Bor	3 plots community 14 1 plot community 17
<i>Eucalyptus megacomuta</i> mallet woodland	Emeg	1 plot community 6 1 plot community 13 1 plot unplaced (R010)
Heath on Komatiite at Bandalup Hill ²	Acop	1 plot community 9
<i>Eucalyptus purpurata</i> woodlands (Bandalup Hill) ²	Not mapped	3 plots community 11

1: *Melaleuca* sp. Kundip (GF Craig 6020) is now *Melaleuca sophisma* (Western Australian Herbarium 1998–).

2: Map polygons sourced DEC Species and Communities Unit, Dec 2010.

the same order as the Fitzgerald River National Park. At present, the vegetation on the Ravensthorpe Range is relatively weed-free and appears to be in excellent condition. Bridle creeper (*Asparagus asparagoides*) was the most extensive weed observed and tended to occur in riparian areas. Within intact vegetation, disturbance is localised and is the result of past mining and exploration activities and timber collection. The main biological threat to the floristic communities on the Ravensthorpe Range is *Phytophthora* infestation. Although largely absent from the range, *Phytophthora* is widespread in the adjacent Fitzgerald River National Park and at points near Kundip and south of Bandalup Hill (Harris et al. 2008). Given the number of access tracks into the range, including recreational tracks and tourist scenic drives, there is a very high risk that dieback may be introduced to the main ridges.

It is likely that some floristic communities of the range have been cleared or greatly reduced in area. Much of the lower slopes and colluvial and alluvial flats surrounding the Ravensthorpe Range possess rich clay soils and have been cleared for agriculture. Sharp boundaries occur around the edges of the range, particularly along the western and northern flanks of the range that abut directly onto pasture and wheatfields. Therefore, few colluvial outwash or lower slope sites with intact vegetation could be located in this survey, and it appears that significant expanses of lowland woodlands and forest dominated by tall trees, especially of *Eucalyptus oleosa*, *E. brachycalyx*, *E. loxophleba*, *E. occidentalis* and *E. salmonophloia*, have been lost to clearing (Beard 1972, 1973).

Inappropriate fire regimes are reported to be another threat to floristic communities on the range. Various authors (Beard 1973; Chapman & Newbey 1995; Craig et al. 2008; Harris et al. 2008) have indicated that fire has been an infrequent event on the Ravensthorpe Range during recent historical times, although Aboriginal burning regimes are unknown. This is indicated by extensive stands of long-unburnt woodlands, mallee and shrublands (Craig et al. 2008), and stands of vegetation appear to have not been burnt for at least 75 years (Chapman & Newbey 1995). There is a high number of fire sensitive, obligate seeder species in the vegetation communities, including shrub taxa in upland mallee shrubland communities. Mallots and moort taxa, such as *Eucalyptus clivicola*, *E. megacornuta*, *E. gardneri* subsp. *ravensthorpensis*, *E. platypus* and *E. cernua* are fire-sensitive species that dominate woodlands on hillslopes. Given the topography and concentration of short-range endemic taxa, the Ravensthorpe Range may have acted as a refuge for fire sensitive flora and fauna. Over the past two decades, there has been an increase in the frequency of fires on the range, resulting from lightning strikes, arson and the implementation of prescribed burning regimes (Craig et al. 2008; Harris et al. 2008). Craig et al. (2008) have reported that vegetation dominated by fire-sensitive species is recovering poorly after fire.

Not only are there management issues, but issues of land tenure and land use also impact on the conservation values of the range. Most of the range is covered by mining and exploration tenements (Harris et al. 2008), and both activities are currently underway. There are only two A-class nature reserves (Overshot Hill Nature Reserve and Kundip Nature Reserve), which only cover a small portion of the range and do not encompass the entire diversity of flora and floristic communities (McDonald 2010). A significant portion of the main range has been proposed for inclusion into the conservation estate (Department of Conservation and Land Management 1992; CTRC 1974), but no progress has been made in the decades since these proposals (Chapman & Newbey 1995; Harris et al. 2008). Mining operations are directly affecting some of the restricted SRE taxa, notably *Hibbertia abyssa*, which is restricted to the immediate area of one of the mining pits.

The Ravensthorpe Range represents one of the major biodiversity hotspots in Western Australia that will require active management to maintain these values into the future. This situation will be complicated by the high mineral prospectivity, the risk of dieback becoming established, increased fire frequency and possible climate change impacts. Given the complex and overlapping land use and tenure on the range its management will need the active participation of the local community, industry and government agencies to ensure long-term protection of these values.

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APPENDIX 1

Flora list for the Ravensthorpe Range collated from material collected during the plot-based survey and arranged by family. Nomenclature follows online Census of Western Australian Flora (The Western Australian Herbarium 1998–), except for *Lepidosperma*, which follows Barrett et al. (2009). Naturalised species are denoted by an asterisk. Threatened taxa (R), taxa of conservation concern (P1–P4) as listed in Smith (2010), and recent updates as shown on Florabase (Western Australian Herbarium, 1998–).

Aizoaceae*Disphyma crassifolium***Amaranthaceae***Ptilotus holosericeus***Apiaceae***Daucus glochidiatus**Platysace deflexa**Platysace maxwellii***Asparagaceae***Asparagus asparagoides* **Laxmannia paleacea**Lomandra collina**Lomandra effusa**Lomandra hastilis**Lomandra micrantha* subsp. *teretifolia**Lomandra mucronata**Thysanotus dichotomus**Thysanotus parviflorus* (P4)*Thysanotus patersonii**Thysanotus sparteus**Thysanotus thyrsoides**Thysanotus triandrus***Asphodelaceae***Asphodelus fistulosus* ***Asteraceae***Argentipallium niveum**Cassinia arcuata* (P2)*Lagenophora huegelii**Olearia ciliata**Olearia imbricata**Olearia muelleri**Ozothamnus lepidophyllus**Podolepis rugata**Pterochaeta paniculata**Senecio quadridentatus**Sonchus oleraceus* **Vittadinia cervicalaris* var. *cervicalaris**Vittadinia gracilis***Boraginaceae***Halgania anagaloides* var. *Southern* (AE Orchard 1609)*Halgania andromedifolia***Brassicaceae***Lepidium africanum* **Lepidium rotundum***Campanulaceae***Lobelia gibbosa***Casuarinaceae***Allocasuarina acutivalvis* subsp. *acutivalvis**Allocasuarina campestris**Allocasuarina huegeliana**Allocasuarina humilis**Allocasuarina hystricosa* (P4)*Allocasuarina microstachya**Allocasuarina scleroclada**Allocasuarina spinosissima**Allocasuarina thuyoides***Celastraceae***Stackhousia monogyna**Stackhousia scoparia**Tripterococcus brunonis***Chenopodiaceae***Atriplex semibaccata**Atriplex vesicaria**Chenopodium desertorum* subsp. *microphyllum**Enchylaena tomentosa* var. *tomentosa**Maireana enchylaenoides**Maireana marginata**Maireana suaedifolia**Rhagodia crassifolia**Rhagodia preissii* subsp. *preissii**Sclerolaena diacantha***Colchicaceae***Wurmbea cernua***Convolvulaceae***Dichondra repens**Wilsonia humilis***Cupressaceae***Callitris drummondii**Callitris roei***Cyperaceae***Caustis dioica**Gahnia ancistrophylla**Gahnia aristata**Gahnia lanigera**Lepidosperma diurnum**Lepidosperma carphoides**Lepidosperma fimbriatum**Lepidosperma gahnioides**Lepidosperma humile**Lepidosperma* aff. *gracile* (ref: Barrett 2009 report)*Lepidosperma* sp. (RL Barrett 4446) [pp. *Lepidosperma* aff. *pruinosum*]*Lepidosperma* sp. (RL Barrett 2984) [pp. *Lepidosperma* aff. *pruinosum*]*Lepidosperma* sp. (RL Barrett 3570)*Lepidosperma* sp. (GF Craig 8243)*Lepidosperma* sp. (R Davis 724)*Lepidosperma* sp. (AS George 9935)*Lepidosperma* sp. (GF Craig 8249)*Lepidosperma* sp. (RL Barrett 2770)*Lepidosperma* sp. (RL Barrett 3553)*Lepidosperma* sp. (RL Barrett 2766)*Lepidosperma* sp. (RL Barrett 3476)*Lepidosperma* sp. (RL Barrett 3522)*Lepidosperma* sp. A2 Inland Flat (GJ Keighery 7000)*Lepidosperma* sp. Archer Drive (S Kern & R Jasper LCH 18300)*Lepidosperma* sp. Bandalup Scabrid (N Eveleigh 10798)*Lepidosperma* sp. Carracarrup Creek (S Kern, R Jasper, D Brassington LCH 16738)*Lepidosperma* sp. Cordingup (GF Craig 6138)*Lepidosperma* sp. Elverdton (R Jasper et al. LCH 16844)*Lepidosperma* sp. Hopetoun Road (S Kern et al. LCH 16552)

Lepidosperma sp. Maydon (S Kern et al. LCH 17844)
Lepidosperma sp. Mt Burdett (MA Burgman & C. Layman MAB 3287)
Lepidosperma sp. Mt Chester (S Kern et al. LCH 16596)
Lepidosperma sp. Mt Short (S Kern et al. LCH 17510)
Lepidosperma sp. Ravensthorpe (GF Craig 5188)
Lepidosperma sp. Saltbush Hill (KR Newbey 4118)
Lepidosperma sp. Shoemaker Levy (L Ang & O Davies 10815A)
Lepidosperma sp. Steere River (S Kern et al. LCH 17764)
Mesomelaena stygia subsp. *stygia*
Schoenus aff. *sesquispiculus* (S Kern & R Jasper LCH 17455)
Schoenus aff. *subbarbatus* (S Kern & R Jasper LCH 17214)
Schoenus breviculmis
Schoenus brevisetis
Schoenus obtusifolius
Schoenus pleiostemoneus
Schoenus racemosus
Schoenus sesquispiculus
Schoenus subbarbatus
Schoenus subfascicularis
Schoenus subflavus subsp. *hispid culms* (KR Newbey 8278)
Schoenus subflavus subsp. *long leaves* (KL Wilson 2865)
Schoenus subflavus subsp. *subflavus*
Schoenus subclaxus
Tetralia sp. Mt Madden (CD Turley 40 BP/897)

Dilleniaceae

Hibbertia abyssa (R)
Hibbertia atrichosepala (P1)
Hibbertia exasperata
Hibbertia gracilipes
Hibbertia hamulosa
Hibbertia mucronata
Hibbertia psilocarpa
Hibbertia pungens
Hibbertia rostellata
Hibbertia rupicola
Hibbertia verrucosa

Droseraceae

Drosera grievii (P1)
Drosera macrantha subsp. *macrantha*

Elaeocarpaceae

Tetralthea appianata (P1)

Ericaceae

Acrotriche cordata
Acrotriche parviflora
Acrotriche ramiflora
Acrotriche orbicularis (P1)
Andersonia aff. *lehmanniana* (S Kern & R Jasper LCH 17769)
Andersonia parvifolia
Astroloma epacridis
Astroloma prostratum
Astroloma serratifolium
Brachyloma geissoloma subsp. *geissoloma*
Coleanthera myrtoides
Leucopogon aff. *opponens* (S Kern & R Jasper LCH 17971)
Leucopogon carinatus
Leucopogon concinnus
Leucopogon cuneifolius
Leucopogon denticulatus
Leucopogon fimbriatus
Leucopogon hamulosus

Leucopogon infuscatus
Leucopogon lloydiorum
Leucopogon sp. Coujinup (MA Burgman 1085)
 [pp. *Leucopogon conostephioides*]
Leucopogon sp. Newdegate (M Hislop 3585)
 [pp. *Leucopogon conostephioides*]
Leucopogon tamminensis var. *australis*
Lissanthe pleurandroides
Lysinema ciliatum
Lysinema pentapetalum
Styphelia intertexta
Styphelia pulchella

Euphorbiaceae

Beyeria brevifolia
Beyeria cockertonii (R)
Beyeria lechenaultii
Beyeria sulcata var. *brevipes*
Beyeria villosa (P4)
Monotaxis grandiflora var. *grandiflora*
Monotaxis paxii
Stachystemon brachyphyllus
Stachystemon polyandrus
Stachystemon vinosus (P4)
Stachystemon virgatus

Fabaceae

Acacia aff. *binata*
Acacia aff. *ferocior* (S Kern LCH 18424)
Acacia bifaria (P3)
Acacia binata
Acacia brachyclada
Acacia chrysellia
Acacia chrysocephala
Acacia crassuloides
Acacia crispula
Acacia cupularis
Acacia curvata
Acacia cyclops
Acacia deficiens
Acacia dermatophylla
Acacia diaphyllodinea
Acacia disticha
Acacia durabilis
Acacia erinacea
Acacia glaucoptera
Acacia gonophylla
Acacia grisea (P4)
Acacia harveyi
Acacia heterochroa subsp. *heterochroa*
Acacia ingrata
Acacia lachnophylla
Acacia laricina var. *crassifolia*
Acacia lasiocalyx
Acacia lasiocarpa var. *bracteolata*
Acacia mimica var. *angusta*
Acacia moirii subsp. *dasycarpa*
Acacia mutabilis subsp. *mutabilis*
Acacia octonervia
Acacia ophiolithica
Acacia patagiata
Acacia pinguiculosa subsp. *pinguiculosa*
Acacia pravifolia
Acacia pusilla
Acacia saligna subsp. *lindleyi*
Acacia sp. Ravensthorpe (RS Cowan & BR Maslin RSC A-760)
Acacia sp. Ravensthorpe Range (BR Maslin 5463) (P1)
Acacia sphaelata subsp. *recurva*
Acacia sphaelata subsp. *sphaelata*

<i>Acacia subcaerulea</i>		<i>Templetonia retusa</i>	
<i>Acacia sulcata</i> var. <i>planoconvexa</i>		<i>Templetonia sulcata</i>	
<i>Acacia sulcata</i> var. <i>platyphylla</i>			
<i>Acacia verrucula</i>		Frankeniaceae	
<i>Bossiaea preissii</i>		<i>Frankenia tetrapetala</i>	
<i>Chorizema aciculare</i> subsp. <i>aciculare</i>		Goodeniaceae	
<i>Chorizema nervosum</i>		<i>Anthotium humile</i>	
<i>Chorizema trigonum</i>		<i>Anthotium rubriflorum</i>	
<i>Chorizema ulotropis</i>	(P4)	<i>Coopernookia polygalacea</i>	
<i>Chorizema uncinatum</i>		<i>Coopernookia strophiolata</i>	
<i>Daviesia anceps</i>		<i>Dampiera angulata</i> subsp. <i>angulata</i>	(P4)
<i>Daviesia articulata</i>		<i>Dampiera deltoidea</i>	
<i>Daviesia benthamii</i> subsp. <i>acanthoclada</i> x subsp. <i>benthamii</i>		<i>Dampiera fasciculata</i>	
<i>Daviesia benthamii</i> subsp. <i>acanthoclona</i>		<i>Dampiera juncea</i>	
<i>Daviesia benthamii</i> subsp. <i>benthamii</i>		<i>Dampiera lavandulacea</i>	
<i>Daviesia dilatata</i>		<i>Dampiera sacculata</i>	
<i>Daviesia emarginata</i>		<i>Goodenia affinis</i>	
<i>Daviesia euryloba</i>		<i>Goodenia concinna</i>	
<i>Daviesia lancifolia</i>		<i>Goodenia incana</i>	
<i>Daviesia megacalyx</i>	(R)	<i>Goodenia laevis</i> subsp. <i>humifusa</i>	
<i>Daviesia mollis</i>		<i>Goodenia phillipsiae</i>	(P4)
<i>Daviesia nematophylla</i>		<i>Goodenia pinifolia</i>	
<i>Daviesia pachyphylla</i>		<i>Goodenia scapigera</i> subsp. <i>scapigera</i>	(P4)
<i>Daviesia pachyphylla</i>		<i>Goodenia stenophylla</i>	
<i>Daviesia retrorsa</i>		<i>Goodenia trichophylla</i>	
<i>Daviesia teretifolia</i>		<i>Goodenia tripartita</i>	
<i>Dillwynia acerosa</i>		<i>Lechenaultia formosa</i>	
<i>Dillwynia divaricata</i>		<i>Scaevola bursariifolia</i>	
<i>Eutaxia cuneata</i>		<i>Scaevola myrtifolia</i>	
<i>Eutaxia microphylla</i> var. <i>diffusa</i>		Gyrostemonaceae	
<i>Gastrolobium congestum</i>		<i>Gyrostemon racemiger</i>	
<i>Gastrolobium crassifolium</i>		<i>Gyrostemon sessilis</i>	
<i>Gastrolobium latifolium</i>		<i>Gyrostemon subnudus</i>	
<i>Gastrolobium musaceum</i>		Haemodoraceae	
<i>Gastrolobium parviflorum</i>		<i>Conostylis argentea</i>	
<i>Gastrolobium racemosum</i>		<i>Conostylis bealiana</i>	
<i>Gastrolobium tetragonophyllum</i>		<i>Haemodorum discolor</i>	
<i>Gastrolobium venulosum</i>		Haloragaceae	
<i>Gompholobium baxteri</i>		<i>Glischrocaryon angustifolium</i>	
<i>Gompholobium confertum</i>		<i>Glischrocaryon flavescens</i>	
<i>Gompholobium cyaninum</i>		Hemerocallidaceae	
<i>Gompholobium knightianum</i>		<i>Agrostocrinum scabrum</i> subsp. <i>scabrum</i>	
<i>Gompholobium marginatum</i>		<i>Dianella brevicaulis</i>	
<i>Gompholobium viscidulum</i>		<i>Dianella revoluta</i> var. <i>revoluta</i>	
<i>Goodia medicaginea</i>		<i>Stypandra glauca</i>	
<i>Hovea acanthoclada</i>		Iridaceae	
<i>Hovea trisperma</i>		<i>Patersonia juncea</i>	
<i>Indigofera australis</i>		<i>Patersonia lanata</i> forma <i>lanata</i>	
<i>Jacksonia alata</i>		<i>Patersonia limbata</i>	
<i>Jacksonia elongata</i>		Lamiaceae	
<i>Jacksonia viscosa</i>		<i>Hemigenia teretiuscula</i>	
<i>Kennedia nigricans</i>		<i>Microcorys barbata</i>	
<i>Labichea lanceolata</i> subsp. <i>brevifolia</i>		<i>Microcorys glabra</i>	
<i>Mirbelia multicaulis</i>		<i>Microcorys loganiacea</i>	
<i>Mirbelia ovata</i>		<i>Microcorys obovata</i>	
<i>Otton microphyllum</i>		<i>Microcorys pimeleoides</i>	
<i>Pultenaea calycina</i> subsp. <i>proxena</i>	(P4)	<i>Microcorys subcanescens</i>	
<i>Pultenaea craigiana</i>	(P3)	<i>Prostanthera baxteri</i>	
<i>Pultenaea indira</i> subsp. <i>indira</i>		<i>Teucrium sessiliflorum</i>	
<i>Pultenaea indira</i> subsp. <i>monstrosita</i>	(P3)	<i>Westringia cephalantha</i>	
<i>Pultenaea purpurea</i>		<i>Westringia dampieri</i>	
<i>Pultenaea rotundifolia</i>		Lauraceae	
<i>Pultenaea wudjariensis</i>	(P1)	<i>Cassytha glabella</i> forma <i>dispar</i>	
<i>Senna artemisioides</i> subsp. <i>filifolia</i>		<i>Cassytha melantha</i>	
<i>Senna artemisioides</i> subsp. x <i>artemisioides</i>		<i>Cassytha pomiformis</i>	
<i>Sphaerolobium daviesioides</i>			
<i>Sphaerolobium racemosum</i>			
<i>Templetonia battii</i>			
<i>Templetonia neglecta</i>			

Cassytha racemosa

Loganiaceae

Logania buxifolia

Logania micrantha

Logania tortuosa

Malvaceae

Alyogyne huegelii var. *grossulariifolia*

Guichenotia anota (P1)

Guichenotia apetala (P1)

Guichenotia micrantha

Lasiopetalum compactum

Lasiopetalum rosmarinifolium

Lysiosepalum involucreatum

Sida calyxhymenia

Thomasia angustifolia

Thomasia foliosa

Thomasia microphylla

Myrtaceae

Baeckea corynophylla

Baeckea crispiflora

Baeckea latens

Baeckea latens x *corynophylla*

Baeckea pachyphylla

Baeckea preissiana

Beaufortia micrantha var. *micrantha*

Beaufortia orbifolia

Beaufortia schaueri

Calothamnus gibbosus

Calothamnus gracilis

Calothamnus pinifolius

Calothamnus quadrifidus

Calothamnus roseus (P1)

Calytrix depressa

Calytrix leschenaultii

Calytrix tetragona

Chamelaucium ciliatum

Cyathostemon tenuifolius

Darwinia diosmoides

Darwinia sp. Ravensthorpe (GJ Keighery 8030)

Darwinia vestita

Eucalyptus aff. *rigidula* (A Markey 7000)

Eucalyptus astringens subsp. *astringens*

Eucalyptus astringens subsp. *redacta*

Eucalyptus x *bennettiae* (P4)

Eucalyptus brachycalyx

Eucalyptus x. *brachycalyx*

Eucalyptus calycogona subsp. *calycogona*

Eucalyptus celastroides subsp. *virella*

Eucalyptus cernua

Eucalyptus x. *cernua* (S Kern & R Jasper LCH 17803)

Eucalyptus cernua x *dielsii*

Eucalyptus clivicola

Eucalyptus desmondensis (P4)

Eucalyptus dielsii

Eucalyptus eremophila subsp. *eremophila*

Eucalyptus x *erythrandra*

Eucalyptus extensa

Eucalyptus falcata subsp. *falcata*

Eucalyptus flocktoniae subsp. *flocktoniae*

Eucalyptus gardneri subsp. *ravensthorpensis*

Eucalyptus incrassata (A Markey 7680)

Eucalyptus x *incrassata*

Eucalyptus indurata

Eucalyptus kessellii subsp. *eugnota*

Eucalyptus lehmannii subsp. *parallela*

Eucalyptus leptocalyx

Eucalyptus megacomuta

Eucalyptus myriadena subsp. *myriadena*

Eucalyptus occidentalis

Eucalyptus oleosa subsp. *corvina*

Eucalyptus olivina

Eucalyptus ovularis

Eucalyptus phaenophylla

Eucalyptus phenax subsp. *phenax*

Eucalyptus pileata

Eucalyptus platypus subsp. *congregata*

Eucalyptus platypus subsp. *platypus*

Eucalyptus pleurocarpa

Eucalyptus pluricaulis subsp. *pluricaulis*

Eucalyptus preissiana subsp. *preissiana*

Eucalyptus proxima

Eucalyptus x. *proxima* (S Kern & R Jasper LCH 16464)

Eucalyptus proxima x *suggrandis*

Eucalyptus purpurata (R)

Eucalyptus salmonophloia

Eucalyptus salubris

Eucalyptus sp. Ravensthorpe (AS George 616)

Eucalyptus sporadica

Eucalyptus stoatei (P4)

Eucalyptus suggrandis subsp. *suggrandis*

Eucalyptus tenera

Eucalyptus thamnoides subsp. *megista*

Eucalyptus uncinata

Hypocalymma strictum subsp. *strictum*

Kunzea affinis

Kunzea cincinnata

Kunzea micromera

Kunzea preissiana

Kunzea similis subsp. *mediterranea* (R)

Kunzea strigosa

Leptospermum erubescens

Leptospermum maxwellii

Leptospermum nitens

Leptospermum sp. Bandalup Hill (G Cockerton 11001)

Leptospermum spinescens

Melaleuca acuminata subsp. *acuminata*

Melaleuca aff. *coccinea* (S Kern & R Jasper LCH 18374)

Melaleuca bracteosa

Melaleuca brevifolia

Melaleuca calycina

Melaleuca carrii

Melaleuca cliffortioides

Melaleuca coronicarpa

Melaleuca cucullata

Melaleuca eleuterostachya

Melaleuca elliptica

Melaleuca glaberrima

Melaleuca hamata

Melaleuca johnsonii

Melaleuca lateriflora subsp. *lateriflora*

Melaleuca pauperiflora subsp. *pauperiflora*

Melaleuca penicula (P4)

Melaleuca pentagona var. *latifolia*

Melaleuca pentagona var. *pentagona*

Melaleuca pomphostoma

Melaleuca pungens

Melaleuca rigidifolia

Melaleuca societatis

Melaleuca ulicoides

Melaleuca stramentosa

Melaleuca striata

Melaleuca strobophylla

Melaleuca subfalcata

Melaleuca subtrigona

Melaleuca teuthidoides

Melaleuca thapsina

- Melaleuca torquata*
Melaleuca tuberculata var. *macrophylla*
Melaleuca undulata
Melaleuca villosisepala
Micromyrtus imbricata
Micromyrtus navicularis (P3)
Micromyrtus obovata
Rinzia communis
Taxandria spathulata
Verticordia acerosa var. *preissii*
Verticordia chrysantha
Verticordia densiflora var. *cespitosa*
Verticordia endlicheriana var. *major*
Verticordia grandiflora
Verticordia inclusa
Verticordia oxylepis
Verticordia picta
Verticordia roei subsp. *roei*
- Olacaceae**
Olax benthamiana
- Orchidaceae**
Caladenia falcata
Caladenia graminifolia
Corunastylis tepperi
Cyanicula aperta
Elythranthera brunonis
Eriochilus dilatatus subsp. *undulatus*
Pterostylis mutica
Pterostylis recurva
Pterostylis sanguinea
Pterostylis aff. *barbata* (A Markey 7223)
Pterostylis sp. Ongerup (KR Newbey 4874) (P4)
Pterostylis vittata
Thelymitra campanulata
Thelymitra graminea
Thelymitra occidentalis
- Oxalidaceae**
Oxalis perennans
- Phyllanthaceae**
Phyllanthus calycinus
Phyllanthus scaber
Poranthera drummondii
Poranthera microphylla
- Pittosporaceae**
Billardiera coriacea
Billardiera fusiformis
Billardiera venusta
Cheiranthra brevifolia
Cheiranthra filifolia var. *filifolia*
Marianthus bicolor
Marianthus microphyllus
Marianthus mollis (R)
- Poaceae**
Amphipogon avenaceus
Amphipogon strictus
Amphipogon turbinatus
Austrodanthonia caespitosa
Austrodanthonia setacea
Austrostipa acroclliata
Austrostipa elegantissima
Austrostipa exilis
Austrostipa hemipogon
Austrostipa nitida
Austrostipa pycnostachya
Austrostipa scabra
- Austrostipa* sp. Carlingup Rd (S Kern & R Jasper LCH 18459)
Austrostipa sp. Ravensthorpe Range (A Markey & J Allen 6261)
Austrostipa variabilis
Avena fatua *
Lolium perenne *
Neurachne alopecuroidea
Spartochloa scirpoidea
- Polygalaceae**
Comesperma ciliatum
Comesperma drummondii
Comesperma polygaloides
Comesperma spinosum
Comesperma volubile
- Portulacaceae**
Calandrinia eremaea
- Proteaceae**
Adenanthos flavidiflorus
Adenanthos glabrescens subsp. *exasperatus*
Adenanthos oreophilus
Banksia cirsioides
Banksia corvijuga (P3)
Banksia erythrocephala var. *erythrocephala* (P4)
Banksia foliosissima (P4)
Banksia heliantha
Banksia laevigata subsp. *laevigata* (P4)
Banksia lemanniana
Banksia media
Banksia obovata
Banksia pallida
Banksia violacea
Grevillea acuaria
Grevillea anethifolia
Grevillea coccinea subsp. *coccinea*
Grevillea concinna subsp. *lemanniana*
Grevillea dolichopoda
Grevillea fastigiata (P4)
Grevillea fulgens (P3)
Grevillea huegelii
Grevillea nudiflora
Grevillea oligantha
Grevillea patentiloba subsp. *patentiloba*
Grevillea patentiloba subsp. *platypoda*
Grevillea pectinata
Grevillea punctata (P3)
Grevillea rigida subsp. *distans*
Grevillea shuttleworthiana subsp. *obovata*
Grevillea sulcata (P1)
Hakea commutata
Hakea corymbosa
Hakea cygna subsp. *cygna*
Hakea gilbertii
Hakea ilicifolia
Hakea incrassata
Hakea laurina
Hakea lissocarpha
Hakea marginata
Hakea multilineata
Hakea nitida
Hakea obtusa
Hakea pandanica subsp. *crassifolia*
Hakea pandanica subsp. *pandanica*
Hakea scoparia subsp. *scoparia*
Hakea subsulcata
Hakea trifurcata
Hakea verrucosa

Hakea victoria
Isopogon polycephalus
Isopogon sp. Fitzgerald River (DB Foreman 813)
Isopogon sp. Newdegate (DB Foreman 771)
Isopogon sp. Ravensthorpe (DB Foreman 1207)
Isopogon trilobus
Persoonia dillwynioides
Persoonia helix
Persoonia striata
Persoonia teretifolia
Petrophile fastigiata
Petrophile glauca
Petrophile seminuda
Petrophile squamata subsp. northern (J Monks 40)
Petrophile teretifolia
Synaphea sp Southern Ranges (S Kern et al. LCH 17378)
Synaphea drummondii (P3)
Synaphea flabelliformis
Synaphea interioris
Synaphea petiolaris

Pteridaceae

Cheilanthes lasiophylla
Cheilanthes sieberi subsp. *sieberi*

Restionaceae

Desmocladus flexuosus
Harperia lateriflora
Hypolaena fastigiata
Lepidobolus chaetocephalus
Lepidobolus preissianus subsp. *arcuatus*

Rhamnaceae

Cryptandra graniticola
Cryptandra minutifolia subsp. *brevistyla*
Cryptandra myriantha
Cryptandra nutans
Cryptandra pungens
Cryptandra wilsonii
Pomaderris brevifolia
Pomaderris paniculosa subsp. *paniculosa*
Siegfriedia darwinioides
Spyridium cordatum
Spyridium glaucum
Spyridium majoranifolium
Spyridium sp. Jerdacuttup (A Williams 332)
Trymalium elachophyllum
Trymalium myrtillus subsp. *myrtillus*

Rubiaceae

Opercularia apiciflora
Opercularia vaginata

Rutaceae

Boronia albiflora
Boronia crassifolia
Boronia crenulata subsp. *obtusata*
Boronia inconspicua
Boronia inornata subsp. *inornata*
Boronia inornata subsp. *leptophylla*
Boronia oxyantha var. *brevicalyx*
Boronia penicillata
Boronia ramosa subsp. *anethifolia*
Boronia scabra subsp. *scabra*
Boronia spathulata
Boronia subsessilis
Boronia ternata var. *elongata*

Microcybe albiflora
Microcybe multiflora subsp. *baccharoides*
Microcybe pauciflora subsp. *grandis* (P3)
Microcybe pauciflora subsp. *pauciflora*
Nematolepis phebalioides
Phebalium ambiguum
Phebalium lepidotum
Phebalium obovatum
Phebalium tuberculatum
Philothea gardneri subsp. *gardneri*
Rhadinothamnus rudis subsp. *amblycarpus*

Santalaceae

Choretrum glomeratum var. *glomeratum*
Exocarpos aphyllus
Exocarpos sparteus
Leptomeria lehmannii
Leptomeria pachyclada
Leptomeria pauciflora
Santalum acuminatum

Sapindaceae

Dodonaea amblyophylla
Dodonaea bursariifolia
Dodonaea caespitosa
Dodonaea concinna
Dodonaea pinifolia
Dodonaea ptarmicaefolia
Dodonaea trifida
Dodonaea viscosa subsp. *angustissima* x subsp. *spathulata*

Scrophulariaceae

Eremophila densifolia subsp. *densifolia*
Eremophila densifolia subsp. *erecta*
Eremophila densifolia subsp. *pubiflora*
Eremophila glabra
Glycocystis beckeri

Stylidiaceae

Levenhookia pusilla
Levenhookia stipitata
Stylidium albomontis
Stylidium breviscapum
Stylidium dichotomum
Stylidium piliferum
Stylidium repens
Stylidium spinulosum subsp. *spinulosum*
Stylidium stowardii
Stylidium zeicolor

Thymelaeaceae

Pimelea argentea
Pimelea brachyphylla
Pimelea cracens
Pimelea erecta
Pimelea physodes (P4)
Pimelea sulphurea

Violaceae

Hybanthus floribundus subsp. *adpressus*
Hybanthus floribundus subsp. *floribundus*

Xanthorrhoeaceae

Xanthorrhoea platyphylla

Zygophyllaceae

Zygophyllum glaucum

APPENDIX 2

Sorted two-way table of Ravensthorpe Ranges floristic data showing species frequency in the 21 communities described. Only species that occur at frequencies of $\geq 20\%$ in at least one community are included in the table. Species groups are shown by horizontal lines.

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
<i>Thomasia microphylla</i>	-	-	-	40	-	-	25	-	-	-	-	-	-	-	-	-	-	-	14	13	-
<i>Lepidosperma</i> sp. (GF Craig 8249)	-	-	3	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Acrotriche plurilocularis</i>	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dodonaea trifida</i>	-	-	3	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Daviesia lancifolia</i>	-	-	-	-	-	-	25	-	-	-	-	-	-	-	17	-	-	-	14	6	-
<i>Melaleuca stramentosa</i>	-	-	-	-	-	-	75	-	-	-	-	-	-	-	33	-	-	-	-	9	-
<i>Dodonaea amblyophylla</i>	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca bracteosa</i>	-	-	-	-	-	-	25	-	-	-	-	-	-	-	17	-	3	-	-	3	-
<i>Acacia patagiata</i>	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus astringens</i>	-	-	-	-	-	-	75	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus thamnoides</i> subsp. <i>megista</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-	3	-
<i>Calothamnus roseus</i>	-	-	-	-	-	2	-	-	-	-	-	-	-	-	25	-	6	10	-	-	-
<i>Daviesia benthamii</i>	-	20	6	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Goodenia laevis</i> subsp. <i>humifusa</i>	-	20	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dillwynia divaricata</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Otton microphyllum</i>	-	20	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus eremophila</i> subsp. <i>eremophila</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca johnsonii</i>	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca societatis</i>	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cryptandra minutifolia</i> subsp. <i>brevistyla</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Phebalium obovatum</i>	-	-	-	20	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
<i>Eucalyptus tenera</i>	-	-	3	80	8	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
<i>Eucalyptus pileata</i>	-	20	21	80	50	20	-	-	-	-	-	25	-	-	-	-	-	-	-	3	-
<i>Melaleuca teuthidoides</i>	-	-	3	60	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca coroncarpa</i>	-	-	6	40	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca eleuterostachya</i>	-	-	3	20	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca undulata</i>	-	-	3	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Microcybe albiflora</i>	-	-	3	40	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus platypus</i>	-	-	6	20	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus clivicola</i>	-	-	6	-	67	-	75	-	-	-	-	25	39	4	-	-	-	-	-	-	-
<i>Lepidosperma</i> sp. Ravensthorpe (GF Craig 5188)	-	20	3	20	25	-	25	-	-	-	-	-	9	4	-	-	3	-	-	19	-
<i>Acrotriche</i> sp. Ravensthorpe (S Kern et al. LCH 16953)	13	-	-	-	-	1	-	-	-	-	-	-	-	-	13	-	-	22	-	-	-
<i>Eucalyptus purpurata</i>	-	-	3	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-

Appendix 2 (cont.)

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
<i>Pimelea erecta</i>	-	-	3	-	-	-	-	-	20	-	-	-	4	-	-	-	-	-	-	-	-	-
<i>Beyeria cockertonii</i>	-	-	-	-	-	3	-	60	-	-	-	-	-	-	60	-	-	20	-	-	-	-
<i>Olearia imbricata</i>	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pultenaea wudjariensis</i>	-	-	-	-	-	1	-	20	-	-	-	-	-	-	20	-	-	20	-	-	-	-
<i>Melaleuca calycina</i>	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	3	-	-
<i>Cryptandra nutans</i>	-	-	-	-	-	-	-	-	20	-	-	-	-	4	-	-	-	-	-	-	-	-
<i>Leucopogon infuscatus</i>	-	-	-	-	-	-	-	-	20	-	-	-	-	-	50	-	6	-	43	16	-	-
<i>Melaleuca pomphostoma</i>	-	-	3	-	-	-	-	-	40	100	-	-	-	4	-	-	-	-	14	6	-	-
<i>Pultenaea rotundifolia</i>	-	-	9	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	14	6	-	-
<i>Choretrum glomeratum</i> var. <i>glomeratum</i>	-	-	3	-	-	-	-	-	20	-	7	-	-	-	-	-	-	-	-	6	-	-
<i>Melaleuca pentagona</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	50	-	6	-	6	-	-
<i>Eriochilus dilatatus</i> subsp. <i>undulatus</i>	-	-	-	-	-	-	-	17	20	-	7	-	4	-	-	-	-	-	14	-	25	-
<i>Banksia media</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	43	9	-	-
<i>Hibbertia exasperata</i>	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	43	-	-	-
<i>Comesperma spinosum</i>	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	43	-	-	-
<i>Eucalyptus kessellii</i> subsp. <i>eugnosta</i>	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	3	-	-
<i>Styphelia intertexta</i>	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	-	-	-
<i>Dodonaea concinna</i>	13	-	38	20	8	-	-	-	20	-	40	25	-	-	-	-	-	-	-	-	-	-
<i>Westringia dampieri</i>	13	-	18	-	-	-	-	17	-	-	40	25	4	-	-	-	-	-	-	-	-	-
<i>Exocarpos sparteus</i>	-	-	9	-	-	-	-	-	-	-	27	25	-	4	-	-	6	-	14	9	-	-
<i>Leptomeria pachyclada</i>	-	-	6	-	-	-	-	17	-	-	40	-	-	-	-	-	-	-	14	3	-	-
<i>Nematolepis phebalioides</i>	-	-	-	-	-	-	25	-	40	-	33	25	-	-	-	-	-	-	-	3	-	-
<i>Beyeria villosa</i>	53	-	-	-	-	3	-	-	-	-	-	-	-	-	53	-	22	-	-	-	-	-
<i>Pultenaea calycina</i> subsp. <i>proxena</i>	-	-	-	-	-	-	-	17	20	-	67	-	-	-	-	-	-	-	-	3	-	-
<i>Boronia inornata</i> subsp. <i>inornata</i>	25	20	12	-	-	20	-	-	-	-	67	100	-	-	-	-	-	-	14	3	-	-
<i>Melaleuca pauperiflora</i> subsp. <i>pauperiflora</i>	-	-	18	40	-	-	-	-	20	-	80	25	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus brachycalyx</i>	-	-	12	-	-	-	-	17	20	-	87	50	-	-	-	-	-	-	14	-	-	-
<i>Eucalyptus indurata</i>	-	-	9	-	-	-	-	-	-	-	80	25	-	-	-	-	-	-	-	-	-	-
<i>Logania buxifolia</i>	-	-	-	-	-	-	-	17	40	-	7	-	4	8	-	-	12	-	29	6	-	-
<i>Eucalyptus leptocalyx</i>	-	-	3	-	-	-	25	-	60	-	7	-	-	-	-	-	-	12	71	16	-	-
<i>Templetonia retusa</i>	-	20	6	-	-	-	25	-	20	-	20	-	4	4	-	-	-	-	29	3	-	-
<i>Hybanthus floribundus</i> subsp. <i>adpressus</i>	-	-	15	-	-	20	-	58	40	50	20	-	-	8	17	-	-	-	14	13	-	-
<i>Melaleuca cliffortioides</i>	-	-	3	20	-	-	-	42	60	50	27	-	-	4	-	-	-	-	14	-	-	-
<i>Dodonaea pinifolia</i>	25	-	18	20	-	-	-	92	80	100	13	-	43	8	-	-	-	-	29	13	50	-
<i>Hakea verrucosa</i>	13	-	24	-	-	20	-	75	100	100	47	-	17	31	-	25	-	-	71	6	-	-
<i>Acacia ophiolithica</i>	-	-	12	-	-	-	-	50	60	-	20	-	-	4	-	-	-	-	57	3	-	-
<i>Eucalyptus</i> sp. Ravensthorpe (AS George 616)	20	-	4	-	-	9	19	20	3	-	-	3	-	17	58	-	-	19	-	-	-	-
<i>Grevillea oligantha</i>	-	-	21	20	-	-	-	25	80	-	7	-	-	-	-	-	-	-	57	16	-	-
<i>Halgania andromedifolia</i>	-	20	24	20	-	-	-	25	40	-	60	25	-	-	-	-	-	-	43	-	-	-
<i>Pomaderris brevifolia</i>	-	-	18	-	-	-	-	8	40	-	47	-	13	12	-	-	3	-	71	3	-	-

<i>Acrotriche cordata</i>	-	-	18	-	8	-	-	17	40	-	20	-	13	4	50	-	12	6	71	25	-
<i>Gahnia aristata</i>	-	-	15	-	-	-	-	17	40	-	13	-	-	-	-	-	-	-	29	22	-
<i>Acacia ingrata</i>	-	-	35	-	-	-	-	17	-	-	80	50	4	4	-	-	-	-	100	44	-
<i>Daviesia anceps</i>	-	-	15	-	-	-	-	50	60	-	33	-	4	15	-	-	12	-	86	56	25
<i>Acacia pusilla</i>	13	-	18	20	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	3	-
<i>Grevillea huegelii</i>	38	20	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-
<i>Coopernookia strophiolata</i>	-	20	18	40	-	-	-	-	20	-	7	-	-	-	-	-	-	-	-	13	-
<i>Cryptandra wilsonii</i>	-	-	12	-	-	-	-	17	40	-	7	-	-	-	-	-	-	-	14	6	-
<i>Marianthus microphyllus</i>	-	-	15	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus extensa</i>	-	-	21	-	58	-	-	-	-	-	7	25	-	-	-	-	-	-	-	-	-
<i>Melaleuca torquata</i>	-	-	26	60	42	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-
<i>Acacia binata</i>	13	-	41	-	8	-	-	-	20	-	-	-	-	-	-	-	-	-	14	-	-
<i>Melaleuca cucullata</i>	-	-	35	40	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus cernua</i>	-	-	32	-	8	60	-	-	40	100	-	-	-	-	-	-	-	-	6	-	-
<i>Exocarpos aphyllus</i>	38	-	41	60	50	40	50	8	-	100	-	50	22	-	-	-	-	-	29	6	-
<i>Daviesia nematophylla</i>	-	40	35	20	-	20	-	-	-	-	7	-	-	-	-	-	-	-	-	6	-
<i>Acacia glaucoptera</i>	63	100	50	-	42	-	-	25	80	-	-	50	-	-	-	-	-	-	-	9	-
<i>Cassyltha melantha</i>	-	40	65	80	8	-	-	8	20	-	13	-	-	8	33	-	-	-	71	19	-
<i>Eucalyptus flocktoniae</i> subsp. <i>flocktoniae</i>	100	20	91	100	58	20	50	17	-	-	-	-	9	15	17	-	-	6	86	34	-
<i>Eucalyptus phenax</i> subsp. <i>phenax</i>	100	40	88	20	-	60	-	17	80	-	7	25	9	8	-	-	-	-	43	19	25
<i>Pultenaea purpurea</i>	13	-	53	60	8	-	-	-	-	-	-	25	-	-	-	-	-	-	29	-	-
<i>Eucalyptus calycogona</i> subsp. <i>calycogona</i>	50	-	53	40	8	-	-	-	20	-	-	-	-	-	-	-	-	-	-	3	-
<i>Lepidosperma fimbriatum</i>	13	25	-	-	-	8	-	20	50	-	-	3	-	-	50	20	-	16	-	-	13
<i>Hakea commutata</i>	25	-	44	40	8	20	-	-	40	-	7	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca sophisma</i>	13	-	68	-	17	-	-	-	60	-	13	-	-	-	-	-	-	-	57	-	-
<i>Boronia inomata</i> subsp. <i>leptophylla</i>	-	-	29	40	25	-	-	17	20	-	7	-	-	-	-	-	-	-	86	9	-
<i>Hibbertia psilocarpa</i>	25	-	26	60	25	-	25	-	60	-	7	25	-	-	-	-	-	-	57	19	-
<i>Daviesia articulata</i>	-	20	24	-	-	20	25	-	-	-	-	-	-	-	-	-	-	-	57	19	-
<i>Grevillea pectinata</i>	-	40	15	60	25	-	-	-	-	-	-	-	-	-	-	-	-	-	57	-	-
<i>Melaleuca lateriflora</i> subsp. <i>lateriflora</i>	-	-	18	40	-	-	-	8	40	-	-	-	-	-	-	-	-	-	29	19	-
<i>Lepidosperma gahnioides</i>	-	-	26	20	-	-	-	-	20	-	-	-	-	-	-	-	-	-	43	13	-
<i>Wilsonia humilis</i>	-	60	24	40	8	-	-	-	20	-	-	-	-	-	-	-	-	-	29	9	-
<i>Lepidosperma</i> sp. Elverdton (R Jasper et al. LCH 16844)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	3	25
<i>Petrophile fastigiata</i>	-	-	-	-	-	-	-	25	-	-	-	-	-	19	-	-	3	-	-	9	25
<i>Spartochloa scirpoidea</i>	-	-	-	-	-	-	-	25	-	-	-	-	-	4	-	-	-	-	-	-	25
<i>Verticordia acerosa</i> var. <i>preissii</i>	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	6	-	3	25	-
<i>Halgania anagaloides</i> var. Southern (AE Orchard 1609)	-	-	-	-	-	3	4	-	-	-	-	3	-	-	25	-	6	11	25	3	-
<i>Astroloma epacridis</i>	-	-	3	-	-	-	-	42	20	-	-	-	4	-	17	-	-	-	14	6	50
<i>Lepidosperma diurnum</i>	-	20	3	-	-	-	-	75	40	-	7	-	-	23	-	-	6	-	-	3	-
<i>Calytrix tetragona</i>	-	-	-	-	-	-	-	67	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Stackhousia monogyne</i>	-	-	-	-	-	-	-	50	20	50	-	-	-	-	-	-	-	-	3	-	-
<i>Styphelia pulchella</i>	-	-	-	-	-	-	-	42	20	-	7	-	-	-	-	-	-	-	-	-	-
<i>Hibbertia rostellata</i>	-	-	-	-	-	-	-	33	-	-	27	-	-	-	-	-	-	-	-	-	-
<i>Cryptandra myriantha</i>	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 2 (cont.)

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
<i>Grevillea fastigiata</i>	-	-	3	-	-	-	-	42	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Allocasuarina hystricosa</i>	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Wurmbea cernua</i>	-	-	-	-	-	-	-	33	40	-	-	-	-	-	-	-	-	-	-	-	-
<i>Acacia mutabilis</i> subsp. <i>mutabilis</i>	-	-	3	-	8	-	-	-	-	-	27	-	-	-	-	-	-	-	-	-	-
<i>Glischrocaryon flavescens</i>	-	-	-	-	-	-	-	17	20	-	13	-	-	-	-	-	-	-	14	3	-
<i>Gahnia lanigera</i>	-	-	6	-	-	-	-	8	-	-	20	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca brevifolia</i>	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-
<i>Verticordia oxylepis</i>	-	-	-	-	-	-	-	8	20	-	-	-	-	-	-	-	-	-	-	-	-
<i>Goodenia scapigera</i> subsp. <i>scapigera</i>	-	-	-	-	-	-	-	8	-	50	-	-	9	8	-	-	3	24	-	3	-
<i>Thysanotus patersonii</i>	-	20	9	-	8	-	-	17	20	50	-	-	26	8	-	-	6	6	-	13	25
<i>Lepidosperma</i> sp. Carracarrup Creek (S Kern, R Jasper, D Brassington LCH 16738)	-	-	-	-	-	4	4	-	3	-	-	19	-	-	20	20	-	15	-	3	13
<i>Lomandra effusa</i>	-	20	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-
<i>Acacia sulcata</i>	13	20	3	-	-	-	-	8	-	100	7	-	17	4	-	-	-	-	-	13	25
<i>Lepidosperma</i> sp. Mt Short (S Kern et al. LCH 17510)	-	-	-	-	-	-	-	-	-	-	-	-	-	4	33	-	12	6	-	13	-
<i>Coopernookia polygalacea</i>	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57	19	-
<i>Melaleuca subfalcata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	13	-
<i>Eucalyptus pluricaulis</i> subsp. <i>pluricaulis</i>	13	-	-	-	-	-	-	-	-	-	-	-	-	15	33	-	-	6	-	19	25
<i>Eucalyptus proxima</i>	-	-	3	-	-	-	-	8	20	-	-	-	-	4	-	-	-	-	-	16	-
<i>Boronia scabra</i> subsp. <i>scabra</i>	-	-	-	-	-	-	-	17	-	100	-	-	-	-	-	-	-	-	-	9	-
<i>Melaleuca elliptica</i>	-	-	-	-	-	-	-	17	-	100	-	-	-	-	-	-	-	-	-	-	25
<i>Pimelea brachyphylla</i>	-	-	-	-	-	-	-	8	-	50	-	-	4	-	-	-	-	-	14	-	-
<i>Grevillea anethifolia</i>	-	-	-	-	-	-	-	8	-	50	-	-	-	-	-	-	-	-	-	-	-
<i>Agrostocrinum scabrum</i> subsp. <i>scabrum</i>	-	-	4	-	-	2	-	-	-	-	-	3	-	-	25	-	6	11	25	-	-
<i>Lepidosperma</i> sp. Maydon (S Kern et al. LCH 17844)	-	-	-	40	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Stypandra glauca</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Mirbelia multicaulis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Pterochaeta paniculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Daviesia pachyphylla</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	3	50
<i>Stylidium dichotomum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
<i>Allocasuarina huegeliana</i>	-	-	-	-	-	-	-	-	-	50	-	-	4	-	-	-	-	-	-	-	25
<i>Baeckea crispiflora</i>	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	50
<i>Gompholobium marginatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6	-	9	75
<i>Grevillea dolichopoda</i>	-	-	-	-	-	-	-	8	-	-	-	-	-	4	-	-	6	12	-	13	100
<i>Schoenus sesquispiculus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	3	75
<i>Melaleuca carrii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	3	50
<i>Acacia mimica</i> var. <i>angusta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	75
<i>Eucalyptus desmondensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75
<i>Allocasuarina campestris</i>	-	-	-	-	-	-	-	25	-	-	-	-	9	12	-	-	3	-	-	3	50
<i>Lepidobolus preissianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	12	-	-	6	50

<i>Eucalyptus megacomuta</i>	-	-	-	-	20	-	-	-	-	-	4	-	-	25	-	-	-	-	-		
<i>Persoonia teretifolia</i>	-	20	3	20	8	40	-	8	-	50	20	-	9	27	-	-	3	-	14	6	-
<i>Eucalyptus lehmannii</i> subsp. northern (M French 425)	-	-	-	-	-	-	-	-	-	-	-	-	8	50	-	6	12	-	3	-	-
<i>Boronia oxyantha</i> var. <i>brevicalyx</i>	-	-	-	-	-	80	75	-	-	-	-	9	-	67	-	3	6	-	6	-	-
<i>Spyridium glaucum</i>	-	-	9	-	-	60	25	-	-	-	-	13	12	17	-	3	6	-	3	-	-
<i>Andersonia</i> aff. <i>lehmanniana</i> (S Kern & R Jasper LCH 18374)	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	3	-	-	-	-	-
<i>Daviesia mollis</i>	-	-	-	-	-	-	-	-	-	-	-	-	4	33	-	-	6	-	6	-	-
<i>Microcorys glabra</i>	-	-	15	-	-	-	-	-	20	50	-	-	4	-	-	-	-	29	9	-	-
<i>Siegfriedia darwinioides</i>	-	-	6	-	-	-	25	-	-	-	-	22	12	33	-	-	-	29	16	-	-
<i>Billardiera coriacea</i>	-	20	-	-	-	-	-	-	-	-	-	-	4	17	25	-	-	-	-	-	-
<i>Spyridium majoranifolium</i>	-	-	-	-	-	-	-	-	-	-	-	-	4	33	25	-	-	-	-	-	-
<i>Pterostylis sanguinea</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	6	6	-	3	-	-
<i>Boronia ternata</i> var. <i>elongata</i>	-	-	-	-	-	-	-	-	-	-	-	4	27	-	-	9	-	-	-	-	-
<i>Hakea multilineata</i>	-	-	-	-	-	-	-	-	-	-	-	4	23	-	-	-	-	-	3	-	-
<i>Hibbertia atrichosepala</i>	-	-	-	-	2	15	-	-	-	-	-	-	-	25	-	-	10	-	-	-	-
<i>Kunzea strigosa</i>	-	-	-	-	2	-	-	-	-	-	-	-	-	25	-	6	11	25	-	-	-
<i>Grevillea concinna</i> subsp. <i>lemanniana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-
<i>Lepidosperma</i> sp. (AS George 9935)	-	-	-	-	-	-	-	-	-	-	-	-	-	33	25	-	6	-	-	-	-
<i>Drosera macrantha</i> subsp. <i>macrantha</i>	-	-	-	20	-	-	-	8	-	-	-	-	-	-	-	6	24	-	3	-	-
<i>Beyeria brevifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	17	25	18	29	-	9	-	-
<i>Dampiera fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	29	-	-	-	-
<i>Calothamnus gracilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	29	-	-	-	-
<i>Jacksonia elongata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	41	-	3	-	-
<i>Xanthorrhoea platyphylla</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53	-	-	-	-
<i>Isopogon trilobus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	3	-	-
<i>Schoenus sublaxus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	6	53	-	-	-	-
<i>Adenanthos oreophilus</i>	-	-	-	-	-	-	-	-	-	-	-	-	8	17	-	-	35	-	-	-	-
<i>Melaleuca striata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	24	-	-	-	-
<i>Chorizema trigonum</i>	-	-	-	-	-	25	-	-	-	-	-	-	-	50	25	-	29	-	19	-	-
<i>Grevillea nudiflora</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	18	-	6	-	-
<i>Leucopogon carinatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	50	25	-	41	-	13	-	-
<i>Patersonia limbata</i>	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-	12	-	-	-	-
<i>Calothamnus pinifolius</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	35	-	-	-	-
<i>Chorizema uncinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-
<i>Hibbertia mucronata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	6	-	-	-	-
<i>Pterostylis vittata</i>	-	-	6	-	8	-	-	8	-	-	7	-	-	-	-	-	29	-	6	-	-
<i>Chamelaucium ciliatum</i>	-	-	-	-	-	-	-	17	-	50	-	4	8	17	-	12	41	-	19	-	-
<i>Banksia heliantha</i>	-	-	-	-	10	-	-	-	-	-	-	-	83	83	-	82	6	-	3	-	-
<i>Eucalyptus preissiana</i> subsp. <i>preissiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	-	24	-	-	-	-
<i>Lepidosperma</i> sp. Archer Drive (S Kern & R Jasper LCH 18300)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	25
<i>Isopogon</i> sp. Fitzgerald River (DB Foreman 813)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	6	-	-
<i>Gompholobium viscidulum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-
<i>Kunzea cincinnata</i>	-	-	-	-	-	-	-	8	-	-	-	4	23	-	-	18	-	-	16	-	-
<i>Melaleuca thapsina</i>	-	-	-	20	-	20	-	-	-	-	-	22	8	-	-	-	-	-	3	-	-

Appendix 2 (cont.)

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
<i>Haemodorum discolor</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	25
<i>Boronia subsessilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	6	-	-	6	-
<i>Logania tortuosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	25
<i>Hakea marginata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	19	25
<i>Lepidosperma</i> sp. (RL Barrett 2770)	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	12	-	16	25
<i>Lepidosperma carphoides</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	24	-	6	-
<i>Conostylis bealiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	13	-
<i>Dampiera lavandulacea</i>	-	-	-	-	-	-	-	33	-	-	-	-	-	4	-	25	6	41	-	25	25
<i>Stachystemon virgatus</i>	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	41	-	-	25
<i>Petrophile squamata</i> subsp. northern (J Monks 40)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	53	-	13	-
<i>Argentipallium niveum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	6	-
<i>Pultenaea indira</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	-	6	-
<i>Allocasuarina acutivalvis</i> subsp. <i>acutivalvis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	12	17	25	9	-	-	-	25
<i>Cassylia racemosa</i>	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	3	-	-	-	-
<i>Banksia corviflora</i>	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	21	-	7	-	21	-
<i>Astroloma serratifolium</i>	-	-	-	-	-	-	-	33	-	-	-	-	-	4	-	25	18	6	-	9	50
<i>Calytrix leschenaultii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	15	18	-	28	75
<i>Schoenus racemosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	12	24	14	38	50
<i>Lepidosperma</i> sp. Bandalup Scabrid (N Eveleigh 10798)	-	-	9	-	40	11	4	-	-	-	-	41	25	-	41	20	6	5	25	-	-
<i>Melaleuca glaberrima</i>	-	-	-	40	-	-	-	8	-	50	-	-	-	4	-	-	-	-	14	44	25
<i>Rinzia communis</i>	-	-	-	20	-	-	25	-	-	-	-	-	-	15	-	-	-	-	-	28	-
<i>Grevillea patentiloba</i> subsp. <i>patentiloba</i>	-	-	6	-	25	20	25	8	-	-	13	-	4	8	17	-	3	24	29	19	-
<i>Acacia gonophylla</i>	-	-	-	-	-	-	25	-	-	-	-	-	-	4	-	25	-	41	-	41	-
<i>Eutaxia cuneata</i>	-	-	-	20	-	-	-	-	-	-	-	-	4	12	-	-	-	6	-	47	-
<i>Dianella revoluta</i> var. <i>revoluta</i>	-	40	18	20	-	-	-	42	20	-	7	-	4	4	17	25	3	6	43	44	25
<i>Boronia inconspicua</i>	-	-	15	40	17	20	25	-	-	-	-	-	17	15	50	-	6	12	29	31	-
<i>Eucalyptus phaenophylla</i>	-	-	9	60	-	-	25	-	-	-	-	-	9	23	17	-	6	12	57	59	-
<i>Eucalyptus suggrandis</i> subsp. <i>suggrandis</i>	-	20	21	20	8	-	25	-	-	-	-	-	-	-	17	-	6	-	71	41	-
<i>Gompholobium confertum</i>	-	20	-	20	-	-	25	-	-	-	-	-	-	15	-	-	3	6	-	41	-
<i>Lasiopetalum rosmarinifolium</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	12	17	75	9	29	-	44	-
<i>Baeckea corynophylla</i>	-	-	-	20	8	-	50	8	20	-	-	-	-	12	-	-	6	12	14	50	-
<i>Melaleuca rigidifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	8	33	-	21	35	14	56	25
<i>Spyridium cordatum</i>	-	-	3	60	-	-	-	8	-	-	-	-	9	19	17	-	30	-	86	47	-
<i>Cassylia glabella</i>	13	-	3	-	-	-	-	42	20	-	33	-	-	8	33	25	39	59	29	44	25
<i>Hibbertia pungens</i>	13	-	3	40	-	-	-	75	-	100	13	-	43	19	67	-	24	-	43	69	100
<i>Melaleuca hamata</i>	25	40	21	40	25	-	50	67	-	-	13	-	65	65	50	-	3	6	86	94	100
<i>Hakea lissocarpha</i>	-	-	3	-	-	-	-	8	-	-	-	-	-	12	-	25	18	24	-	66	75
<i>Lomandra micrantha</i> subsp. <i>teretifolia</i>	-	20	-	-	-	-	-	8	-	-	-	-	-	-	33	25	27	41	57	53	-
<i>Hakea laurina</i>	-	-	12	20	-	-	25	-	20	-	-	-	26	15	-	25	9	29	57	69	-
<i>Tetraria capillaris</i>	-	-	3	-	-	-	-	17	-	-	27	-	4	8	50	50	39	18	57	78	-

<i>Neurachne alopecuroidea</i>	-	40	-	20	-	-	-	83	-	-	-	-	4	19	-	25	64	24	14	75	75
<i>Eucalyptus incrassata</i>	-	-	-	-	-	-	25	-	-	-	-	-	13	15	33	25	39	71	14	75	-
<i>Eucalyptus uncinata</i>	-	-	-	-	-	-	-	-	40	-	7	-	4	31	67	-	48	29	71	84	50
<i>Gahnia ancistrophylla</i>	-	40	9	40	17	-	-	25	20	-	7	-	-	19	17	-	42	29	57	81	75
<i>Lepidosperma</i> sp. Mt Benson (RL Barrett 3553)	-	-	-	-	-	-	-	17	-	-	-	-	4	46	-	25	18	12	-	9	50
<i>Brachyloma geissoloma</i> subsp. <i>geissoloma</i>	-	-	-	-	-	3	38	-	-	-	-	3	-	-	38	-	6	3	-	3	-
<i>Philotheca gardneri</i> subsp. Ravensthorpe (GF Craig 6902)	7	-	26	-	-	6	62	-	-	50	-	6	8	-	62	-	-	3	-	3	-
<i>Lepidosperma</i> sp. Cordingup (GF Craig 6138)	-	-	-	-	-	20	-	8	-	-	-	-	26	42	67	25	18	-	14	-	25
<i>Acrotriche ramiflora</i>	25	-	-	20	-	-	-	-	-	-	-	-	22	35	50	25	21	18	14	9	-
<i>Rhadinthamnus rudis</i> subsp. <i>amblycarpus</i>	-	-	-	-	-	-	-	-	-	-	-	-	22	31	33	-	21	-	-	6	-
<i>Banksia laevigata</i> subsp. <i>laevigata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-	21	-	-	-	-
<i>Acacia</i> sp. Ravensthorpe (RS Cowan & BR Maslin RSC A-760)	-	-	-	20	-	-	-	-	-	-	-	-	26	54	-	-	33	12	-	19	-
<i>Hakea obtusa</i>	-	-	-	-	-	-	-	-	-	-	-	-	13	65	100	25	45	18	14	19	-
<i>Beaufortia orbifolia</i>	-	-	-	-	-	20	-	-	-	-	-	-	-	69	67	-	18	-	-	6	-
<i>Isopogon</i> sp. Ravensthorpe (DB Foreman 1207)	-	-	-	-	-	-	-	-	-	-	-	-	4	46	33	-	48	6	-	6	-
<i>Leucopogon cuneifolius</i>	-	-	-	20	-	-	-	-	-	100	-	-	-	35	17	-	52	-	-	6	-
<i>Goodenia pinifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	35	-	-	55	-	-	3	25
<i>Persoonia helix</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	23	-	-	33	-	-	3	25
<i>Santalum acuminatum</i>	25	40	12	-	-	-	-	17	40	50	13	50	43	50	17	-	3	6	-	6	-
<i>Gastrolobium parviflorum</i>	50	20	3	40	17	80	25	-	-	-	-	-	74	62	67	-	6	-	-	16	-
<i>Lasiopetalum compactum</i>	38	20	18	-	33	20	25	8	-	-	-	50	43	38	33	-	18	6	71	25	-
<i>Stylidium albomontis</i>	-	-	-	-	8	20	-	17	-	-	-	-	30	65	83	25	39	12	14	44	-
<i>Lepidosperma</i> sp. Saltbush Hill (KR Newbey 4118)	-	25	17	-	-	16	15	-	3	-	-	38	-	50	50	20	24	6	-	21	25
<i>Calothamnus quadrifidus</i>	-	-	-	-	-	-	-	67	-	-	7	-	22	31	-	50	9	6	-	38	25
<i>Platysace maxwellii</i>	25	-	6	20	-	-	-	17	-	50	13	25	61	31	17	50	21	18	-	41	-
<i>Grevillea coccinea</i> subsp. <i>coccinea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	24	6	-	-	-
<i>Thysanotus sparteus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	21	-	-	9	-
<i>Dampiera angulata</i> subsp. <i>angulata</i>	13	-	-	-	-	-	-	-	-	-	-	-	-	27	17	-	15	-	14	16	-
<i>Marianthus bicolor</i>	-	-	3	-	17	20	-	-	-	-	-	-	17	12	-	25	18	18	29	38	-
<i>Cassytha pomiformis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	36	-	-	6	-
<i>Guichenotia anota</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	30	-	-	-	-
<i>Hakea pandanica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	35	-	6	-
<i>Daviesia teretifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	35	-	-	25
<i>Hakea trifurcata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	12	-	-	-
<i>Schoenus pleiostemoneus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	18	-	3	-
<i>Adenanthos flavidiflorus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-
<i>Drosera grievei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-
<i>Lepidobolus chaetocephalus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	3	-
<i>Hakea cygna</i> subsp. <i>cygna</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-
<i>Hemigenia teretiuscula</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	3	-
<i>Hakea incrassata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	25
<i>Stachystemon brachyphyllus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-
<i>Astroloma prostratum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
<i>Lepidosperma</i> sp. (RL Barrett 3522)	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	21	18	-	-	-
<i>Schoenus obtusifolius</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	18	-	9	-
<i>Chorizema aciculare</i> subsp. <i>aciculare</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	6	-	13	50

Appendix 2 (cont.)

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
<i>Leucopogon concinnus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	12	-	3	75
<i>Acacia heterochroa</i> subsp. <i>heterochroa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	33	-	30	29	-	3	-
<i>Gompholobium knightianum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	18	-	3	-
<i>Billardiera venusta</i>	-	-	-	-	-	5	12	-	-	-	-	25	-	17	33	-	6	7	-	33	-
<i>Dampiera sacculata</i>	-	-	-	-	-	-	-	8	-	-	-	-	-	4	-	-	24	12	-	22	-
<i>Leptospermum spinescens</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	19	17	-	30	29	-	9	-
<i>Lepidosperma</i> sp. Mt Burdett (MA Burgman & C Layman MAB 3287)	13	-	-	-	-	7	4	-	-	-	-	16	-	17	53	-	53	9	-	27	-
<i>Taxandria spathulata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	8	67	25	45	88	-	22	-
<i>Banksia lemnniana</i>	-	-	-	-	-	-	-	-	-	-	-	-	9	19	50	25	58	71	-	25	-
<i>Beaufortia schaueri</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	15	50	-	76	41	14	38	25
<i>Leucopogon conostephioides</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	25	36	76	-	44	25
<i>Eucalyptus falcata</i> subsp. <i>falcata</i>	13	-	-	-	-	-	25	-	-	-	-	-	74	92	33	75	70	82	-	34	-
<i>Eucalyptus pleurocarpa</i>	-	-	-	-	-	-	-	8	-	-	-	-	13	85	67	75	94	100	29	50	-
<i>Hibbertia gracilipes</i>	13	-	-	-	-	-	-	8	-	-	-	-	4	46	17	-	85	76	14	44	50
<i>Lomandra mucronata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	8	50	100	70	88	-	44	25
<i>Jacksonia viscosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	48	18	-	-	-
<i>Conostylis argentea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	17	25	58	6	-	31	100
<i>Boronia crassifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	8	33	-	70	53	-	9	-
<i>Leptospermum</i> sp. Bandalup Hill (G Cockerton 11001)	-	-	-	-	-	9	4	-	-	-	-	6	-	33	79	-	53	7	-	79	-
<i>Beaufortia micrantha</i> var. <i>micrantha</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58	29	-	13	-
<i>Lysinema ciliatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61	65	-	9	-
<i>Amphipogon turbinatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	25	61	76	-	31	50
<i>Allocasuarina humilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	25	73	82	-	6	-
<i>Mesomelaena stygia</i> subsp. <i>stygia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64	82	-	9	50
<i>Persoonia striata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42	24	-	3	-
<i>Petrophile seminuda</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	35	-	3	25
<i>Schoenus brevisetis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	-	-	-	-
<i>Banksia pallida</i>	-	-	-	-	-	3	-	-	-	-	-	-	-	-	61	-	-	7	-	61	-
<i>Lepidosperma</i> sp. (RL Barrett 3570)	-	-	-	-	-	-	-	8	-	-	-	-	-	8	-	-	61	-	-	13	-
<i>Banksia cirsioides</i>	-	-	-	-	-	6	8	-	-	-	-	13	-	33	73	-	-	7	-	73	-
<i>Petrophile glauca</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	33	-	55	-	-	6	-
<i>Dampiera juncea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	67	-	-	3	-
<i>Melaleuca villosisepala</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	85	-	-	16	25
<i>Banksia foliosissima</i>	-	-	-	-	-	1	-	-	-	-	-	3	-	-	21	-	-	7	-	21	-
<i>Daviesia euryloba</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-
<i>Stylidium piliferum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	24	-	9	25
<i>Corunastylis tepperi</i>	7	-	-	-	-	2	-	-	9	-	-	-	-	-	20	20	6	15	-	-	-
<i>Eucalyptus celastroides</i> subsp. <i>virella</i>	-	-	3	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-
<i>Eucalyptus myriadena</i> subsp. <i>myriadena</i>	-	20	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-
<i>Maireana marginata</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

<i>Austrostipa exilis</i>	13	-	3	-	17	-	-	-	-	-	-	25	4	-	-	-	-	-	-	-	
<i>Acacia</i> sp. Ravensthorpe Range (BR Maslin 5463)	25	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Atriplex semibaccata</i>	-	-	-	-	-	-	-	-	-	-	-	25	4	-	-	-	-	-	-	-	
<i>Melaleuca acuminata</i> subsp. <i>acuminata</i>	-	-	-	40	-	-	-	-	-	-	7	25	13	-	-	-	-	-	-	3	
<i>Acacia cyclops</i>	13	-	-	-	-	-	-	17	-	-	-	25	4	-	-	-	-	-	-	-	
<i>Acacia subcaerulea</i>	13	-	-	-	8	-	-	-	-	-	-	-	13	4	-	25	-	18	-	-	
<i>Hovea acanthoclada</i>	-	-	-	-	17	20	-	-	-	-	-	50	17	8	67	100	-	6	-	-	
<i>Labichea lanceolata</i> subsp. <i>brevifolia</i>	13	-	-	-	-	-	-	-	-	-	-	-	30	-	-	75	-	-	-	-	
<i>Beyeria sulcata</i> var. <i>brevipes</i>	-	-	39	40	-	8	35	-	6	-	-	3	-	17	40	-	-	12	-	13	
<i>Eucalyptus gardneri</i> subsp. <i>ravensthorpensis</i>	25	20	3	-	-	100	-	-	-	-	-	-	39	-	-	-	-	-	-	-	
<i>Grevillea patentiloba</i> subsp. <i>platypoda</i>	50	-	-	-	-	-	-	-	-	-	-	-	13	4	17	25	-	-	-	3	
<i>Phebalium tuberculosum</i>	13	-	-	-	-	-	-	-	-	-	50	-	65	12	-	-	-	-	-	-	
<i>Trymalium elachophyllum</i>	13	-	-	-	-	-	-	-	-	-	-	-	26	4	-	-	-	-	-	-	
<i>Billardiera fusiformis</i>	-	-	13	-	-	3	-	-	9	-	-	-	-	-	25	20	-	14	-	25	
<i>Austrodanthonia setacea</i>	63	40	6	-	8	-	-	8	-	-	-	-	39	4	-	25	-	-	-	9	
<i>Austrostipa hemipogon</i>	63	60	3	-	8	-	-	8	-	-	-	-	30	-	-	-	-	-	-	3	
<i>Sonchus oleraceus</i>	25	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	
<i>Daucus glochidiatus</i>	25	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Sclerolaena diacantha</i>	25	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Enchylaena tomentosa</i> var. <i>tomentosa</i>	38	20	3	-	-	-	-	-	-	-	-	25	4	-	-	-	-	-	-	-	
<i>Austrostipa acrociliata</i>	38	20	6	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	
<i>Austrostipa</i> sp. Carlingup Rd (S Kern & R Jasper LCH 18459)	63	20	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Vittadinia gracilis</i>	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Oxalis perennans</i>	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ptilotus holosericeus</i>	63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus oleosa</i> subsp. <i>corvina</i>	25	-	6	-	17	-	-	-	-	-	7	100	-	-	-	-	-	-	-	-	
<i>Senna artemisioides</i> subsp. <i>x artemisioides</i>	75	40	12	-	8	20	-	8	-	-	7	75	22	-	-	-	-	-	-	3	
<i>Acacia erinacea</i>	50	100	12	-	17	40	-	-	-	-	-	25	-	-	-	-	-	-	-	-	
<i>Austrostipa elegantissima</i>	38	80	3	-	-	-	-	-	-	-	7	50	17	-	-	-	-	-	-	-	
<i>Olearia muelleri</i>	38	100	3	-	25	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	
<i>Asparagus asparagoides</i>	-	20	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	3	
<i>Disphyma crassifolium</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Lepidium rotundum</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Cassinia arcuata</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Rhagodia crassifolia</i>	-	60	-	-	-	-	-	-	-	-	7	50	-	-	-	-	-	-	-	-	
<i>Lepidosperma</i> sp. Mt Chester (S Kern et al. LCH 16596)	-	-	-	-	-	6	-	-	3	-	25	3	-	-	80	80	-	15	-	-	
<i>Austrostipa pycnostachya</i>	-	60	3	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	
<i>Dianella brevicaulis</i>	13	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus salmonophloia</i>	-	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Acacia chrysella</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Lepidosperma</i> sp. (GF Craig 8243)	-	20	3	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	
Number of plots	8	5	34	5	12	5	4	12	5	2	15	4	23	26	6	4	33	17	7	32	4

APPENDIX 3

Significant indicator taxa of the 21 floristic community types recognised on the Ravensthorpe Range. Indicator values (%) are shown only for taxa which were significant at $p \leq 0.05$ (from Monte Carlo permutation test). Species with high indicator values (≥ 14) are indicated by shading. Community 10 was not included as the low number of plots (2) precluded this type of analysis.

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21	
<i>Acacia</i> sp. Ravensthorpe Range	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Austrodanthonia setacea</i>	17	7	-	-	-	-	-	-	-	-	-	7	-	-	3	-	-	-	-	3	
<i>Austrostipa acrociliata</i>	21	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Austrostipa hemipogon</i>	22	20	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	
<i>Austrostipa</i> sp. Ravensthorpe Range	43	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Daucus glochidiatus</i>	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Enchylaena tomentosa</i> var. <i>tomentosa</i>	16	4	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus phenax</i> subsp. <i>phenax</i>	19	3	14	1	-	7	-	1	12	-	1	-	-	-	-	-	-	3	1	1	
<i>Grevillea patentiloba</i> subsp. <i>platypoda</i>	22	-	-	-	-	-	-	-	-	-	-	2	-	2	6	-	-	-	-	-	
<i>Oxalis perennans</i>	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ptilotus holosericeus</i>	63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Sonchus oleraceus</i>	20	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	
<i>Vittadinia gracilis</i>	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Acacia erinacea</i>	10	41	1	-	1	7	-	-	-	-	3	-	-	-	-	-	-	-	-	-	
<i>Acacia glaucoptera</i>	9	24	6	-	4	-	-	1	15	-	6	-	-	-	-	-	-	-	-	-	
<i>Austrostipa elegantissima</i>	7	33	-	-	-	-	-	-	-	-	13	2	-	-	-	-	-	-	-	-	
<i>Austrostipa pycnostachya</i>	-	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Dianella brevicaulis</i>	2	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus salmonophloia</i>	-	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Lepidosperma</i> sp. Mt Chester	-	58	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Olearia muelleri</i>	7	53	-	-	3	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	
<i>Rhagodia crassifolia</i>	-	31	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-	
<i>Wilsonia humilis</i>	-	19	3	8	-	-	-	-	2	-	-	-	-	-	-	-	-	4	-	-	
<i>Acacia binata</i>	2	-	18	-	1	-	-	-	4	-	-	-	-	-	-	-	-	2	-	-	
<i>Eucalyptus calycogona</i> subsp. <i>calycogona</i>	14	-	16	9	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	
<i>Lepidosperma fimbriatum</i>	1	2	15	-	-	-	-	-	2	1	4	-	-	-	-	-	-	1	-	-	
<i>Melaleuca sophisma</i>	1	-	20	-	1	-	-	-	16	1	-	-	-	-	-	-	-	14	-	-	
<i>Cassythia melantha</i>	-	4	11	17	-	-	-	-	1	-	-	-	-	3	-	-	-	14	1	-	
<i>Daviesia benthamii</i>	-	6	1	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus tenera</i>	-	-	-	67	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus flocktoniae</i> subsp. <i>flocktoniae</i>	16	1	13	16	5	1	4	-	-	-	-	-	-	-	-	-	-	12	2	-	
<i>Eucalyptus pileata</i>	-	2	2	29	11	2	-	-	-	-	3	-	-	-	-	-	-	-	-	-	
<i>Grevillea pectinata</i>	-	8	1	18	3	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	
<i>Lepidosperma</i> sp. (GF Craig 8243)	-	6	-	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	
<i>Lepidosperma</i> sp. Maydon	-	-	-	22	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	9	
<i>Melaleuca acuminata</i> subsp. <i>acuminata</i>	-	-	-	18	-	-	-	-	-	1	7	2	-	-	-	-	-	-	-	-	
<i>Melaleuca coronicarpa</i>	-	-	1	30	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

<i>Melaleuca johnsonii</i>	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca societatis</i>	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca teuthioides</i>	-	-	-	45	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca torquata</i>	-	-	5	24	12	-	-	-	3	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca undulata</i>	-	-	-	57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Microcybe albiflora</i>	-	-	-	24	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pultenaea purpurea</i>	1	-	15	19	-	-	-	-	-	3	-	-	-	-	-	-	4	-	-
<i>Thomasia microphylla</i>	-	-	-	17	-	7	-	-	-	-	-	-	-	-	-	-	2	2	-
<i>Eucalyptus extensa</i>	-	-	4	-	31	-	-	-	-	6	-	-	-	-	-	-	-	-	-
<i>Eucalyptus platypus</i>	-	-	-	5	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Boronia oxyantha</i> var. <i>brevicalyx</i>	-	-	-	-	-	26	23	-	-	-	-	-	18	-	-	-	-	-	-
<i>Eucalyptus cernua</i>	-	-	7	-	-	25	-	-	11	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus gardneri</i> subsp. <i>ravensthorpensis</i>	3	2	-	-	-	53	-	-	-	-	8	-	-	-	-	-	-	-	-
<i>Gastrolobium parviflorum</i>	5	1	-	3	1	14	1	-	-	-	12	8	10	-	-	-	-	1	-
<i>Spyridium glaucum</i>	-	-	1	-	-	24	4	-	-	-	1	1	2	-	-	-	-	-	-
<i>Dodonaea trifida</i>	-	-	-	-	-	-	47	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus astringens</i>	-	-	-	-	-	-	75	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eucalyptus clivicola</i>	-	-	-	-	21	-	26	-	-	3	7	-	-	-	-	-	-	-	-
<i>Lepidosperma</i> sp. (GF Craig 8249)	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melaleuca stramentosa</i>	-	-	-	-	-	-	48	-	-	-	-	9	-	-	-	-	-	1	-
<i>Calothamnus quadrifidus</i>	-	-	-	-	-	-	-	18	-	-	2	4	-	10	-	-	-	6	2
<i>Calytrix tetragona</i>	-	-	-	-	-	-	-	48	-	-	-	-	-	-	-	-	-	-	7
<i>Cryptandra myriantha</i>	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-	-	-	-
<i>Dodonaea pinifolia</i>	2	-	1	1	-	-	-	22	16	-	5	-	-	-	-	-	2	-	6
<i>Eucalyptus</i> sp. Ravensthorpe	-	-	-	-	-	-	-	20	2	2	-	2	2	-	-	5	-	-	-
<i>Grevillea fastigiata</i>	-	-	-	-	-	-	-	39	-	-	-	-	-	-	-	-	-	-	-
<i>Hibbertia rostellata</i>	-	-	-	-	-	-	-	19	-	12	-	-	-	-	-	-	-	-	-
<i>Hybanthus floribundus</i> subsp. <i>adpressus</i>	-	-	1	-	-	2	-	17	8	2	-	-	1	-	-	-	1	1	-
<i>Lepidosperma diuumum</i>	-	2	-	-	-	-	-	32	9	-	-	3	-	-	-	-	-	-	-
<i>Neurachne alopecuroidea</i>	-	4	-	1	-	-	-	16	-	-	-	1	-	1	9	1	-	13	13
<i>Stackhousia monogyna</i>	-	-	-	-	-	-	-	34	5	-	-	-	-	-	-	-	-	-	-
<i>Styphelia pulchella</i>	-	-	-	-	-	-	-	25	6	1	-	-	-	-	-	-	-	-	-
<i>Acacia ophiolithica</i>	-	-	1	-	-	-	-	12	17	2	-	-	-	-	-	-	16	-	-
<i>Beyeria cockertonii</i>	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-
<i>Grevillea oligantha</i>	-	-	2	2	-	-	-	3	28	-	-	-	-	-	-	-	15	1	-
<i>Hakea verrucosa</i>	-	-	1	-	-	1	-	13	23	5	1	2	-	1	-	-	12	-	-
<i>Melaleuca cliffortioides</i>	-	-	-	2	-	-	-	10	21	4	-	-	-	-	-	-	1	-	-
<i>Melaleuca pomphostoma</i>	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	3	1	-
<i>Pultenaea rotundifolia</i>	-	-	1	-	-	-	-	-	23	-	-	-	-	-	-	-	3	1	-
<i>Wurmbea cernua</i>	-	-	-	-	-	-	-	15	22	-	-	-	-	-	-	-	-	-	-
<i>Acacia mutabilis</i> subsp. <i>mutabilis</i>	-	-	-	-	2	-	-	-	-	19	-	-	-	-	-	-	-	-	-
<i>Beyeria villosa</i>	-	-	-	-	-	-	-	-	-	53	-	-	-	-	-	-	-	-	-
<i>Eucalyptus brachycalyx</i>	-	-	1	-	-	-	-	1	2	38	13	-	-	-	-	-	1	-	-
<i>Eucalyptus incurata</i>	-	-	1	-	-	-	-	-	-	56	5	-	-	-	-	-	-	-	-
<i>Halgania andromedifolia</i>	-	2	2	2	-	-	-	2	6	14	2	-	-	-	-	-	7	-	-
<i>Leptomeria pachyclada</i>	-	-	-	-	-	-	-	3	-	20	-	-	-	-	-	-	3	-	-
<i>Melaleuca brevifolia</i>	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-
<i>Melaleuca pauperiflora</i> subsp. <i>pauperiflora</i>	-	-	2	9	-	-	-	-	2	35	3	-	-	-	-	-	-	-	-
<i>Pultenaea calycina</i> subsp. <i>proxena</i>	-	-	-	-	-	-	-	3	4	42	-	-	-	-	-	-	-	-	-

Appendix 3 (cont.)

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21	
<i>Boronia inornata</i> subsp. <i>inornata</i>	2	2	1	-	-	2	-	-	-	17	38	-	-	-	-	-	-	1	-	-	
<i>Eucalyptus celastroides</i> subsp. <i>virella</i>	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	
<i>Eucalyptus oleosa</i> subsp. <i>corvina</i>	4	-	-	-	2	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	
<i>Senna artemisioides</i> subsp. <i>x artemisioides</i>	21	6	1	-	-	1	-	-	-	-	21	2	-	-	-	-	-	-	-	-	
<i>Phebalium tuberculosum</i>	2	-	-	-	-	-	-	-	-	-	-	48	1	-	-	-	-	-	-	-	
<i>Trymalium elachophyllum</i>	4	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	
<i>Acacia</i> sp. <i>Ravensthorpe</i>	-	-	-	2	-	-	-	-	-	-	-	4	18	-	-	7	1	-	2	-	
<i>Banksia laevigata</i> subsp. <i>laevigata</i>	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	9	-	-	-	-	
<i>Beaufortia orbifolia</i>	-	-	-	-	-	2	-	-	-	-	-	-	27	25	-	2	-	-	-	-	
<i>Boronia ternata</i> var. <i>elongata</i>	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	2	-	-	-	-	
<i>Brachyloma geissoloma</i> subsp. <i>geissoloma</i>	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	1	-	-	-	
<i>Eucalyptus falcata</i> subsp. <i>falcata</i>	-	-	-	-	-	-	1	-	-	-	-	11	17	2	11	10	14	-	2	-	
<i>Hakea multilineata</i>	-	-	-	-	-	-	-	-	-	-	-	1	17	-	-	-	-	-	-	-	
<i>Philotheca gardneri</i> subsp. <i>gardneri</i>	-	-	-	-	1	-	-	-	-	-	-	6	34	-	-	-	-	-	-	-	
<i>Andersonia</i> aff. <i>lehmanniana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	
<i>Banksia heliantha</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	36	3	-	35	-	-	-	
<i>Boronia subsessilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	1	-	-	1	-	
<i>Chorizema trigonum</i>	-	-	-	-	-	-	4	-	-	-	-	-	-	17	4	-	6	-	2	-	
<i>Daviesia mollis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	23	-	-	1	-	1	-	
<i>Eucalyptus lehmannii</i> subsp. <i>parallela</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	32	-	-	2	-	-	-	
<i>Eucalyptus preissiana</i> subsp. <i>preissiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	8	-	-	-	
<i>Grevillea concinna</i> subsp. <i>lehmanniana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	
<i>Grevillea nudiflora</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	-	5	-	1	-	
<i>Hakea obtusa</i>	-	-	-	-	-	-	-	-	-	-	-	1	14	33	2	7	1	1	1	-	
<i>Lepidosperma</i> sp. <i>Cordingup</i>	-	-	-	-	-	2	-	-	-	-	-	3	7	18	3	1	-	1	-	3	
<i>Leucopogon carinatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	19	5	-	13	-	1	-	
<i>Leucopogon infuscatus</i>	-	-	-	-	-	-	-	-	3	-	-	-	-	19	-	-	-	14	2	-	
<i>Spyridium majoranifolium</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	18	10	-	-	-	-	-	
<i>Stylidium albomontis</i>	-	-	-	-	-	1	-	1	-	-	-	3	12	19	2	4	-	1	5	-	
<i>Hibbertia mucronata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45	-	1	-	-	
<i>Hovea acanthoclada</i>	-	-	-	-	1	1	-	-	-	-	9	1	-	16	35	-	-	-	-	-	
<i>Labichea lanceolata</i> subsp. <i>brevifolia</i>	1	-	-	-	-	-	-	-	-	-	-	8	-	-	48	-	-	-	-	-	
<i>Lasiopetalum rosmarinifolium</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	1	30	-	5	-	10	-	
<i>Lomandra mucronata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	7	26	13	20	-	5	2	
<i>Melaleuca pentagona</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	12	26	-	-	-	-	-	
<i>Adenanthos flavidiflorus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	
<i>Astroloma prostratum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	
<i>Banksia cirsioides</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	42	-	-	1	-	
<i>Banksia corvijuga</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-	
<i>Banksia foliosissima</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	
<i>Banksia pallida</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61	-	-	-	-	

<i>Beaufortia micrantha</i> var. <i>micrantha</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	9	-	2	-
<i>Beaufortia schaueri</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	10	-	22	7	1	5	2
<i>Boronia crassifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	28	16	-	1	-
<i>Cassytha pomiformis</i>	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	26	-	-	1	-
<i>Dampiera juncea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-
<i>Daviesia euryloba</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-
<i>Drosera grievii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-
<i>Goodenia pinifolia</i>	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	25	-	-	-	5
<i>Guichenotia anota</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
<i>Hakea cygna</i> subsp. <i>cygna</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-
<i>Hakea subsulcata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-
<i>Hemigenia teretiuscula</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
<i>Hibbertia gracilipes</i>	-	-	-	-	-	-	-	-	-	-	-	6	1	-	20	16	1	5	7	-
<i>Isopogon</i> sp. Ravensthorpe (DB Foreman 1207)	-	-	-	-	-	-	-	-	-	-	-	15	8	-	16	-	-	-	-	-
<i>Jacksonia viscosa</i>	-	-	-	-	-	-	-	-	-	-	-	3	-	-	29	4	-	-	-	-
<i>Lepidobolus chaetocephalus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-
<i>Lepidosperma</i> sp. (RL Barrett 3570)	-	-	-	-	-	-	1	-	-	-	-	1	-	-	41	-	-	2	-	-
<i>Leptospermum</i> sp. Bandalup Hill (G Cockerton 110-1)	-	-	-	-	-	-	-	-	-	-	-	-	6	-	35	16	-	-	-	-
<i>Leucopogon cuneifolius</i>	-	-	-	3	-	-	-	-	-	-	-	9	2	-	21	-	-	-	-	-
<i>Melaleuca villosisepala</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	54	-	-	2	5	-
<i>Persoonia striata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	8	-	-	-	-
<i>Petrophile glauca</i>	-	-	-	-	-	-	-	-	-	-	-	-	11	-	30	-	-	-	-	-
<i>Petrophile seminuda</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	12	-	-	6	-
<i>Schoenus brevisetis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	-	-	-	-	-
<i>Stachystemon brachyphyllus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-	-
<i>Adenanthos oreophilus</i>	-	-	-	-	-	-	-	-	-	-	-	1	5	-	-	21	-	-	-	-
<i>Allocasuarina humilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	3	26	33	-	-	-	-
<i>Amphipogon turbinatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	2	14	22	-	4	10	-
<i>Argentipallium niveum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	1	-	-
<i>Banksia lemanniana</i>	-	-	-	-	-	-	-	-	-	-	-	1	10	2	13	19	-	2	-	-
<i>Calothamnus gracilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
<i>Calothamnus pinifolius</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	21	-	-	-	-
<i>Chorizema uncinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-
<i>Conostylis bealiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	4	-	-
<i>Dampiera fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	19	-	-	-	-
<i>Eucalyptus pleurocarpa</i>	-	-	-	-	-	-	-	-	-	-	-	14	9	11	17	19	2	5	-	-
<i>Gompholobium viscidulum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-
<i>Hakea pandanica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	19	-	1	-	-
<i>Isopogon</i> sp. Fitzgerald River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	1	-	-
<i>Isopogon trilobus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-
<i>Jacksonia elongata</i>	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	28	-	-	-	-
<i>Lepidosperma</i> sp. Mt Burdett	-	-	-	-	-	-	-	-	1	-	-	-	2	-	5	19	1	2	-	-
<i>Leucopogon conostephioides</i>	-	-	-	-	-	-	-	-	-	-	-	1	-	3	6	26	-	9	3	-
<i>Lysinema ciliatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	31	-	1	-	-
<i>Mesomelaena stygia</i> subsp. <i>stygia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	33	-	-	12	-
<i>Petrophile squamata</i> subsp. northern	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	38	-	2	-	-
<i>Pultenaea indira</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	1	-	-

Appendix 3 (cont.)

Taxon	Woodlands							Mallee shrublands					Species-rich mallee shrublands								
	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21	
<i>Schoenus subclaxus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	37	-	-	-	
<i>Stachystemon virgatus</i>	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	23	-	-	8	
<i>Taxandria spathulata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	17	2	8	31	-	2	-	
<i>Xanthorrhoea platyphylla</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53	-	-	-	
<i>Acacia ingrata</i>	-	-	4	-	-	-	-	1	-	19	7	-	-	-	-	-	-	30	6	-	
<i>Acrotriche cordata</i>	-	-	1	-	-	-	-	1	6	1	-	1	-	9	-	1	-	18	2	-	
<i>Banksia media</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	29	1	-	
<i>Boronia inornata</i> subsp. <i>leptophylla</i>	-	-	4	7	3	-	-	1	2	-	-	-	-	-	-	-	-	32	-	-	
<i>Comesperma spinosum</i>	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	37	-	-	
<i>Coopernookia polygalacea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41	4	-	
<i>Daviesia anceps</i>	-	-	1	-	-	-	-	7	10	3	-	-	1	-	-	-	-	21	9	2	
<i>Daviesia articulata</i>	-	2	3	-	-	2	4	-	-	-	-	-	-	-	-	-	-	20	2	-	
<i>Eucalyptus kessellii</i> subsp. <i>eugnosta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38	-	-	
<i>Eucalyptus leptocalyx</i>	-	-	-	-	-	-	3	-	19	-	-	-	-	-	-	-	1	26	1	-	
<i>Eucalyptus suggrandis</i> subsp. <i>suggrandis</i>	-	2	2	2	-	-	3	-	-	-	-	-	-	1	-	-	-	22	7	-	
<i>Hibbertia exasperata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	-	-	
<i>Melaleuca subfalcata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	4	-	
<i>Pomaderris brevifolia</i>	-	-	1	-	-	-	-	-	7	10	-	1	1	-	-	-	-	24	-	-	
<i>Spyridium cordatum</i>	-	-	-	13	-	-	-	-	-	-	-	-	1	1	-	3	-	26	8	-	
<i>Styphelia intertexta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	
<i>Eucalyptus incrassata</i>	-	-	-	-	-	-	2	-	-	-	-	1	1	4	2	5	16	1	18	-	
<i>Eucalyptus uncinata</i>	-	-	-	-	-	-	-	-	4	-	-	-	2	10	-	5	2	12	16	6	
<i>Eutaxia cuneata</i>	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	
<i>Gahnia ancistrophylla</i>	-	3	-	3	1	-	-	1	1	-	-	-	1	1	-	4	2	7	14	12	
<i>Hakea laurina</i>	-	-	-	1	-	-	2	-	1	-	-	2	1	-	2	-	3	11	15	-	
<i>Harperia lateriflora</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	-	
<i>Melaleuca rigidifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	2	6	1	16	3	
<i>Tetraria capillaris</i>	-	-	-	-	-	-	-	1	-	2	-	-	-	7	7	4	1	9	17	-	
<i>Acacia mimica</i> var. <i>angusta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72	
<i>Allocasuarina campestris</i>	-	-	-	-	-	-	-	6	-	-	-	1	1	-	-	-	-	-	-	25	
<i>Astroloma serratifolium</i>	-	-	-	-	-	-	-	8	-	-	-	-	-	-	4	2	-	-	1	17	
<i>Baeckea crispiflora</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	
<i>Calytrix leschenaultii</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	2	-	5	38	
<i>Chorizema aciculare</i> subsp. <i>aciculare</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	2	29	
<i>Conostylis argentea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	14	-	-	4	42	
<i>Daviesia pachyphylla</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	37	
<i>Eucalyptus desmondensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75	
<i>Gompholobium marginatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	60	
<i>Grevillea dolichopoda</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	70	
<i>Haemodorum discolor</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	18	
<i>Hakea lissocarpha</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	1	2	-	19	24	

<i>Hibbertia pungens</i>	-	-	-	3	-	-	-	11	-	-	-	4	1	9	-	1	-	4	9	20
<i>Lepidobolus preissianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	35
<i>Leucopogon concinnus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	1	-	-	46
<i>Logania tortuosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
<i>Melaleuca carrii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	42
<i>Melaleuca hamata</i>	1	2	1	2	1	-	3	6	-	-	-	6	6	3	-	-	-	10	12	13
<i>Schoenus racemosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	1	10	18
<i>Schoenus sesquispiculus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	62
Number of plots	8	5	34	5	12	5	4	12	5	4	15	23	26	6	4	33	17	7	32	4

Baseline water quality of the Jurien Bay Marine Park: a benchmark for warm temperate Western Australia?

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ABSTRACT

Spatial and seasonal nutrient dynamics were examined at three locations in the coastal waters of the Jurien Bay Marine Park (JBMP), to establish a quantitative baseline for water quality in this park. Nutrient concentrations were typically low across all sampling periods. Differences between locations were apparent for some variables, while few differences were found between nearshore, lagoonal and offshore sampling sites. Concentrations of most nutrients tended to be highest during autumn and lowest during spring, but there were significant interactions between season, location and site for almost all parameters measured, suggesting an inconsistent effect of these factors. The findings reported here are likely to be a result of two major processes: 1) the onset of autumn/winter storms that detach macroalgae and seagrass and transport it onshore, where it decays and releases nutrients back into the water column; and 2) the synergistic effects of reduced nutrient supply during spring and increased macroalgal growth assimilating significant quantities of nutrients during this period. The JBMP represents a relatively unimpacted example of marine water quality in warm temperate Western Australia. Given that there are mechanisms for actively managing inputs into these waters into the future, these data could provide a suitable benchmark for assessing water quality management targets for biogeographically similar coastal waters where water quality may have been degraded from anthropogenic activities.

Keywords: water quality, nutrient, Western Australia, baseline

INTRODUCTION

Many coastal marine ecosystems are becoming increasingly degraded by anthropogenic pressures such as fishing, direct physical damage by boats and people, the introduction of non-indigenous species, contamination by pollutants and nutrient enrichment (Gray 1997). Of particular concern to naturally oligotrophic (i.e. low nutrient status) coastal waters is the problem of nutrient enrichment, which may be a significant environmental stressor in coastal areas adjacent to urban and industrial centres and/or those subject to discharge from agricultural catchments (Gorgula & Connell 2004; Gorman et al. 2009). The impacts of enrichment can be localised, such as those commonly related to urban effluent outfalls, or diffuse and widespread, such as the impacts from catchment degradation adjacent to the Great Barrier Reef in north-eastern Australia (Moss et al. 2005). Unchecked nutrient enrichment can lead to responses in the form of, for example, algal blooms and changes in benthic community structure (Gorgula & Connell 2004) or, in extreme cases,

the loss of organisms due to hypoxia (e.g. Anderson et al. 2002).

Oceanic waters adjacent to warm temperate Western Australia are typically oligotrophic and nitrogen-limited, which is largely a consequence of the relatively warm, southwards-flowing Leeuwin current and a lack of significant upwelling along the coast (Weaver & Middleton 1989; Johannes et al. 1994; Hanson et al. 2005). Annual rainfall in this area is also relatively low, resulting in limited nutrient transport into coastal waters from terrestrial sources. This marine environment is, however, characterized by high biodiversity and endemism (Phillips 2001; Roberts et al. 2002) and since the 1980s a system of marine protected areas (MPAs) has been established to protect marine biodiversity in the coastal waters of south-west Western Australia.

Integral to the effective management of MPAs is the long-term monitoring of key ecological assets and the pressures that act on them (Fancy et al. 2008). Rigorously documented benchmark measures are required to understand long-term trends in asset condition, and to avoid 'shifting baseline syndrome', whereby perceptions of 'normal' resource condition alter over time in response

to long-term, and typically gradual, ecosystem degradation (Sheppard 1995). Such incremental changes to inshore marine water quality may occur near industrial and/or population centres that are subject to sustained anthropogenic impacts from, for example, industrial and municipal discharges and catchment inflows over many decades.

Despite such potential impacts, these areas may still support a range of high biodiversity conservation values, and many MPAs are located in close proximity to such areas of high human use. In Western Australia, for example, the Marmion and Shoalwater Islands Marine Parks are located close to the Perth metropolitan area, and coastal industrial infrastructure and oceanic wastewater outfalls discharge within, or near, both of these MPAs (Oceanica Consulting 2010). Under specific weather conditions, Marmion Marine Park is also subject to discharge from the significantly degraded catchment of the Swan–Canning River system (Brearley 2005). Given this context, it is possible that baseline values of water quality for such ‘urban’ MPAs are, or eventually will be, confounded by such impacts.

In contrast, the Jurien Bay Marine Park (JBMP) is located along Western Australia’s relatively remote mid-west coast. Although 200 km north of the Perth area, this marine environment is biogeographically similar (Commonwealth of Australia 2006), but is subject to fewer and less intense environmental stressors. The adjacent hinterland is sparsely populated with no major towns, and there are limited impacts from terrestrial runoff and agricultural activity (Department of Conservation and Land Management 2005). The primary aim of this study was to establish baseline water quality conditions for the coastal waters of the JBMP. Given the relatively remote location of this marine park, we anticipated that anthropogenic nutrient enrichment of these coastal waters would be low and we further sought to assess whether these data could also provide benchmark values for water quality in biogeographically similar, but possibly impacted, coastal waters in warm temperate south-western Australia.

METHODS

This study was conducted in the JBMP on the central west coast of Western Australia (Fig. 1). The study area is not subject to major anthropogenic pollutant or riverine discharges, and the circulation of nearshore marine waters is primarily wind-driven (Sanderson 2000). The region’s complex seabed topography is characterized by limestone barrier reefs and emergent rocks and islands that lie parallel to the coast inshore from the 20 m depth contour. These structures form inshore lagoons that are relatively sheltered from oceanic swell. Corresponding with coastal bathymetric features, water sampling sites were identified as nearshore sheltered, nearshore exposed, lagoon and offshore. While both nearshore sheltered and exposed sites were located close to the shore in depths of typically <5 m, exposed sites differed in being directly adjacent to openings in the barrier reef system and could thus be

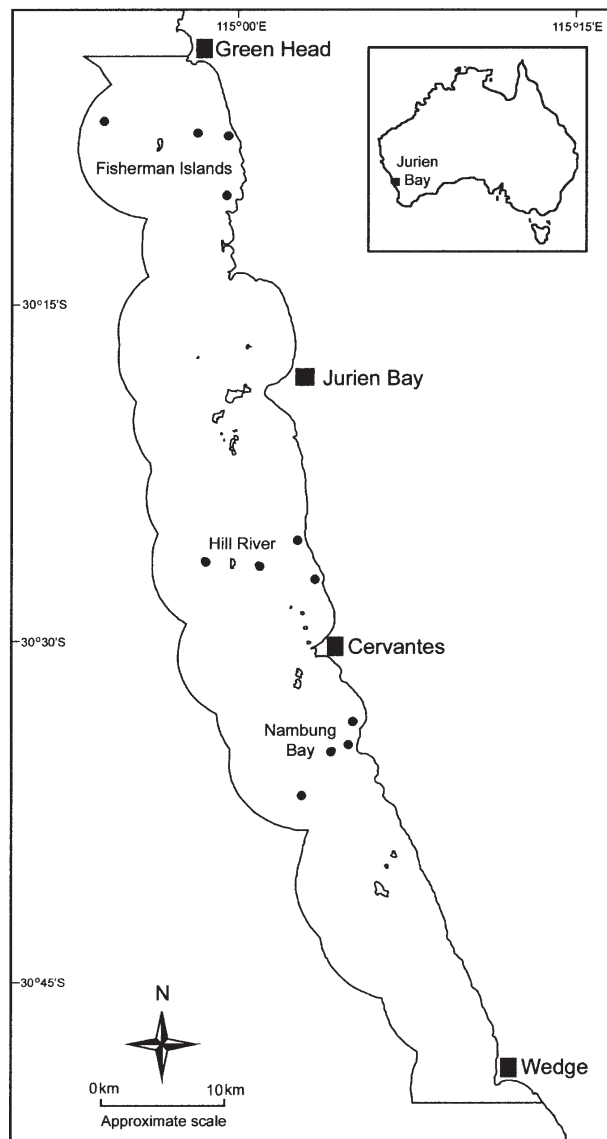


Figure 1. The Jurien Bay Marine Park. Sampling sites (black dots) were adjacent to Fisherman Islands, Hill River and Nambung Bay.

expected to be subject to greater wave action and mixing than the relatively protected sheltered sites. Lagoon sites were located midway between the shore and the barrier reef system in depths of 6–8 m, whereas offshore sites were located in oceanic waters >20 m deep outside the reef.

The full set of sampling sites was established at each of three locations: Fisherman Islands (30° 07' S, 114° 56' E), Hill River (30° 23' S, 115° 03' E) and Nambung Bay (30° 32' S, 115° 05' E) in the JBMP (Fig. 1). Within each site, three independent replicate samples were collected (see below). All sites within a location were sampled on a single day (i.e. over three days for all locations) during the austral summer (December to February), autumn (March to May), winter (June to August) and spring (September to November) of 2004, and samples were collected as close as was possible to the middle of each season. In order to examine finer-scale

temporal variation, monthly samples were collected across the year from each site in the Hill River location.

Temperature ($^{\circ}\text{C}$), salinity (ppt) and dissolved oxygen (mg L^{-1}) were measured at each site using either a YSI Inc. (Yellow Springs, Ohio, USA) 6600 SDL recorder or a YeoKal Electronics (Brookvale, New South Wales, Australia) model 602 temperature/salinity bridge. Both instruments were laboratory-calibrated before field use. Physical parameters were recorded at approximately 20 cm depth intervals through the water column and these values were averaged to provide an integrated value for each site. Prior to integration of water column values, data were examined to determine the level of difference between surface and bottom values. In general, differences were larger during summer than the other seasons; however, in all cases these differences were negligible. For instance, the maximum difference in temperature between surface and bottom waters at a single site (Fisherman Islands nearshore exposed) was 1.3°C , but in general, the difference was less than 0.5°C . Differences in salinities and dissolved oxygen concentrations were similarly small.

At each site, three 20 L water samples were collected, which comprised equal volumes of water collected ca. 1 m from both the surface and the seabed. Water was only collected mid-depth when sites were <3 m deep. Samples were collected with a submersible pump or with a 10 L Niskin bottle when depths exceeded 15 m. Sampling equipment was thoroughly pre-rinsed at each site and the pump was run for two minutes prior to sample collection to purge the previous sample. An equal measured volume of water from surface and bottom samples was mixed and filtered to $1.2\ \mu\text{m}$ and the GF/C (Whatman glass microfibre filter) filter papers were wrapped in another filter paper and stored. A second sub-sample was then drawn through a $45\ \mu\text{m}$ cellulose nitrate syringe filter and stored in two 10 mL tubes; one for analysis and the second as a contingency. All samples were stored on ice in the field and frozen within 12 hours until laboratory analysis.

Water from the 10 mL sample was analysed for ammonium (NH_4^+) by the alkaline phenate method (Switala 1993), nitrate/nitrites (NO_x) by the copper-cadmium reduction method (Johnson & Petty 1983) and orthophosphate (OP) by the ascorbic acid method (Johnson & Petty 1982) using a Lachal Quick Chem 8000 Automated Flow Injection Analyser. Filter papers were stored in the dark for 24 hours at 4°C , after which chlorophyll-*a* (Chl-*a*) was extracted by grinding in 90% acetone and measured using a Varian Cary 50 Spectrophotometer (Greenburg et al. 1992). This method does not detect plankton $<0.8\ \mu\text{m}$ in diameter. The concentration of Chl-*a* was measured to a resolution of $0.1\ \mu\text{g L}^{-1}$, while NH_4^+ was measured to a resolution of $3.00\ \mu\text{g L}^{-1}$ and NO_x and OP were measured to a resolution of $2.00\ \mu\text{g L}^{-1}$.

For the seasonal dataset, concentrations of NH_4^+ , NO_x , OP and Chl-*a* were analysed using a three-factor (season, location and site) analysis of variance (ANOVA) with GMAV5 (Underwood et al. 1998). For all tests, season and site were considered to be fixed factors while location was designated as a random factor. In addition, monthly

data from the Hill River location were examined using a two-factor ANOVA with month and site designated as fixed factors. For graphical and analytical purposes, data that were below the limits of laboratory resolution (i.e. below detectable limits, BDL) were designated to be 0.5 of that limit (Australian and New Zealand Environment and Conservation Council 2000). However, substituting values is not recommended where $>25\%$ of values are BDL (Australian and New Zealand Environment and Conservation Council 2000), as was the case for NH_4^+ in spring where all values were BDL. These data were removed from the analysis and only comparisons between the remaining seasons were performed. Prior to analysis, all data were checked to meet the assumption of homogeneity of variances using Cochran's test (Underwood 1997) and data were appropriately transformed to correct heterogeneity where this assumption was violated. Where significant ($\alpha < 0.05$) results were returned for the main fixed effects (season and site) multiple comparisons were made using the Student–Newmans–Keuls test.

RESULTS

Mean temperature varied significantly across seasons (ANOVA; $f_{3,44} = 106.07$, $p < 0.001$) and ranged from an average of $17.09 \pm 0.37^{\circ}\text{C}$ during winter to $23.47 \pm 0.19^{\circ}\text{C}$ during summer (Table 1). Mean salinity also varied significantly across seasons (ANOVA; $f_{3,44} = 461.30$, $p < 0.001$) and ranged between 34.16 ± 0.05 ppt and 36.41 ± 0.03 ppt, with the maximum mean value recorded during summer (Table 1). Values for dissolved oxygen were only recorded during summer and autumn, and there was no difference between these seasons (Table 1).

Nutrient concentrations were typically low across all seasons (Table 1). With the exception of ammonium, the mean concentration of nutrients was highest in samples collected during autumn and lowest in samples collected in spring (Table 1, Fig. 2). The effects of the main factors of season, location and site are discussed below, but for all parameters, the highest-order interactions (season \times location \times site) were significant, suggesting that sites were affected differently across locations and seasons.

The concentration of NH_4^+ was low but variable across all locations and seasons except spring, where all values were BDL ($<3\ \mu\text{g L}^{-1}$; Table 1, Fig. 2). Concentrations BDL were recorded during each season, while the maximum concentration ($10\ \mu\text{g L}^{-1}$) was recorded from the nearshore sheltered site at Nambung Bay during autumn (Table 1). There were no significant differences in mean NH_4^+ concentrations between seasons (Table 2). Overall, the concentration of NH_4^+ was significantly higher at Nambung Bay than at either Fishermans Islands or Hill River; however, the effect of season within locations was not consistent (Table 2). For example, mean concentrations were significantly lower in spring than all other seasons across all locations, but at Fisherman Islands, summer values were significantly higher than winter and autumn values, while at Hill River, winter values were

Table 1

Summary of minimum, maximum and mean (\pm SE, $n = 9$) concentrations ($\mu\text{g L}^{-1}$) for water quality parameters measured in each site. Overall ranges and means for temperature, salinity and dissolved oxygen are also given.

	Summer	Autumn	Winter	Spring
NH₄⁺				
Nearshore sheltered	3.00–9.00 (4.67 \pm 0.58)	<3.00*–10.00 (3.39 \pm 0.95)	<3.00*–6.00 (3.94 \pm 0.44)	<3.00*
Nearshore exposed	<3.00*–5.00 (3.39 \pm 0.49)	<3.00*–3.00 (2.33 \pm 0.26)	<3.00*–7.00 (3.00 \pm 0.63)	<3.00*
Lagoon	<3.00*–4.00 (3.11 \pm 0.34)	<3.00*–4.00 (2.94 \pm 0.39)	<3.00*–6.00 (4.11 \pm 0.56)	<3.00*
Offshore	3.00–5.00 (3.44 \pm 0.24)	<3.00*–4.00 (2.53 \pm 0.33)	<3.00*–7.00 (3.53 \pm 0.50)	<3.00*
NO_x				
Nearshore sheltered	2.00–5.00 (3.33 \pm 0.33)	2.00–8.00 (4.33 \pm 0.76)	<2.00*–4.00 (3.00 \pm 0.29)	2.00–4.00 (3.00 \pm 0.17)
Nearshore exposed	3.00–5.00 (3.44 \pm 0.24)	<2.00*–6.00 (3.56 \pm 0.53)	2.00–6.00 (3.33 \pm 0.47)	2.00–5.00 (3.00 \pm 0.33)
Lagoon	2.00–4.00 (3.11 \pm 0.26)	3.00–9.00 (5.78 \pm 0.78)	3.00–7.00 (4.78 \pm 0.49)	2.00–5.00 (3.22 \pm 0.28)
Offshore	3.00–4.00 (3.11 \pm 0.11)	3.00–7.00 (4.83 \pm 0.41)	3.00–7.00 (5.06 \pm 0.49)	2.00–3.50 (2.56 \pm 0.19)
OP				
Nearshore sheltered	5.00–7.00 (6.00 \pm 0.17)	6.00–8.00 (6.78 \pm 0.22)	3.00–5.00 (4.11 \pm 0.26)	4.00–6.00 (5.00 \pm 0.17)
Nearshore exposed	5.00–7.00 (5.89 \pm 0.31)	6.00–8.00 (7.00 \pm 0.29)	3.00–5.00 (4.11 \pm 0.31)	5.00–6.00 (5.33 \pm 0.17)
Lagoon	6.00–7.00 (6.33 \pm 0.17)	6.00–8.00 (7.22 \pm 0.22)	3.00–6.00 (4.22 \pm 0.32)	5.00–8.00 (5.67 \pm 0.33)
Offshore	7.00–8.00 (7.22 \pm 0.15)	6.50–7.00 (6.83 \pm 0.08)	3.00–5.00 (3.83 \pm 0.19)	4.00–6.00 (5.56 \pm 0.23)
Chl-<i>a</i>				
Nearshore sheltered	0.30–0.50 (0.36 \pm 0.02)	0.40–1.10 (0.69 \pm 0.08)	0.20–0.30 (0.24 \pm 0.02)	<0.10*–0.20 (0.09 \pm 0.02)
Nearshore exposed	0.20–0.40 (0.28 \pm 0.02)	0.30–0.50 (0.41 \pm 0.03)	0.10–0.30 (0.27 \pm 0.02)	<0.10*–0.20 (0.09 \pm 0.02)
Lagoon	0.10–0.30 (0.20 \pm 0.02)	0.20–0.40 (0.27 \pm 0.02)	0.20–0.30 (0.22 \pm 0.01)	<0.10*–0.10 (0.08 \pm 0.01)
Offshore	0.10–0.40 (0.24 \pm 0.03)	0.25–0.50 (0.34 \pm 0.03)	0.40–0.65 (0.52 \pm 0.03)	0.10–0.20 (0.17 \pm 0.01)
Temperature (°C)	21.46–25.24 (23.47 \pm 0.19)	21.08–22.31 (21.63 \pm 0.07)	15.20–19.66 (17.09 \pm 0.37)	17.97–20.10 (19.12 \pm 0.18)
Salinity (ppt)	36.03–36.73 (36.41 \pm 0.03)	35.89–36.24 (35.99 \pm 0.02)	33.9–34.50 (34.16 \pm 0.05)	35.02–35.55 (35.34 \pm 0.05)
DO (mgL ⁻¹)	5.76–7.47 (6.80 \pm 0.08)	5.39–8.13 (7.20 \pm 0.09)	No data	No data
DO (% saturation)	85.82–107.18 (98.52 \pm 0.93)	74.86–115.17 (100.71 \pm 1.28)	No data	No data

* = measured to the lowest limit of resolution

significantly higher than both autumn and summer values. (Table 2).

The concentration of NO_x was generally BDL (<2 $\mu\text{g L}^{-1}$) in the nearshore sheltered site during winter, while the maximum value (9 $\mu\text{g L}^{-1}$) was recorded from the lagoon site at Nambung Bay during autumn (Table 1). In general, the concentration of NO_x was highest in autumn; however, this pattern was not observed in samples from all locations, with samples from Hill River having the highest concentration during winter (Fig. 2, Table 2). The

mean concentration of NO_x was significantly higher at Nambung Bay than Fisherman Islands, while concentrations from Hill River were significantly lower than both of these locations. No significant differences were returned for the tests between seasons or sites (Table 2). In general, concentrations of NO_x in samples collected from Nambung Bay were significantly higher across all sites than at either Fisherman Islands or Hill River; there was no significant difference between locations for samples collected from nearshore sheltered sites.

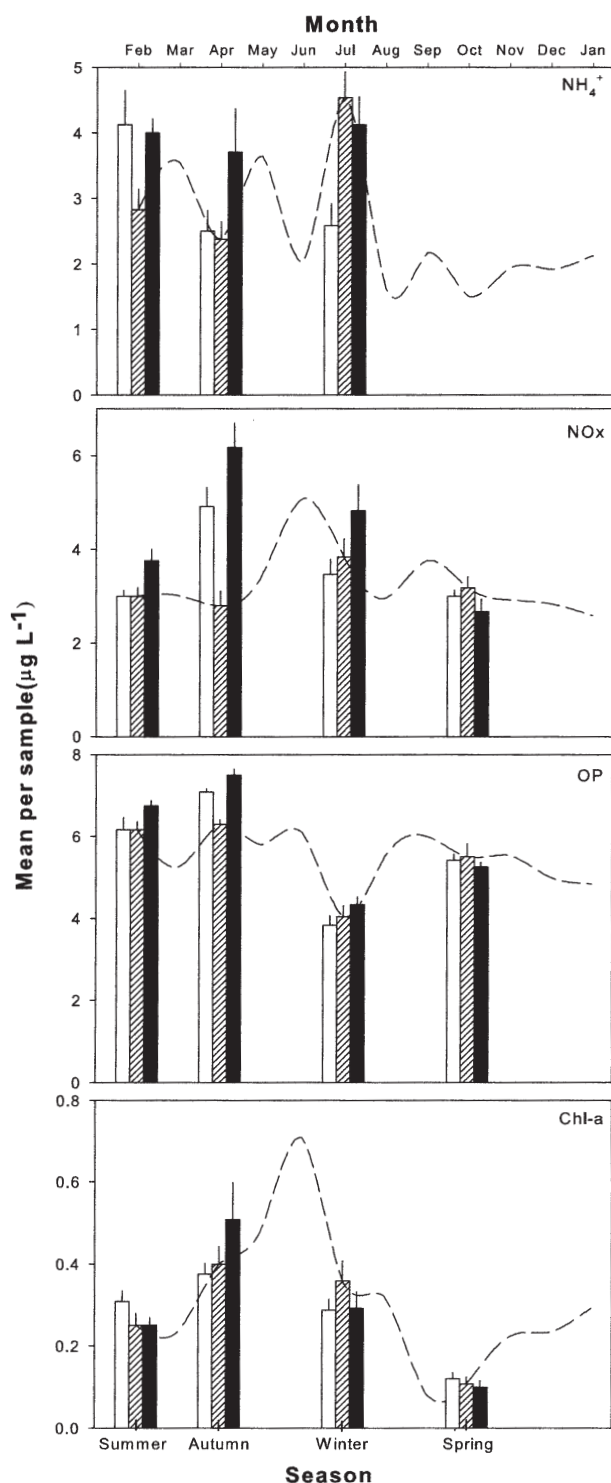


Figure 2. Mean (\pm SE, $n = 12$) concentrations of: a) NH_4^+ ; b) NO_x ; c) OP; d) Chl-a in water samples collected at Fisherman Islands (unfilled bars), Hill River (hatched bars) and Nambung Bay (filled bars) during each season of 2004. Monthly means collected at the Hill River transect are also included (dotted line).

The concentration of OP ranged from a minimum of $3 \mu\text{g L}^{-1}$ in a number of samples collected during winter to a maximum of $8 \mu\text{g L}^{-1}$ collected in each of the other seasons (Table 1). The mean concentration of OP was generally higher during autumn than any other season, with the exception of offshore sites where the concentration was highest in summer (Table 1). Analysis of variance revealed a difference between seasons (Table 2) with the mean OP concentration in winter ($4.07 \pm 0.13 \mu\text{g L}^{-1}$) being significantly lower than any other season, and the mean OP concentration in autumn ($6.96 \pm 0.11 \mu\text{g L}^{-1}$) being significantly higher than both summer ($6.36 \pm 0.13 \mu\text{g L}^{-1}$) and spring ($5.39 \pm 0.12 \mu\text{g L}^{-1}$). Overall, there was a difference between locations, with concentrations from Nambung Bay being significantly higher than both Fisherman Islands and Hill River (Table 2). This pattern was not seen in spring when concentrations from Nambung Bay were significantly lower than both Fisherman Islands and Hill River. Differences between sites were not consistent across locations. For example, at both Hill River and Nambung Bay, nearshore sheltered samples had significantly lower values than any other sites; however, at Fisherman Islands, nearshore sheltered samples had significantly higher concentrations of OP than both nearshore exposed and lagoon samples.

The concentration of Chl-*a* ranged from BDL ($<0.1 \mu\text{g L}^{-1}$) in a number of samples collected from spring to a maximum of $1.1 \mu\text{g L}^{-1}$ in samples collected from the nearshore sheltered site at Nambung Bay during autumn (Table 1). The mean concentration of Chl-*a* was typically below $0.5 \mu\text{g L}^{-1}$ in all seasons, locations and sites (Table 1). Analysis of variance revealed significant differences for all comparisons except for the test between locations (Table 2). Overall, the mean concentration of Chl-*a* was significantly lower in spring ($0.11 \pm 0.01 \mu\text{g L}^{-1}$) than in all of the other seasons. Mean concentrations in summer ($0.27 \pm 0.15 \mu\text{g L}^{-1}$) and winter ($0.31 \pm 0.02 \mu\text{g L}^{-1}$) were also significantly lower than those in autumn (0.43

Table 2

Summary of the three-factor ANOVA conducted on ammonium (NH_4^+), nitrate/nitrites (NO_x), orthophosphate (OP) and chlorophyll-*a* (Chl-*a*) concentration. The test for ammonium did not include data from spring where concentrations were all below the detectable limit. *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.

Source of variation	df	All other parameters				
		NH_4^{a}	df	NO_x	OP ^a	Chl- <i>a</i>
Season (Se)	2	-	3	-	***	**
Location (L)	2	***	2	***	***	-
Site (Si)	3	-	3	-	-	**
Se x L	4	***	6	***	*	***
Se x Si	6	-	9	-	-	**
L x Si	6	-	6	*	***	***
Se x L x Si	18	***	18	**	*	***
Error	72		96			

^a data sqrt_(x+1) transformed

Table 3

Summary of the two-factor ANOVA examining concentrations of ammonium (NH_4^+), nitrate/nitrites (NO_x), orthophosphate (OP) and chlorophyll-*a* (Chl-*a*) across months at a single site. *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.

Source of variation	df	NH_4^{a}	NO_x^{a}	OP ^a	Chl- <i>a</i> ^a
Month (Mo)	11	***	ns	***	***
Site (Si)	3	ns	ns	***	***
Mo x Si	33	*	**	ns	***
Error	96				

^adata $\log_{(x+1)}$ transformed

$\pm 0.04 \mu\text{g L}^{-1}$); however, this was not consistent between locations. In most sites, the mean concentration of Chl-*a* was lowest during spring and highest during autumn (Table 1, Fig. 2); however, at the offshore sites mean Chl-*a* concentration was highest in winter (Table 1). Significant differences between sites were only returned for Chl-*a* (Table 2) where mean concentrations at nearshore sheltered ($0.35 \pm 0.04 \mu\text{g L}^{-1}$) and offshore ($0.32 \pm 0.03 \mu\text{g L}^{-1}$) sites were significantly higher than at lagoon sites ($0.19 \pm 0.01 \mu\text{g L}^{-1}$; Table 1).

The analyses of nutrient concentrations collected from the Hill River transect revealed significant differences between months for NH_4^+ , OP and Chl-*a* and between sites for OP and Chl-*a* (Table 3, Fig. 2). For both Chl-*a* and NO_x , the maximum mean concentrations were recorded in June, while for OP and NH_4^+ , maximum mean concentrations were recorded during April and July, respectively. The timing of the minimum mean concentrations was different for each parameter: NO_x in January, OP in April, Chl-*a* in September, and NH_4^+ in October (Fig. 2). A significant interaction between month and site was also found for all parameters except OP (Table 3).

DISCUSSION

This study demonstrated that the coastal waters of the JBMP have a relatively depauperate nutrient regime. The concentration of all chemical parameters measured was consistently low across seasons and months, with mean values ranging from BDL (for NH_4^+ and NO_x) to $7.22 \pm 0.22 \mu\text{g L}^{-1}$ for OP. In contrast, background levels of nutrients in other locations at similar latitudes are considerably higher. For example, coastal waters around the east and west coast of South Africa have mean OP values ranging between 20 to $40 \mu\text{g L}^{-1}$, while management target values for NH_4^+ are set at $20 \mu\text{g L}^{-1}$ (Department of Water Affairs and Forestry 1995). While this outcome conforms to expectations regarding south-western Australia's typically oligotrophic warm temperate marine environment, these data will form an important baseline against which to measure future water quality in the JBMP.

Other studies support these findings by illustrating the generally oligotrophic nature of coastal waters in this

region. For example, mean (\pm SE) concentrations of ammonium, nitrate-nitrite and filterable reactive phosphorous (orthophosphate) of 5 ± 3 , 4 ± 1 and $6 \pm 1 \mu\text{g L}^{-1}$, respectively were recorded in Cockburn and Warnbro Sounds (immediately south of Perth) by Wilson and Paling (2006). Water quality monitoring over 13 years (1986–2009) at reference sites for the Perth Ocean Outlet in Marmion Marine Park (adjacent to Perth) found that mean summer concentrations of Chl-*a* ranged between 0.2 – $0.75 \mu\text{g L}^{-1}$, while dissolved inorganic nitrogen (DIN) ranged between 6.75 – $21.1 \mu\text{g L}^{-1}$ (Oceanica Consulting, unpublished data). This study also found that mean summer Chl-*a* and DIN concentrations ranged from 0.06 – $0.42 \mu\text{g L}^{-1}$ and 2.64 – $7.33 \mu\text{g L}^{-1}$, respectively, at reference sites for the Sepia Depression Ocean Outfall (west of Garden Island). These data indicate that while reference sites in Marmion Marion Park may have slightly elevated concentrations of both Chl-*a* and DIN, the Sepia Depression values are much closer to those recorded in this study at the JBMP. The typically low nutrient levels in coastal waters of south-west Western Australia are maintained by broad-scale down-welling of surface waters caused by the Leeuwin Current and prevailing onshore winds (Weaver & Middleton 1989; Hanson et al. 2005). Consequently, these marine habitats are characterised by relatively high benthic productivity and macroalgal growth.

Despite an a priori expectation that differences in nutrient concentration would be observed between sites, this was generally not found in the current study, although there were usually significant interactions with location. Nutrient levels in nearshore environments were anticipated to be higher than other sites as a result of the influence of factors such as rainfall and terrestrial run-off (Johannes et al. 1994), groundwater flows (Johannes 1980), nearshore productivity and the accumulation and the decay of shoreline algal wrack (Crossland et al. 1984; Kirkman & Kendrick 1997). Such accumulations of wrack can be common during winter in waters of south-west Western Australia (Kirkman & Kendrick 1997) and can provide a significant nutrient resource (Crawley & Hyndes 2007). However, the lack of elevated nutrients at lagoon and nearshore sites observed during this study suggested that either: 1) sufficient flushing or mixing was occurring to disperse nutrients that may have derived from such sources; or 2) that assimilation of nutrients by macrophytes (seaweeds and seagrasses) in these habitats was rapid. As these waters are generally oligotrophic and marine plants are nutrient-limited, the rapid assimilation of nutrients is a more likely explanation (Cambridge & Hocking 1997).

While the concentrations of most nutrients measured during this study were low overall, they did typically differ between locations. This result is not altogether surprising as many authors have reported spatial variation in coastal nutrient parameters across scales from metres to kilometres (Elsdon & Connell 2009), and such differences are generally attributed to localised oceanographic conditions (Gibbs 2000; Hanson et al. 2005; Lourey & Kirkman 2009) or differences in the rate of supply (Gorman et al. 2009). In general, samples from Nambung Bay had higher

nutrient concentrations than those from other locations, although this pattern was not consistent across seasons. It is currently unclear what is driving the elevated nutrient concentrations at this location; however, it may be that waters adjacent to Nambung Bay are receiving higher inputs of nutrients than at other locations.

Similarly, although identifying seasonal patterns was not the primary aim of this study, some patterns were evident in these data. Concentrations of Chl-*a* and OP were significantly higher in autumn than any other season. This finding is generally consistent with previous studies in this region, which have found higher nutrients levels during winter months in coastal waters of the Perth region and in shallow waters of the Houtman Abrolhos Islands, which are north of the JBMP (Crossland et al. 1984; Johannes et al. 1994; Lourey & Kirkman 2009). This peak in nutrient concentration may result from large volumes of macroalgae and seagrass being removed and transported onshore by winter storm activity (Kirkman & Kendrick 1997), where it breaks down through wave action and/or biological decay and is and recycled back into the water column. While wave action in the JBMP is typically greatest in winter, mean maximum wave height during the current study was actually highest in the autumn months (Western Australian Department of Transport, unpublished data), and the peak of some nutrients recorded here may be a result of storm activity during that time.

In addition to the autumn peaks in concentration, there was a trend for most parameters to be lowest in spring. Most notably, NH_4^+ was BDL at all locations and sites during this season. Despite the oligotrophic nature of Western Australian coastal waters, shallow benthic macroalgal and seagrass assemblages display exceptionally high rates of primary productivity, with the dominant habitat-forming kelp *Ecklonia radiata* producing as much as 20.7 kg-wet-wt m^{-2} per annum (Kirkman 1984, 1989), while the seagrass *Posidonia sinuosa* produces 30–50% of the *E. radiata* value (Cambridge & Hocking 1997). Kelp reaches its maximum rate of productivity during spring as solar irradiance intensifies and water temperatures begin to increase (Kirkman 1984). It is possible that the low level of nutrients reported here, and particularly that of nitrogenous compounds, which are limiting to plant growth, may be a result of the synergistic effects of: 1) the decreased accumulation and breakdown of macroalgae over spring (see above), resulting in lower nutrient supply; and 2) the assimilation of these compounds by marine plants during this period of rapid growth.

In demonstrating that the nutrient content of these coastal waters is generally low, we propose that this study has broader significance than simply providing a benchmark for future monitoring in the JBMP. Given the relative lack of anthropogenic impacts on marine water quality in the JBMP, we suggest that the outcomes of this study could have long-term relevance as a reference for water quality in biogeographically similar areas of Western Australia that have been subjected to sustained anthropogenic impacts. While water quality adjacent to the Perth metropolitan area is currently broadly

comparable with that of the JBMP, continuing pressure from urban and industrial growth (e.g. Gorgula & Connell 2004) and associated increases in outfall discharges and catchment inflows means that background marine nutrient levels in these areas may rise. Under such circumstances, and in the continuing absence of similar broadly-based and sustained impacts in the JBMP, it is probable that the water quality of this area will continue to approximate that of the marine waters in the Perth area prior to such long-term influences. Given that there is a statutory framework for managing and controlling inputs into the JBMP that does not exist in many other areas, background water quality will be maintained in a near-pristine state into the future. Hence, waters of the JBMP are likely to have increasing significance as a regional 'unimpacted' reference site for the coastal water quality of south-west Western Australia.

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Comparison of three digital image analysis techniques for assessment of coral cover and bleaching

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ABSTRACT

Digital imagery techniques for quantifying the benthos are increasingly used to monitor the health of coral reefs. There are many techniques to assess coral habitats from images, but there is no clear answer as to which one is the most effective. The aim of this study was to compare the effectiveness and relative cost (processing time) of three image analysis techniques commonly used to assess coral/benthic cover and coral bleaching. Digital photographs, taken 1 m above the substrate at 1 m intervals along 16 transects (50 images per transect), were used to examine the extent of coral cover and bleaching within coral communities of the Montebello and Barrow Islands in February 2011, following a temperature anomaly event. Each image was evaluated by: 1. assessing habitat under six randomly placed points ('point count'); 2. dividing images into 20 square blocks and recording the dominant item in each block ('block'); and 3. visually estimating benthic cover and bleaching without reference to points or grids ('visual'). Overall, there was a high degree of congruence between the commonly used techniques and there were no significant differences when comparing coral cover or the extent of bleaching. Similarly, there was no detectable difference in the precision of coral and bleaching estimates made using the three techniques. However, analyses carried out using the point count and visual techniques were quicker and therefore more efficient than the block technique. This study demonstrated that the techniques commonly used to assess coral cover and bleaching from digital images are compatible and that they may be combined to provide greater spatial and temporal assessment of coral reef condition.

Keywords: monitoring coral cover, coral bleaching, digital photographs, Western Australia, *Acropora*

INTRODUCTION

Scleractinian corals are the major builders of the coral reef environment (Veron 2000), providing essential habitat for thousands of fish and invertebrate species (Wilson et al. 2006; Pratchett et al. 2008; Plaisance et al. 2011). Corals are, however, threatened by a combination of increasing anthropogenic disturbance and enduring shifts in the oceanic environment brought about by rising levels of atmospheric pollutants (Hughes et al. 2003; Jenkins 2003). Bleaching is a response of corals to environmental stress, where there is a breakdown in the symbiotic relationship between the coral host and photosynthetic zooxanthellae. The reduced abundance of zooxanthellae makes the coral appear pale or 'bleached'. Reports of coral bleaching have increased dramatically over the past 30 years, partially reflecting a greater awareness of this process and an increased number of reef monitoring activities (Oliver et al. 2009). However, increases in sea temperatures over this time-frame also suggest that corals in many locations are living closer to their thermal thresholds than

in the past (Hoegh-Guldberg 1999; Eakin et al. 2009; Veron et al. 2009). Moreover, prolonged exposure to abnormally high water temperatures has resulted in several 'mass bleaching' events that have caused extensive coral bleaching and subsequent mortality (Glynn 1983; Brown 1997; Goreau et al. 2000; Berkelmans et al. 2004).

To assess the impact of bleaching and other disturbances on coral reefs it is essential that long-term monitoring programs are developed, using robust and comparable techniques to scrutinize coral health (Hughes et al. 2010). Yet it is difficult to assess the accuracy of techniques used to estimate coral cover (Andrew & Mapstone 1987). For this reason, monitoring programs often use relative measures of abundance to assess spatial and temporal differences and choose methods that have few biases and high levels of precision. The choice of which technique is most appropriate is also based on the spatial scale of the program, level of detail and precision required, as well as the resources available (Hill & Wilkinson 2004).

Some of the most common techniques used to assess coral/benthic cover and bleaching include intensive in-situ observations of quadrats and belt transects (Hill & Wilkinson 2004) or more extensive aerial surveys

(Berkelmans & Oliver 1999). Photographs or video have also been used to assess reef condition, and have the advantage that they provide a permanent record of reef condition and allow rapid collection of data in the field (George et al. 1985). The development of digital image capture (still and video) technologies has resulted in an increase in the use of imagery as a monitoring method, due to their ease of use. The cost of camera equipment and time to process images can, however, make it a relatively expensive method compared with data collected in-situ (Jokiel et al. 2005; Leujak & Ormond 2007). It is therefore important that efficient, yet robust, techniques are used to analyse photographic images. Researchers typically analyse benthic images using techniques such as point count or quadrat estimates, or by digitising shapes from an image to quantify a specific habitat type (e.g. Connell et al. 1997; Smith et al. 2008). There is, however, no clear answer as to which technique is the best, or if information gathered using different techniques is comparable. This is an important question, as many management and research agencies adopt different techniques for assessing coral health and associated threats from digital images.

Previous studies have compared the compatibility of different field techniques to estimate coral cover (e.g. Berkelmans & Oliver 1999; Jokiel et al. 2005; Leujak & Ormond 2007; Wilson et al. 2007); compared field techniques with the analysis of digital images (e.g. Carleton & Done 1995; Long et al. 2008); and determined the number of points needed to robustly estimate benthic cover from images (e.g. Pante & Dunstan 2012) and how these points are arranged (e.g. Carleton & Done 1995). Here we explicitly examine the compatibility of techniques used by different agencies and institutes in Western Australia to evaluate coral cover and bleaching from digital images. We examined the precision of each technique as a proxy for power to detect change, and measured the time it took to process images in order to compare labor costs associated with each technique. The study provided an indication of which technique is most suitable for analyzing benthic images and assessed the validity of combining data from different sources to provide regional-scale evaluations of coral bleaching.

METHODS

Images for this study were collected between 12–16 February 2011 from coral reefs of the Barrow and Montebello Islands, which are located approximately 130 km off the north-west coast of Western Australia (20.798 S, 115.406 E). Corals in this area were subjected to abnormally high water temperatures between December 2010 and March 2011 (Pearce & Feng 2012), which resulted in extensive coral bleaching (Moore et al. in press).

At each of four sites, four 50 m transects at 2–6 m depth were surveyed as part of a routine monitoring exercise. The transects were swum with a Canon G12 camera held ~1 m above the substrate, and an image was taken every metre (50 images per transect; 800 in total).

A 1 m length of steel, attached to the camera base and placed at a 90° angle to the substratum, was used to maintain a constant distance between the camera and the reef for each image. For each image, the percentage cover of *Acropora* and non-*Acropora* corals, as well as coral health (bleached or unbleached) were estimated using three different techniques:

1. Point count: EcoPAAS software (Ocean Vision Environmental Research) overlaid six random points on each image and the habitat beneath each point was categorised as *Acropora*, non-*Acropora* coral or non-coral, providing six data points per image. Corals under points were further classified as unbleached or bleached. This technique is currently used by Western Australia's Marine Monitoring Program, Department of Environment and Conservation, and similar techniques are used in Western Australia by the Australian Institute of Marine Science (AIMS; e.g. Smith et al. 2008), and Commonwealth Scientific and Industrial Research Organisation (CSIRO; e.g. Thomson and Frisch 2010)
2. Block: Transect Measure software (SeaGIS) overlaid a 4 × 5 block grid over each image, forming 20 blocks per image. The dominant item (*Acropora*, non-*Acropora* or non-coral) in each block was identified, providing 20 data points per quadrat. Where corals dominated a block it was also noted if that coral was bleached or unbleached. This technique is currently used by Western Australia's Department of Fisheries monitoring program.
3. Visual: An unaltered image was placed on the screen for a visual estimation of percent cover of *Acropora*, non-*Acropora* coral, non-coral habitat and the bleaching status of corals.

The three techniques were used to assess all images in all transects; however, the order in which each technique and transect was undertaken was randomised to eliminate the possibility that prior knowledge would bias estimates of any particular technique. *Acropora* corals were chosen for analyses because they are the most prominent genera on many West Australian reefs (Dinsdale & Smith 2004; Cassata & Collins 2008), are highly susceptible to bleaching (Marshall & Baird 2000; McClanahan et al. 2004), provide food and habitat for reef-associated fish (Wilson et al. 2008), and are easily identified on digital images. Bleached corals were identified as those where the concentration of algal pigment had decreased, resulting in a fading of coral colour because the white calcareous skeleton became more prominent (Ben-Haim et al. 2003). As there may be problems with the level of light exposure on images and no colour reference was included with each image (sensu Siebeck et al. 2006), we only included corals that were white compared with surrounding benthos and were definitely 'bleached'. A single, trained observer recorded all observations in order to eliminate observer bias among classifications of healthy, bleached or bleaching corals. A timer was used to record the length of time it took to collect data among the different techniques for each image and transect.

Statistical analyses

Habitat composition (*Acropora* and non-*Acropora* corals), and bleaching status (bleached *Acropora* and bleached non-*Acropora*) estimates were calculated for each transect and for each of the three techniques, then compared using PERMANOVA. Data were normalised prior to analysis and PERMANOVA performed on a dissimilarity matrix calculated from the Euclidean distance between replicates (Anderson 2001). The PERMANOVA model included sampling technique (point count, block or visual) as a fixed factor and site (1, 2, 3 or 4) as a random factor, with transects (n = 16) as replicates. The results were displayed using a Principal Components Analysis (PCA)

To further explore comparability of techniques, the mean and standard error for total, *Acropora* and non-*Acropora* coral coverage was calculated for each technique, based on the number of transects sampled (n = 16). Equality between treatments was tested using a Kruskal–Wallis ANOVA by Ranks test at a transect level (n = 16). This non-parametric analysis was chosen because the assumption of normality was not met, even after transformations. A post-hoc multiple comparisons test was performed to further investigate any significant results.

To assess the precision of each technique the coefficient of variation (standard error/mean) was calculated at a site level (n = 4) for each technique and compared using a Kruskal–Wallis ANOVA. Similarly, the time to

process all of the images from a single transect was compared using a Kruskal–Wallis ANOVA.

RESULTS

Differences in the amount of coral cover, *Acropora* and extent of bleaching were largely attributable to differences between the sites, rather than to the technique used to analyse images. There was no significant difference in habitat composition or bleaching status detected due to analysis technique or the interaction between technique and site (Table 1). Coral cover and extent of bleaching did, however, differ among sites, primarily due to a high *Acropora* coverage and bleaching of *Acropora* corals at site 2 relative to other sites (Fig. 1). Sites 1, 3 and 4 were

Table 1
Statistical results from PERMANOVA comparing coral cover and bleaching status estimates from three techniques and four sites.

	df	MS	Pseudo F	P
Technique	2	1.3	0.9	0.615
Site	3	46.7	45.2	0.001
Technique x Site	6	1.4	1.3	0.203

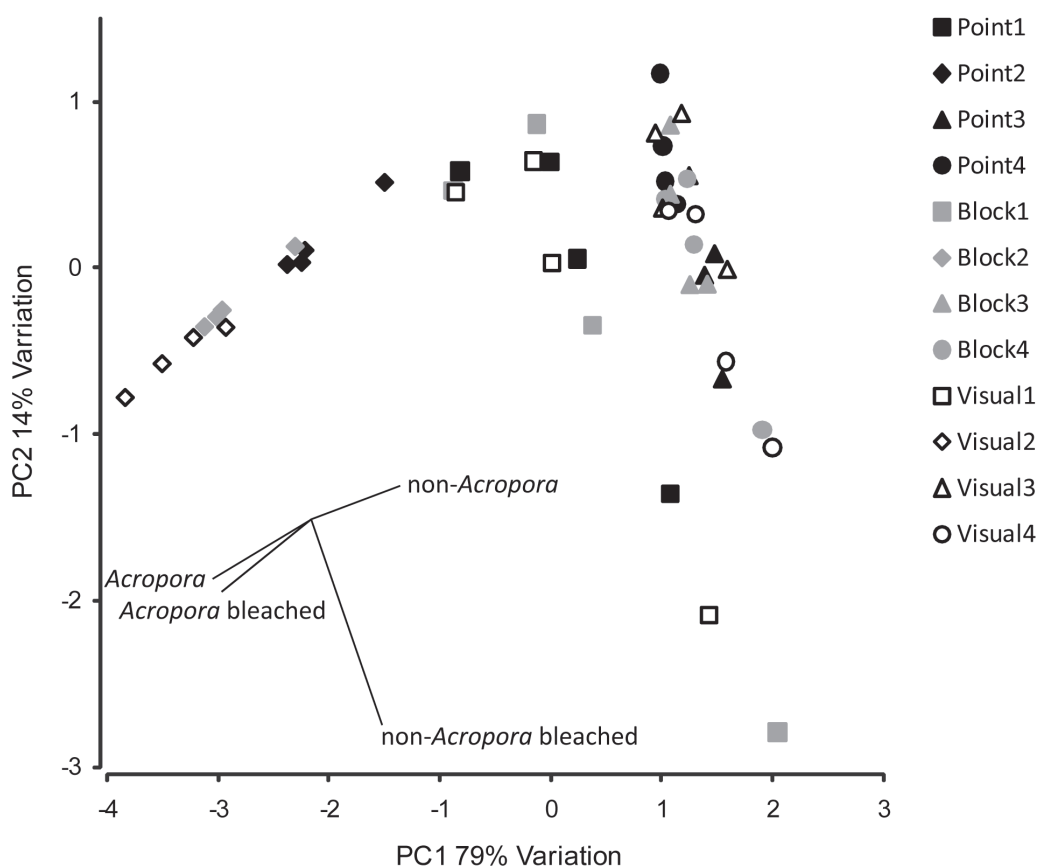


Figure 1. Principal Component Analysis showing habitat composition quantified using the three techniques (point count, block and visual) for assessing digital images. Each symbol represents a single transect at one of four sites.

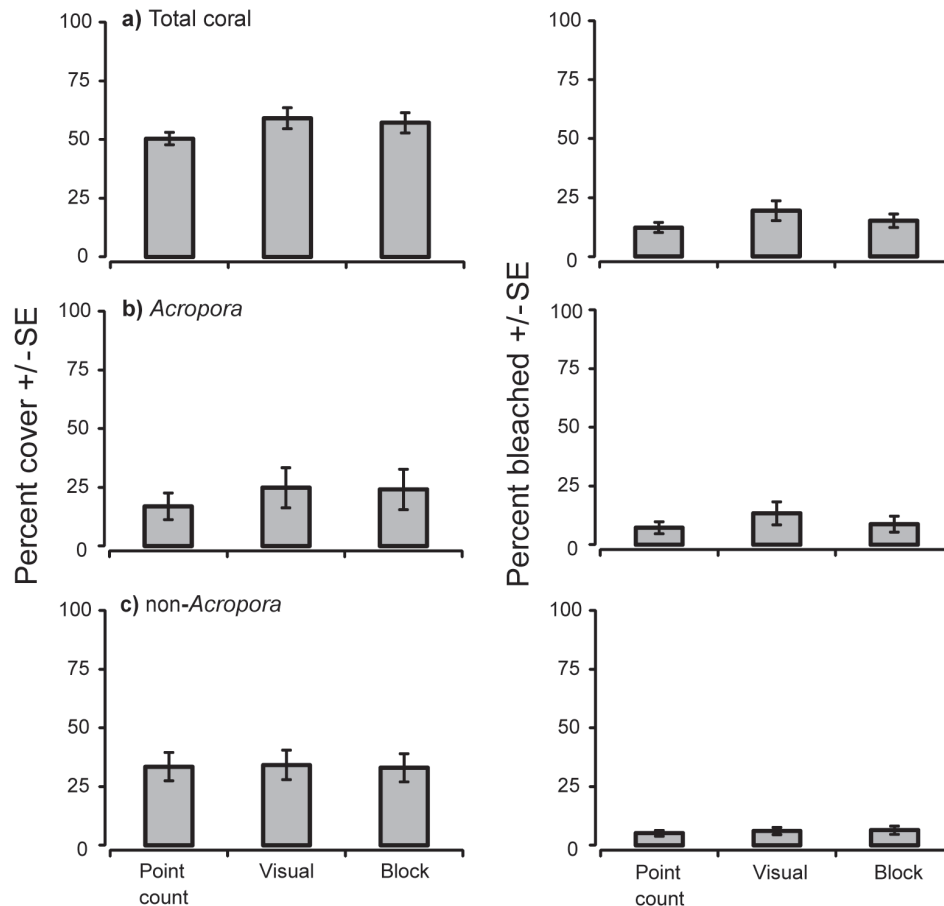


Figure 2. Coral cover and bleaching estimates from the three techniques used to evaluate digital images: percent cover \pm SE and percent bleached \pm SE of (a) total coral cover, (b) *Acropora* cover and (c) non-*Acropora* cover. Standard errors were calculated from 16 transects. There were no statistical differences detected with respect to type of method, bleached or unbleached measures of total, *Acropora* or non-*Acropora* coral cover.

characterized by high coverage of non-*Acropora* corals, although bleaching extent of these corals varied among transects within sites (Fig. 1).

All three techniques had comparable results with respect to estimations of total (~50–60%), *Acropora* (~15–25%) and non-*Acropora* (~30–35%) coral cover (Fig. 2, Table 2). Approximately 10–20% of all coral was bleached, of which ~5–15% was *Acropora* and ~5% was non-*Acropora* (Fig. 2). There were no significant differences between the three techniques in terms of bleaching assessments or for coral cover (Table 2).

Table 2

Nonparametric Kruskal–Wallis ANOVA by Ranks results for coral and bleaching assessment from the three techniques used to evaluate digital images.

Measurement	$H_{(2, 48)}$	p
% Hard coral	2.38	0.305
% <i>Acropora</i>	0.79	0.675
% Non- <i>Acropora</i>	0.21	0.902
% Hard coral bleached	1.41	0.494
% <i>Acropora</i> bleached	0.85	0.653
% Non- <i>Acropora</i> bleached	0.21	0.902

Precision was best when estimating broad categories of total coral cover, with coefficient of variation values ~6 for all techniques. However, as categories became more specific, the coefficient of variation increased, indicating weaker precision estimations for assessments of *Acropora* and non-*Acropora* coverage, as well as their bleaching status (Table 3).

The average time to assess coral health and cover for both the point count and visual technique was ~35 minutes per transect. This was significantly faster than the surveys undertaken using the block technique (Kruskal–Wallis ANOVA by Ranks $H = 10.045$, $p = 0.007$), which took ~50 minutes per transect (Fig. 3).

DISCUSSION

The three techniques investigated provided similar estimates and levels of precision for coral cover and bleaching status. This infers that coral cover and bleaching data collected using these techniques are comparable and may be combined to improve spatial and temporal monitoring of coral reefs. These findings are consistent with those that have shown total coral cover estimates

Table 3

Precision estimates for coral and bleaching assessments from three techniques (point count, visual and block) used to evaluate digital images. Precision calculated as standard error/mean for each of four sites.

Measurement	Coefficient of variation			$H_{(2, 12)}$	p
	Point count	Visual	Block		
% Hard coral	6.7 ± 2.6	6.0 ± 1.7	5.7 ± 2.5	0.500	0.779
% <i>Acropora</i>	27.7 ± 11.7	43.4 ± 20.4	39.2 ± 21.3	0.608	0.738
% Non- <i>Acropora</i>	17.8 ± 7.6	18.4 ± 9.8	17.2 ± 7.8	0.462	0.794
% Bleached	20.7 ± 3.3	21.0 ± 2.0	24.6 ± 3.3	0.500	0.789
% <i>Acropora</i> bleached	32.4 ± 10.6	53.1 ± 18.2	50.6 ± 17.2	1.862	0.394
% Non- <i>Acropora</i> bleached	46.9 ± 14.4	48.0 ± 18.9	36.1 ± 11.3	0.808	0.668

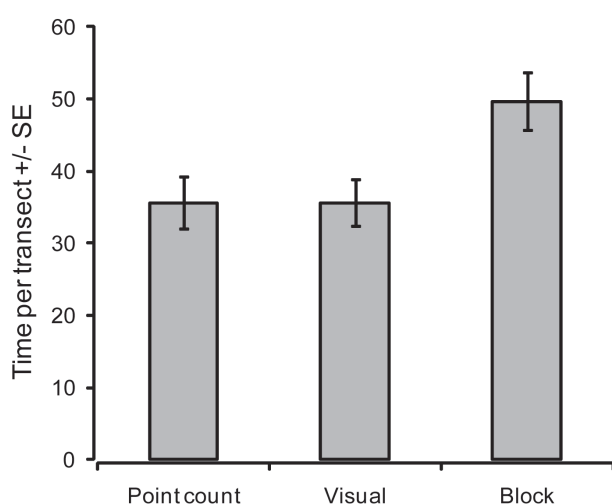


Figure 3. Average time (minutes) to analyze a transect (50 photographs) for three techniques (point count, visual, block) used to assess coral cover and bleaching. Error bars are standard error calculated from 16 transects for each technique.

from different field techniques are generally compatible (Carleton & Done 1995; Jokiel et al. 2005; Leujak & Ormond 2007; Wilson et al. 2007). However, the capacity to compare results collected at finer taxonomic scales (e.g. genera) may be reduced as the resolution at which different techniques effectively collect data may differ (Carleton & Done 1995; Leujak & Ormond 2007). In particular, it has been suggested that estimates of arborescent *Acropora* are often lower when using point-count techniques as points may fall between colony branches and be categorized as non-coral, whereas other techniques consider the entire area encompassed by a colony to be live coral (Long et al. 2008). Furthermore, when compiling and comparing information on coral bleaching it is important to determine at what spatial scale the data was collected (Andrefouet et al. 2002), as techniques used to collect bleaching data at different spatial scales may not be compatible (Berkelmans & Oliver 1998).

When selecting a suitable technique for monitoring, consideration should be given to precision and cost (Quinn & Keogh 2002; Roelfsema et al. 2006). Whilst mean values and precision estimates derived from the three techniques were similar, our results indicated that point count and visual assessments of coral cover and bleaching can be carried out over shorter time frames than block

assessments. This partially relates to the number of points or blocks surveyed per image, which were based on the methods used by the monitoring agencies that use these techniques. Hence, it is expected that the time taken to process images using point count and block estimates will be similar if the number of blocks and points analysed per image is the same.

The similarity of coral cover and bleaching estimates obtained from the visual technique with those from point count and block techniques underlines the ability of the human eye to rapidly and reliably compute estimates of coral cover (Long et al. 2004; Clua et al. 2006; Wilson et al. 2007). The visual technique is comparatively simple and requires less equipment or computer software than other techniques. But visual techniques are sensitive to subjective interpretation of images, and standard protocols for assessing images combined with constant training and inter-observer comparison are required to limit the influence of observer bias on results (Miller & De'ath 1996). Although less critical with the point count and block techniques, a level of inter-observer variability is likely to influence all of these analysis methods, which could be limited through training and regular inter-observer comparison. One of the benefits of capturing digital imagery is that there is a permanent record of the benthic community. As a result, any concerns associated with method or inter-observer differences can be overcome through reanalysis of the imagery using a single method by a single observer.

Conclusion

Digital imagery is increasingly being used as a tool to monitor the condition of benthic habitats on coral reefs using cameras in situ (Dalton & Smith 2006), and to validate broad-scale assessments of habitat collected remotely from aircraft (e.g. Mumby et al. 2001). It is therefore imperative that the methods of analysis of digital images are effective for the assessment of threats such as coral bleaching. Moreover, bleaching and other disturbances often occur over large spatial scales across the jurisdiction of different management agencies within and between countries. To obtain a comprehensive account of these large-scale events it is often necessary that data be compiled from sources that use different methods and techniques for capturing and processing data. Here we have demonstrated that the techniques commonly used

by Western Australian agencies to assess coral cover and bleaching from benthic images are compatible within the bounds of the taxonomic level investigated. Consequently information collected using these techniques may be combined and analysed for broad-scale assessments of bleaching and monitoring of coral reef health.

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