

The flora and vegetation of the seasonal and perennial wetlands of the southern Carnarvon Basin, Western Australia

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Abstract – A total flora of 265 taxa was recorded from 58 wetland areas in the southern Carnarvon Basin. The flora was dominated by arid species but also included 34 temperate taxa at the northern end of their range and 18 tropical taxa at the southern end of their range. Five species (*Dichopogon tyleri*, *Calandrinia* sp. Coolcalalaya (GJK and NG 698), *Myriocephalus gascoynensis* ms, *Lythrum* sp. Towrana (RJC 2183), *Psammagrostis wiseana*) are endemic to the study area. The *Calandrinia* sp. appears not to have been collected previously. A collection of *Rumex crystallinus* was the first recorded in Western Australia since 1885.

Classification of the wetlands was undertaken at two different scales; at both scales heterogeneity was high. The major division in the data sets was between the saline and non-saline wetlands. Percentage of single species occurrences was high in both datasets, ranging from 46–55%; this component of the flora adds significantly to plant biodiversity but is not a predictable component of vegetation communities. In the seven-group classification no floristic groups were restricted to particular habitat types but at the finer scale sampling there is a stronger correlation between floristic community type and habitat type. At this scale the major habitat types (e.g. river pools) encompassed a range of floristic groupings. The patterns in low species richness and very patchy species distribution found in this study are similar to those reported for wetlands in the higher rainfall areas of the south west but the underlying causal factors determining these patterns remain unclear.

INTRODUCTION

The flora and vegetation of the wetlands of the southern Carnarvon Basin (Anonymous, 1975) have been little studied (Figure 1). In the most recent and comprehensive review of nationally significant wetlands only two non-marine wetlands are listed from the study area (ANCA, 1996). These two large wetland systems highlight the diverse nature of wetlands in this area. Lake MacLeod covers some 150 000 ha formed on calcareous marine deposits and lies 30 km north west from Carnarvon. In part, it is fed by ocean water through 18 km of coastal limestone which upwells in sinkholes in the central western section of the wetland, but precipitation can also make a significant contribution to water supply in wetter years (Scott, 1962; ANCA, 1996). The mangrove community of Lake MacLeod is one of only two inland occurrences (ANCA, 1996). In contrast the McNeill claypan system is located on outwash alluvial deposits near the mouth of the Gascoyne River. The soils have been described by Bettenay *et al.* (1971) as saline-alkaline with high levels of exchangeable sodium and a high content of soluble salts. These flats are inundated with fresh water when the Gascoyne River floods. Both wetlands are important for migratory birds (ANCA, 1996).

Other major wetland habitats found in the study area include those associated with permanent and semi permanent river pools, and freshwater and saline springs, wetlands of seasonally inundated claypans, and the widespread saline samphire flats and birridas (gypsum pans) (Battye, 1915; Payne *et al.*, 1987). The flora and vegetation of Rocky Pool on the Gascoyne River (Kenneally, 1978) and the occurrence of *Psilotum nudum* in the lower Murchison River (Smith and Butler, 1961) are among the few accounts of wetland vegetation that have been published for this area.

Numerous classification systems for wetlands have been published both at the regional (Paijamans *et al.*, 1985; Lane and McComb, 1988; Jacobs and Brock, 1993; ANCA, 1996) and local scales (Semeniuk, 1987), using geomorphic and physical features, but none of these systems clearly differentiate the major geomorphic types recognised in the study area; as a consequence the terminology of Payne *et al.* (1987) is adopted here.

The aim of this paper is to describe the flora and vegetation of the major seasonal and permanent wetland types of the southern Carnarvon Basin and determine how floristic units correlate with major habitat types.

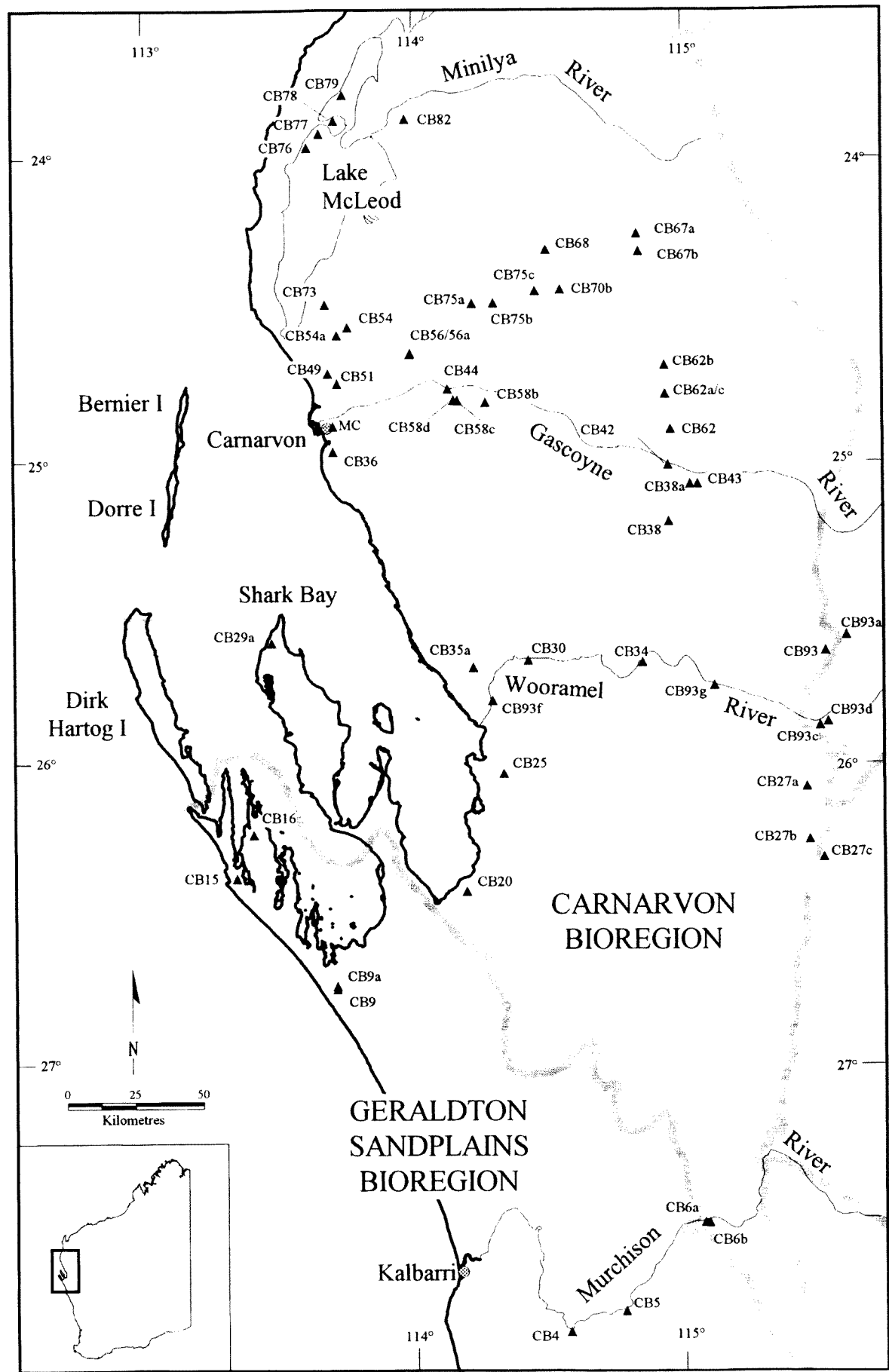


Figure 1 Location of wetland areas sampled and showing boundaries of major phytogeographic regions (Thackway and Cresswell, 1996).

METHODS

Fifty-eight wetland areas were sampled across the study area (Figure 1 and Appendix 1) in August and September 1995. No coastal saline wetlands or mangroves were included in the present survey. Several locations within some of the larger wetlands (e.g. Lake MacLeod) were sampled. The sites were the same as those used for the invertebrate sampling by Halse *et al.* (2000) with one exception, and the addition of a site on McNeill claypan. As clear vegetation zonation was apparent around many of the wetlands a series of 1 m x 1 m quadrats was used to sample each vegetation type, running along a transect at right angles to the shoreline. Lists were compiled of all taxa (species, subspecies and varieties) found in these quadrats. Taxa seen at each wetland but not recorded in quadrats were also noted. Sites were classified according to similarities in species composition using the Czekanowski coefficient and 'unweighted pair-group mean average' fusion method (UPGMA; Sneath and Sokal, 1973), while species were classified using the 'two step' method of Austin and Belbin (1982) and the UPGMA fusion method. This analysis of vegetation patterning was carried out at two scales — a larger scale using lists of species from each wetland area and the finer scale based on individual quadrats. Trees were excluded from the analysis of the quadrat data.

Water chemistry data were collected during the sampling of these sites for macro invertebrates in August 1994 and/or March 1995 [see Halse *et al.* (2000) for detailed methods]. These data were used as correlates for soil chemistry in analysis of between group differences. Statistical relationships between site groups were tested using Kruskal - Wallis non-parametric analysis of variance and Mann-Whitney U-tests (Siegel, 1956).

Species habitat preference and distribution information were compiled from collections held in the Western Australian Herbarium. Nomenclature follows Green (1985) and current usage at the Western Australian Herbarium. Selected voucher specimens have been lodged in that institution.

RESULTS

Flora

The flora of the wetlands was found to be dominated by arid zone species (Jessop, 1985). Two hundred and sixty three taxa were recorded from the fifty-eight wetland areas (Appendix 1). The best represented families were Asteraceae (32 native, 4 introduced species), Poaceae (25 native, 10 introduced species), Chenopodiaceae (24 natives), Cyperaceae (17 native, 1 introduced species) and Scrophulariaceae (10 natives). This composition clearly reflects the arid nature of the flora. At the

Table 1 Wetland taxa endemic to the southern Carnarvon Basin.

<i>Dichopogon tyleri</i>
<i>Calandrinia</i> sp. Coolcalalaya (GJK and NG 698)
<i>Myriocephalus gascoynensis</i> ms
<i>Lythrum</i> sp. Towrana (RJC 2183)
<i>Psammagrostis wiseana</i>

generic level *Calandrinia* (8 taxa), *Eragrostis* (8 taxa), *Cyperus* (7 taxa), *Atriplex* (5 taxa) and *Goodenia* (5 taxa) were the most species rich.

Thirty-one introduced species were recorded from the wetlands. The wetland vegetation was heavily disturbed around some of the springs and river pools with either the complete removal of understorey, or with taxa such as *Cenchrus ciliaris* and *Asphodelus fistulosus* becoming dominant. The vegetation of the saline wetlands and the wetlands of the ephemeral claypans was generally much less impacted.

A total of seven new populations of four taxa (*Bergia auriculata*, *Goodenia neogoodenia*, *Rumex crystallinus*, *Wurmbea murchisoniana*) listed on CALM's priority flora list (CALM, 1996) were located during the course of the survey. These taxa require further investigation before consideration of listing as threatened flora. *Rumex crystallinus* was collected on the McNeill claypan near Carnarvon; this was the first collection of this species in Western Australia since 1885 when it was recorded by Carey on the Lyndon River some 150 km to the north.

Five taxa endemic to the study area were recorded from the fifty-eight wetlands (Table 1). Of these, *Calandrinia* sp. Coolcalalaya (GJK and NG 698) and *Lythrum* sp. Towrana (RJC 2183) appear to be restricted to edges of ephemeral claypans. *Myriocephalus gascoynensis* ms may also be restricted to this habitat.

Seven of the taxa recorded in this study are totally restricted to water bodies while another six generally grow as emergents around permanent or semipermanent wetlands (Table 2). Two of the

Table 2 List of submerged and emergent aquatic taxa recorded from 58 wetlands in the southern Carnarvon Basin (* indicates introduced species).

Submerged or floating aquatic	Emergent aquatic
* <i>Callitriche stagnalis</i>	<i>Alternanthera nodiflora</i>
* <i>Crassula natans</i>	<i>Avicennia marina</i>
<i>Elatine gratioloides</i>	<i>Baumea articulata</i>
<i>Najas marina</i>	<i>Eleocharis acuta</i>
<i>Potamogeton pectinatus</i>	<i>Eleocharis geniculata</i>
<i>Ruppia megacarpa</i>	<i>Schoenoplectus subulatus</i>
<i>Ruppia polycarpa</i>	<i>Typha domingensis</i>
<i>Ruppia tuberosa</i>	

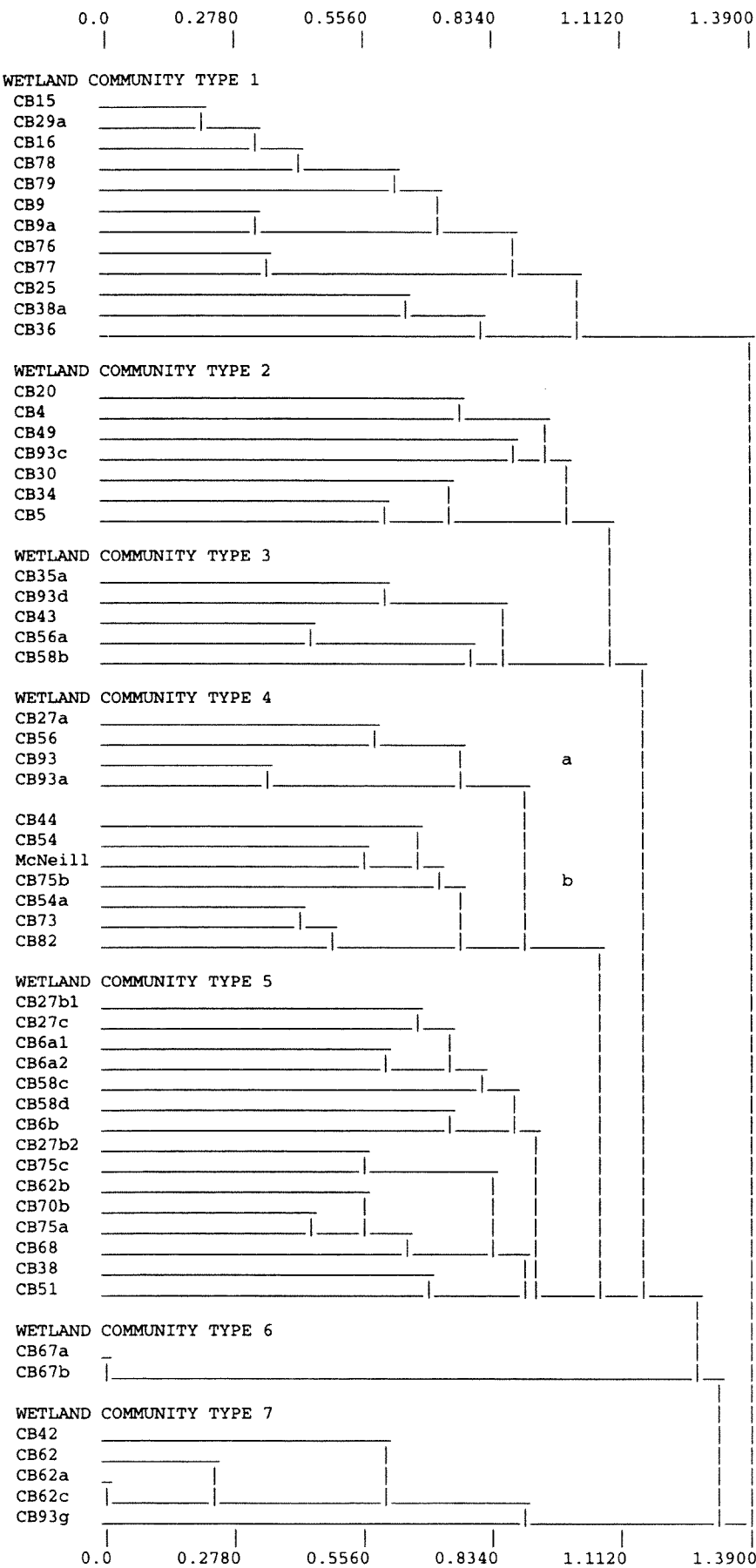


Figure 2 Dendrogram showing the UPGMA fusion of the wetland vegetation of 57 wetland areas in the southern Carnarvon Basin.

submerged aquatic taxa are widespread weed species across southern Australia (Aston, 1973). The habitat preference of other taxa generally restricted to wetland areas is listed (Appendix 1) where such information could be determined from herbarium labels. This information is lacking for some genera where the material is on loan.

The poor state of knowledge of the wetland flora of the southern Carnarvon Basin is highlighted by the first collections of one apparently undescribed *Calandrinia* sp. and major range extensions of 15 other taxa (Appendix 1).

Thirty-four taxa reach the northern limit of their range in the study area and another 18 primarily tropical taxa reach the southern ends of their range. The study area straddles Beard's (1990) major phytogeographic boundary between the temperate south west and the Eremaean zones (Figure 1).

Vegetation

Large scale patterning – the wetland classification

Amalgamation of some species was necessary as material could not always be positively identified to species level (e.g. *Centipeda* spp.). One of the claypans was completely bare of vegetation and was excluded from the analysis. Of the 259 taxa included in the final dataset some 142 taxa (55%) occurred only at one wetland area. The dataset was analysed with and without singletons (i.e. taxa that occurred at only one site). The results of both analyses were similar with clearer patterning seen in the analysis with the singletons excluded; these are the results presented below. Species richness varied from one to 25 taxa per wetland (with singletons excluded), with individual taxa occurring at between two and 22 wetlands. In this analysis

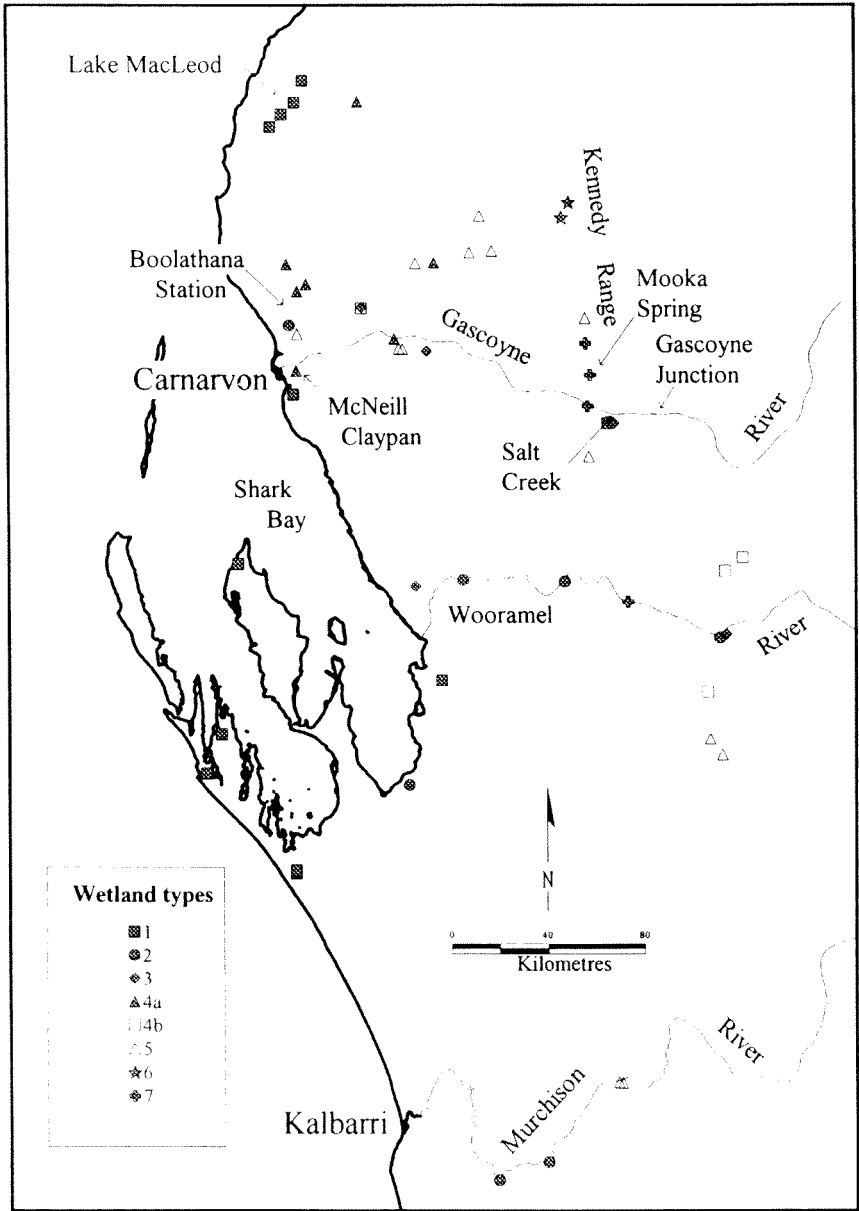


Figure 3 Distribution of the seven wetland community types across the southern Carnarvon Basin.

Table 3 Two way table showing species distribution across the seven wetland community types identified by the UPGMA fusion.

WETLAND AREAS	WETLAND COMMUNITY TYPES							SPECIES GROUPS
	1	2	3	4a	4b	5	6	7
	CCCCCCCCCCCC	CCCCCCC	CCCCC	CCCC	CCMCCCC	CCCCCCCCCCCCCCCC	CC	CCCCC
	BBBBBBBBBBBBBB	BBBBBBBB	BBBBB	BBBB	BBcBBBB	BBBBBBBBBBBBBBBB	BB	BBBBB
	121779977233	2449335	39455	2599	45N7578	226655627677635	66	46669
	59689 a67586	0 9304	53368	7633	44e5432	77aa88b75205881	77	22223
	a	a	c	ad ab	a a	iba	bc12cd bcbba	ab acg
						1 2		
Actinobole uliginosum				*		*		A
Isoetopsis graminifolia				*		**		
Peplidium sp. C (Burbidge and Kain 8152)				*		** * * *		
Calotis hispidula			*	*	*	***		
Calandrinia granulifera						* *		
Gnephosis eriocephala						**		
Gypsophila australis						*	*	B
Crassula natans			*			*		
Pentaschistis airoides			*			* *		
Melaleuca uncinata			*			* *		
Atriplex holocarpa			**			*		
Myriocephalus gascoynensis MS						*	*	
Eragrostis leptocarpa						*	*	
Trichanthodium skirrophorum			*			*	*	
Calotis multicaulis		*	*		*	** ** *		
Cyperus rigidellus					*	* ** *	*	
Calandrinia ptychosperma						**	*	
Bergia auriculata						***		C
Bergia perennis subsp. obtusifolia						*** ** *		
Calandrinia pumila						***	*	
Goodenia neogoodenia						**	*	
Eragrostis pergracilis	*					*		
Peplidium aithocheilum						**		
Glossostigma drummondii						* ** *		
Marsilea angustifolia						* ** *	*	
Isoetes sp.		*				* * *		
Calandrinia sp.Coolcalalaya (GJK and NG 698)	*					*		
Pogonolepis muelleriana	*					**		
Crassula colorata	*	*				**	*	D
Eragrostis dielsii	*	**	**			* * * * *	*	
Triglochin calcitrapum	*	*	*	*		*** *		
Asphodelus fistulosus			*****					
Myriocephalus guerinae			**				*	
Atriplex lindleyi	*		*					

Apium prostratum
Tetragonia cristata
Medicago polymorpha
Wurmbea murchisoniana
Heliotropium curassavicum
Typha domingensis
Ruppia sp.
Cyperus gymnocaulos
Eucalyptus camaldulensis var. *obtus*
Polypogon monspeliensis
Lotus australis
Samolus junceus

Figure 1 displays a 5x5 grid of star patterns, labeled E through I. The grid is defined by dashed lines. The patterns are as follows:

- Row E:**
 - Cell 1: 1 star at (1,1).
 - Cell 2: 1 star at (2,2).
 - Cell 3: 5 stars at (1,3), (2,3), (3,3), (4,3), (5,3).
 - Cell 4: 1 star at (4,4).
 - Cell 5: 1 star at (1,5).
- Row F:**
 - Cell 1: 1 star at (1,1).
 - Cell 2: 1 star at (2,2).
 - Cell 3: 1 star at (2,3).
 - Cell 4: 10 stars at (1,4), (2,4), (3,4), (4,4), (5,4), (1,5), (2,5), (3,5), (4,5), (5,5).
 - Cell 5: 10 stars at (1,5), (2,5), (3,5), (4,5), (5,5), (1,6), (2,6), (3,6), (4,6), (5,6).
- Row G:**
 - Cell 1: 1 star at (1,1).
 - Cell 2: 1 star at (2,2).
 - Cell 3: 1 star at (2,3).
 - Cell 4: 10 stars at (1,4), (2,4), (3,4), (4,4), (5,4), (1,5), (2,5), (3,5), (4,5), (5,5).
 - Cell 5: 10 stars at (1,5), (2,5), (3,5), (4,5), (5,5), (1,6), (2,6), (3,6), (4,6), (5,6).
- Row H:**
 - Cell 1: 1 star at (1,1).
 - Cell 2: 1 star at (2,2).
 - Cell 3: 1 star at (2,3).
 - Cell 4: 1 star at (4,4).
 - Cell 5: 1 star at (1,5).
- Row I:**
 - Cell 1: 1 star at (1,1).
 - Cell 2: 1 star at (2,2).
 - Cell 3: 1 star at (2,3).
 - Cell 4: 1 star at (4,4).
 - Cell 5: 1 star at (1,5).

Table 3 (cont.)

	WETLAND COMMUNITY TYPES								SPECIES GROUPS
	1	2	3	4a	4b	5	6	7	
WETLAND AREAS	CCCCCCCCCCCC BBBBBBBBBBBB 121779977233 59689 a67586 a	CCCCCCC BBBBBBB 2449335 0 9304 c	CCCCC BBBBB 39455 53368 ad ab	CCCC BBBB 2599 7633 a a	CCMCCCC BBcBBBB 45N7578 44e5432 iba	CCCCCCCCCCCCCCCC BBBBBBBBBBBBBBBB 226655627677635 77aa88b75205881 bc12cd bcbba 1 2	CC BB 66 77 ab	CCCCC BBBBB 46669 22223 acg	
<i>Avicennia marina</i>	* **								
<i>Halodule uninervis</i>	**								
<i>Halosarcia pterygosperma</i> subsp. <i>denticulata</i>	* * ***								
<i>Ruppia tuberosa</i>	*** *								
<i>Frankenia pauciflora</i>	* * **								
<i>Muellerolimon salicorniaceum</i>	** * ***								
<i>Sarcocornia quinqueflora</i>	*****								
<i>Halosarcia halocnemoides</i>	** * * *								J
<i>Halosarcia indica</i>	**** * * *	**							
<i>Cotula cotuloides</i>	*	*							
<i>Triglochin centrocarpum</i>	*	*							
<i>Lawrencea viridigrisea</i>	**								
<i>Neosciadium glochidiatum</i>	**								
<i>Samolus repens</i>	**								
<i>Triglochin mucronatum</i>	**	*							
<i>Rostraria pumila</i>	* *				*				
<i>Senecio glossanthus</i>	* * *				*				
<i>Anagallis arvensis</i>			*	***				*	
<i>Schoenoplectus lateriflorus</i>				* * *	*			*	
<i>Eucalyptus victrix</i>		***		* *	*				
<i>Daucus glochidiatus</i>	*			***					
<i>Glossostigma diandrum</i>				* * *					
<i>Setaria dielsii</i>				* *					
<i>Isolepis congrua</i>				* * *	*		*		
<i>Centrolepis eremica</i>		*		*				*	
<i>Hypericum japonicum</i>		*		*					K
<i>Brachyscome iberidifolia</i>				*		*			
<i>Cyperus</i> aff. <i>cunninghamii</i> (GJK and NG 592)				**					
<i>Lipocarpha microcephala</i>				**					
<i>Oldenlandia galioides</i>				**					
<i>Schoenus elegans</i>				**					
<i>Drosera indica</i>				**			*		
<i>Eragrostis basedowii</i>				**			*		
<i>Elatine gratioloides</i>				**	*				
<i>Wahlenbergia tumidifructa</i>				**	*				

site groups are discussed at the seven group level (referred to as 'wetland community types' or 'community types') which best reflected the scale of patterning seen in the field.

The wetland areas sampled showed a high level of heterogeneity in species composition (Figure 2). The primary division in the classification separates the vegetation of the saline flats (wetland community type 1) from all other sites. This can also be seen in the sorted two-way table (Table 3) where species group J is largely restricted to this community type. Most taxa in this group are highly faithful to it and species such as *Halosarcia halocnemoides*, *H. indica* and *Sarcocornia quinqueflora* have a high level of constancy. All other species groups are completely or almost completely lacking from this wetland community type except for low frequencies of species in species groups D and E. Species richness in this community type ranges from three to 16 taxa/wetland (average 6.8). This community type is largely restricted to the near coastal samphires and birridas between Shark Bay and Lake MacLeod (Figure 3). One outlying site was found at Salt Gully near Gascoyne Junction. The inland mangrove stands from Lake MacLeod are members of this group. While coastal samphires and mangroves were not sampled in this study they appear very similar to this community type.

Wetland community type 2 is generally associated with deeper river pools; one wetland formed from an uncapped artesian bore also belongs with this group. This community type is characterised by the occurrence of species group I. While a number of species are restricted to this community type, constancy values rarely exceed 50%. Species in species groups A, B, E and H are completely lacking, while species frequency in other species groups is low to very low. Average species richness was low (6 taxa/wetland). This community type was associated with the deepest pools which would not dry out in any but the driest years; it occurred from the Murchison River to north of Carnarvon and east along the Wooramel River (Figure 3).

Community type 3 are typically species-poor claypans (mean species richness 5.6 taxa/wetland). The only species constant and faithful to this group

is the weed *Asphodelus fistulosus*. One species poor riverine site also belongs to this group. The occurrence of *A. fistulosus* indicates moderate levels of grazing. Whether the low species richness of these sites is also related to disturbance or local soil or moisture conditions is not clear. Several chenopod species were also recorded from this wetland community type.

Community types 4 and 5 encompass riverine wetlands and ephemeral claypans and swamps characterised by the occurrence of *Alternanthera nodiflora*, *Centipeda* spp. and to a lesser extent *Myriocephalus nudus*. Community type 4 differs from type 5 by the reasonably high frequency of other taxa in species group F while largely lacking taxa in species groups A, B, C, D and E which further characterise community type 5, although constancy of species in these groups is generally only moderate to low. Community type 4 was found both in riverine vegetation and ephemeral wetlands of the claypans and swamps while community type 5 was largely restricted to claypans and swamps (Table 4).

Two distinct subtypes are discernible in wetland community type 4. Subtype 4a was the most species-rich of the wetland groups sampled (mean species richness of 17.0/wetland), while community subtype 4b was much less rich (mean species richness of 10.6 taxa/wetland). Both subtypes are characterised by the occurrence of taxa in species group F, while the occurrences of species in species groups G and K define the subgroupings.

Three of the four sites in community subtype 4a are riverine and this subgroup is characterised by a moderate to high fidelity and constancy of taxa in species group K. The river pools tended to have a variety of microhabitats generally with a dense band of sedges (*Schoenoplectus lateriflorus* and/or *Cyperus vaginatus*) along the water's edge. This community subtype was found on upstream areas of the Wooramel River and its tributaries and around a large semi-permanent water body on Boolathana Station (north of Carnarvon) (Figure 3).

Community subtype 4b is restricted to claypans, ephemeral swamps and two river pools in the north west of the study area (Figure 3). Wetlands in this

Table 4 Comparison of the occurrences of the seven wetland community types with a broad habitat classification.

Wetland community type	Birrida (gypsum pan)	Samphire	River pool	Spring	Ephemeral swamp	Claypan
1	7	4	1	–	–	–
2	–	–	6	1	–	–
3	–	–	1	–	–	4
4	–	–	6	–	1	4
5	–	–	1	–	8	6
6	–	–	1	1	–	–
7	–	–	4	1	–	–

group were characterised by taxa in species group G while almost totally lacking taxa in species group K, which are typical of community subtype 4a. Subtype 4b wetlands tended to have a significant shrub component and the claypans and swamps were quite extensive.

The majority of the ephemeral swamps and claypans form wetland community type 5, and while *Centipeda* spp. and *Alternanthera nodiflora* were also common in this community type, the herbs of species groups A, B, C and D clearly differentiate it from the previous type. The sites in this type were quite heterogenous, with few constant taxa, but none the less species rich (mean 10.7 taxa/wetland). The most constant taxon was *Eragrostis dielsii*, occurring in 75% of sites in this group and totally lacking from the related community type 4. Species group C is most typical of this community type and is composed of annual taxa that either germinate in very shallow waters or rapidly germinate as the clay soils dry. This community type was very widespread across the study area (Figure 3). One riverine site was classified into this group. That site had rich alluvial soil on which suites of annuals were growing. Typically the riverbanks in the study area are either sandy or rocky.

A series of permanent springs are found along the western foothills of the Kennedy Range. These have until recently long been used as watering points for cattle. Some of the springs are fenced off and water piped from them but two have been used as cattle

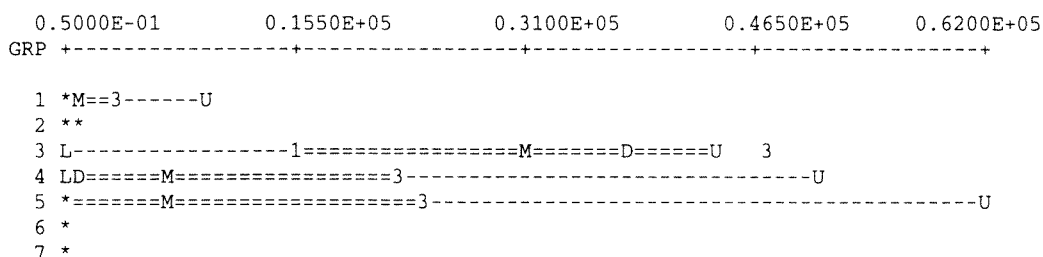
yards. There are no understorey species left at these two sites. The overstorey tree is *Eucalyptus camaldulensis* subsp. *obtusata*. These two sites form wetland community type 6 based on the sole occurrence of this species. One site was located at the spring itself while the second was along the watercourse below the spring.

The final community type (type 7) is comprised of tall dense species-poor sedgelands that occur at the less modified springs and the streams draining the west side of the Kennedy Range and as far south as a dammed section of the Wooramel River. These stands are typical of permanent or near permanent water bodies. *Cyperus vaginalis* is constant in this group but is also common in wetland community subtype 4b. *Typha domingensis* is also a common component of this community type. Mean species richness is 3.2 taxa/wetland.

While no soil sampling or analysis was undertaken during the present study, Halse *et al.* (2000) collected water chemistry data from all but one of these wetlands in their study of invertebrate patterning. This water chemistry data could be expected to be related to aspects of the soil chemistry. Measures of electrical conductivity and turbidity highlight patterns as discussed above (Figure 4).

When the claypans fill, the water becomes red brown in colour due to suspended clay particles. Only wetland community types 3, 4, and 5 occur in claypans, with the percentage of claypan sites

Turbidity (NTU) Kruskal-Wallis: 20.236, df: 6, Probability = 0.0025



Electrical conductivity (mSm⁻¹) Kruskal-Wallis: 37.524, df: 6, Probability < 0.0000

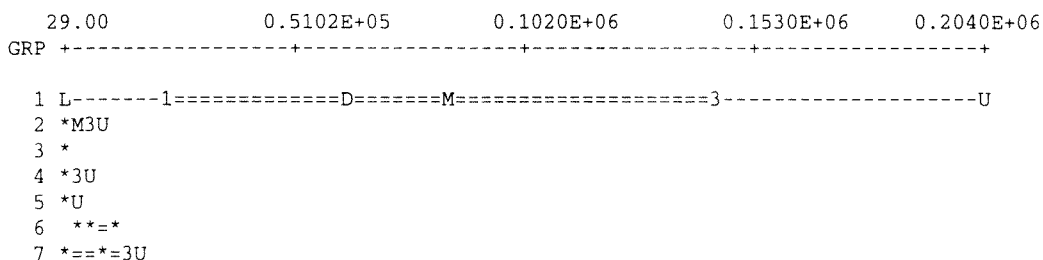


Figure 4 Turbidity (NTU) and electrical conductivity (mSm⁻¹) for the seven community types. L = lower limit, 1 = Mean - 1 standard deviation, M = mean, D = Median, 3 = Mean + 1 standard deviation, U = upper limit, * = more than one symbol at print position.

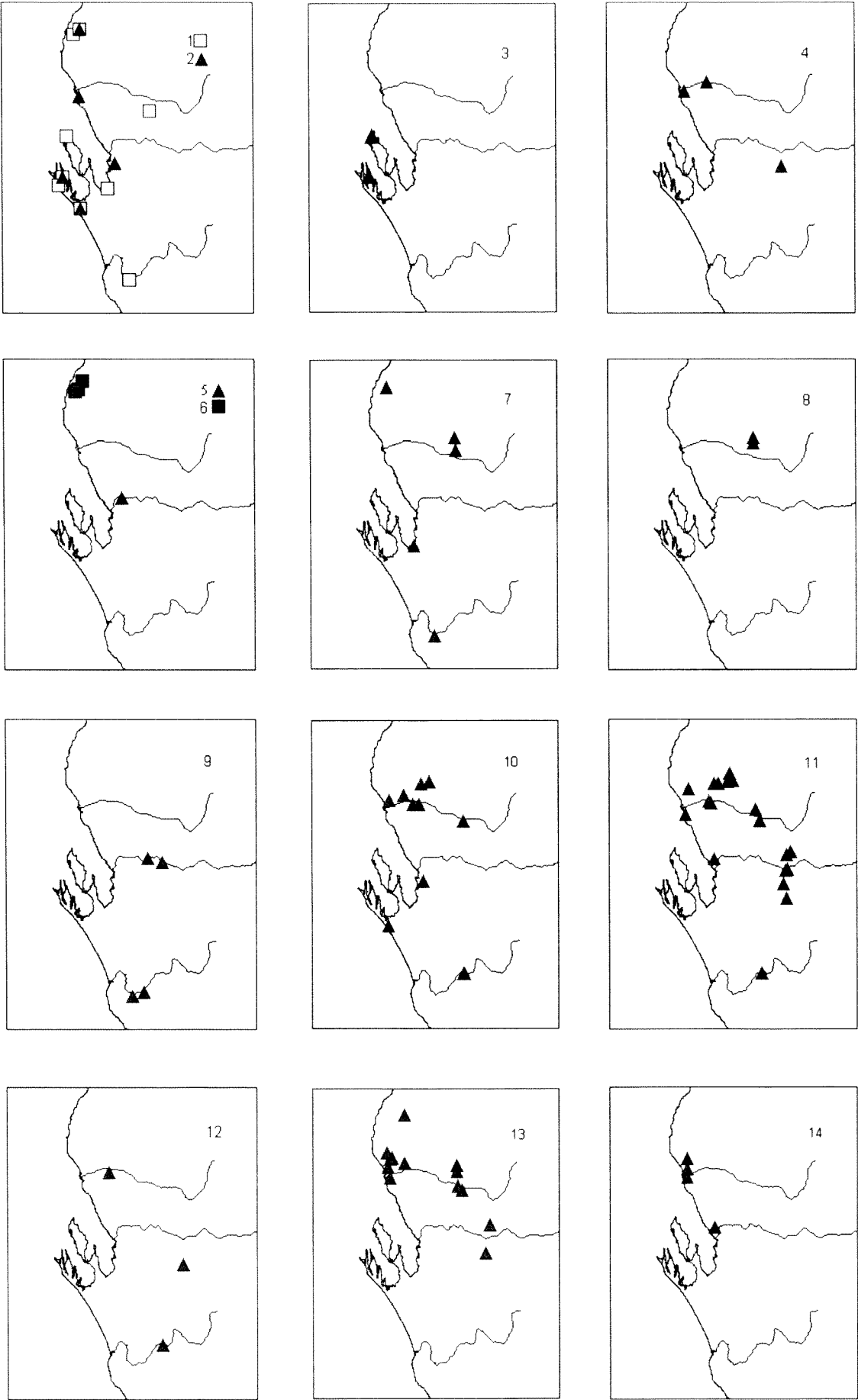


Figure 5 Distribution of the 14 site groups based on individual 1 m² across the southern Carnarvon Basin.

Table 5 Two-way table derived from the UPGMA classification of the 124 wetland quadrats from the southern Carnarvon Basin study area.

QUADRAT IDENTIFIER	SITE GROUPS														SPECIES GROUPS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1797222111372429999	17923	12	24b	33	77777	26647	666	334595	292666554555577	29924999393767766766222663555	22226522	25534669475588b575	355M		
58_6999556860_0_aa	68a56	69	74r	00	66769	022_8	222	44_3_	5_5aab113688855	73374333538520522588777aa6488	7777b877	76682223934422r434	514c		
q_aaa_a_q_q_q			a_o			acq		qqcq	q_22_abbdbc	a_aa_aaad_bbbabbc_ccc11_acc	bbbb_dbb	a_a_a_g_a_oa	a_N		
qq1q_qqq_qq3q2qq3	qqqqq	q	qw	qq	qqqqq	q_1q	qqq	qq22_3	q4q_qqqq	q_q_q_q_qq_q	1212q_12	qq_q_q_qq_qqqw_qq	qqe		
23_5qqq341q43_2_14	32323	2q	qln	12	12131	1qq_1	123	12_q	3_4qq1231qqqqqq	q1qq2q2qqq1qqqqqqq12qqqqq2qqq	2q	q21q2q4q11q212nq23	q11i		
124_2			3	4			21	1	12	112212	2_23_3_121_2311121_13212_321	qqqq_1qq	1_1_3_1_1_2	1_1	
			q								1332_21		q	1	
			2										3		
<i>Actinobole uliginosum</i>										**					a
<i>Calandrinia granulifera</i>										**					
<i>Pentaschistis airoides</i>										***					
<i>Crassula natans</i>			*							*					
<i>Wahlenbergia preissii</i>										*					
<i>Brachyscome iberidifolia</i>										*					
<i>Isoetopsis graminifolia</i>										*					
<i>Calandrinia</i> sp.Coolcalalaya (GJK and NG 698)										*		*			
<i>Pogonolepis muelleriana</i>										*					b
<i>Maireana oppositifolia</i>										*					
<i>Rostraria pumila</i>										*					
<i>Bergia perennis</i> subsp. <i>obtusifolia</i>										*		*			
<i>Calandrinia pumila</i>										*		*			
<i>Goodenia neogoodenia</i>										*		*			
<i>Gnephosis eriocephala</i>										*		*			
<i>Wurmbea murchisoniana</i>										*		*			
<i>Isoetes</i> sp.										*		*			c
<i>Triglochin calcitrapum</i>		*								*		*			
<i>Elatine gratioloides</i>										*		*			
<i>Melaleuca uncinata</i>										*		*			
<i>Peplidium aithocheilum</i>										*		*			
<i>Glossostigma drummondii</i>										*		*			
<i>Peplidium</i> sp. C (Burbidge and Kain 8152)										*		*			
<i>Marsilea angustifolia</i>										*		*			
<i>Asphodelus fistulosus</i>										*		*			
<i>Myriocephalus guerinae</i>										*		*			
<i>Atriplex lindleyi</i>		*								*		*			
<i>Dysphania rhadinostachya</i>										*		*			
<i>Cenchrus ciliaris</i>	*				**					*		*			d
<i>Eragrostis dielsii</i>										*		*		*	
<i>Calotis hispidula</i>										*		*			
<i>Atriplex holocarpa</i>										*		*			
<i>Myriocephalus gascoymensis</i> MS										*		*			
<i>Trichanthodium skirophorum</i>										*		*			
<i>Eragrostis leptocarpa</i>										*		*			
<i>Brachyscome ciliaris</i>										*		*		*	
<i>Lotus cruentus</i>										*		*		*	
<i>Diplachne muelleri</i>										*		*		*	
<i>Eriachne flaccida</i>										*		*		*	
<i>Chenopodium auricomum</i>										*		*		*	
<i>Calotis multicaulis</i>								**		*		*		*	
<i>Cyperus rigidellus</i>										*		*		*	
<i>Goodenia berardiana</i>										*		*		*	
<i>Avicennia marina</i>						****									
<i>Halodule uninervis</i>						**									
<i>Halosarcia pterygosperma</i> subsp. <i>denticulata</i>	**	**	*			**									
<i>Ruppia tuberosa</i>			**												
<i>Eragrostis australasica</i>										*					****
<i>Ruppia</i> sp.															
<i>Typha domingensis</i>							***	*							

	f
<i>Halosarcia pruinosa</i>	***
<i>Heliotropium curassavicum</i>	.
<i>Samolus junceus</i>	. *
<i>Polypogon monspeliensis</i>	*****
<i>Cyperus gymnocaulos</i>	..
<i>Tetragonia cristata</i>	**
<i>Decazesia hecatocephala</i>	..
<i>Phalaris minor</i>	..
<i>Bergia auriculata</i>	
<i>Schoenoplectus lateriflorus</i>	 *
<i>Calandrinia polyandra</i>	* .. *
<i>Cotula cotuloides</i>	. **
<i>Lawrenzia viridigrisea</i>	. *
<i>Samolus repens</i>	..
<i>Neosciadium glochidiatum</i>	
<i>Triglochin mucronatum</i>	. * .
<i>Parapholis incurva</i>	..
<i>Frankenlia pauciflora</i>	*** ..
<i>Halosarcia halocnemoides</i>	.. *****
<i>Muellerolimon salicorniaceum</i>	**** .. *
<i>Sarcocornia quinqueflora</i>	*** . *
<i>Halosarcia indica</i>	** *
<i>Alternanthera nodiflora</i>	
<i>Centipeda sp.</i>	
<i>Cyperus vaginatus</i>	. *
<i>Eleocharis pallens</i>	. *
<i>Goodenia corynocarpa</i>	
<i>Eulalia aurea</i>	.
<i>Myriocephalus nudus</i>	
<i>Sporobolus mitchellii</i>	.
<i>Marsilea drummondii</i>	..
<i>Ranunculus pumilio</i>	..
<i>Helipterum strictum</i>	
<i>Streptoglossa tenuiflora</i>	*
<i>Paractaenum novae-hollandiae</i>	..
<i>Pseudognaphalium luteoalbum</i>	
<i>Ammannia multiflora</i>	.. *
<i>Eriochloa procera</i>	.. *
<i>Emex australis</i>	
<i>Mimulus gracilis</i>	.
<i>Muehlenbeckia cunninghamii</i>	.. *
<i>Stemodia viscosa</i>	
<i>Senecio glossanthus</i>	.
<i>Anagallis arvensis</i>	
<i>Daucus glochidiatus</i>	
<i>Setaria dielsii</i>	.
<i>Cyperus aff. cunninghamii</i> (GJK and NG 592)	..
<i>Wahlenbergia tumidifructa</i>	..
<i>Drosera indica</i>	.
<i>Lipocarpus microcephala</i>	.
<i>Eragrostis basedowii</i>	..
<i>Glossostigma diandrum</i>	..
<i>Isolepis congrua</i>	..
<i>Atriplex semilunaris</i>	.. *
<i>Dysphania glomulifera</i> subsp. <i>eremaea</i>	..
<i>Tecticornia verrucosa</i>	..
<i>Tragus australianus</i>	..
<i>Tetragonia diptera</i>	..
<i>Sclerolaena recurvicauspis</i>	..
<i>Sonchus oleraceus</i>	..
<i>Calandrinia ptychosperma</i>	..
<i>Centaurium spicatum</i>	..
<i>Crassula colorata</i>	..
k	

increasing from 31% in community type 4 to 80% in community type 3. Mean turbidity values increase in the same fashion. Only one wetland in the saline community type 1 has turbidity values approaching those of claypan groups. The high levels of electrical conductivity seen in community type 1 clearly separates it from all other wetland types. Essentially the same pattern was seen for other elements such Ca, Mg, Na, K, Cl, and SO₄. The only other community types with significant but much lower levels of electrical conductivity, Ca, Mg, Na, K, Cl, and SO₄ were the wetlands fed from springs along the western edge of the Kennedy Range (community types 6 and 7).

Fine scale patterning - the quadrat classification

In addition to the floristic analysis of the wetland areas a second analysis was undertaken of the 1 m x 1 m quadrats which sampled the finer scale vegetation pattern. In all, 124 quadrats were established in 55 of the 58 wetland areas. Three of the wetland areas had no shrub or herb layer. Two hundred and thirteen taxa were recorded from these quadrats. Of these 213 taxa, 99 (46%) only occurred in one quadrat; these taxa were excluded from the analysis as discussed above. With these exclusions species richness varied from one to 13 taxa/quadrat with individual taxa represented in between two and 31 quadrats.

Fourteen quadrat groupings (referred to as 'site groups') and 11 species groupings were recognised (Table 5). The data set showed high levels of heterogeneity with few quadrats in many of the site groups and generally low species richness (Table 6). The first division in the classification again separated the *Halosarcia* flats (site groups 1 and 2) from the rest of the data set. The two remaining saline groups, the quadrats containing *Ruppia tuberosa* (site group 3) and the mangrove quadrats (site group 6), totally lack taxa in species group g which are faithful to site groups 1 and 2.

Table 6 Mean species richness of the 14 site groups identified in the analysis of the 124 wetland quadrats.

Site group	Mean species richness	Number of quadrats
1	4.2	19
2	2.2	5
3	1.0	2
4	1.7	3
5	1.5	2
6	1.8	5
7	1.4	5
8	2.0	3
9	3.8	6
10	9.9	15
11	6.6	29
12	4.0	8
13	5.6	18
14	1.3	4

Other species-poor site groups include groups 4, 7, 8, and 9 which are mostly fringing freshwater sedgelands or *Typha* stands, and site group 14, the cane grass swamps (*Eragrostis australasica*). The characteristic taxa of each of these communities are different but all belong to species group f. The other species-poor site group (group 5) occurred on the Wooramel River flats which had been heavily grazed. The sole species recorded in these quadrats was the introduced Buffel Grass (*Cenchrus ciliaris*).

The three remaining site groups are herblands (groups 10, 11, and 12). *Eragrostis dielsii* is the typical species of site group 10. Species groups a, b, d and k are largely confined to this type. Site groups 11 and 12 differ from each other primarily in the proportions of species groups c and h (Table 5). Site group 13 is generally a sedgeland on riverbanks or drainage channels usually dominated by *Cyperus vaginatus*. Taxa in species group h are also well represented in this group.

This fourteen site group classification showed a

Table 7 Comparison of the number of quadrats of the fourteen site groups with a broad habitat classification.

Site group	Birrida (gypsum pan)	Samphire	Spring	River pool	Ephemeral swamp	Claypan
1	14	1	2	2	-	-
2	2	3	-	-	-	-
3	2	-	-	-	-	-
4	-	-	-	2	-	1
5	-	-	-	2	-	-
6	4	1	-	-	-	-
7	-	1	2	2	-	-
8	-	-	-	3	-	-
9	-	-	-	6	-	-
10	1	2	-	-	3	9
11	-	1	-	10	13	5
12	-	-	-	-	6	2
13	-	-	-	11	-	7
14	-	-	-	-	-	4

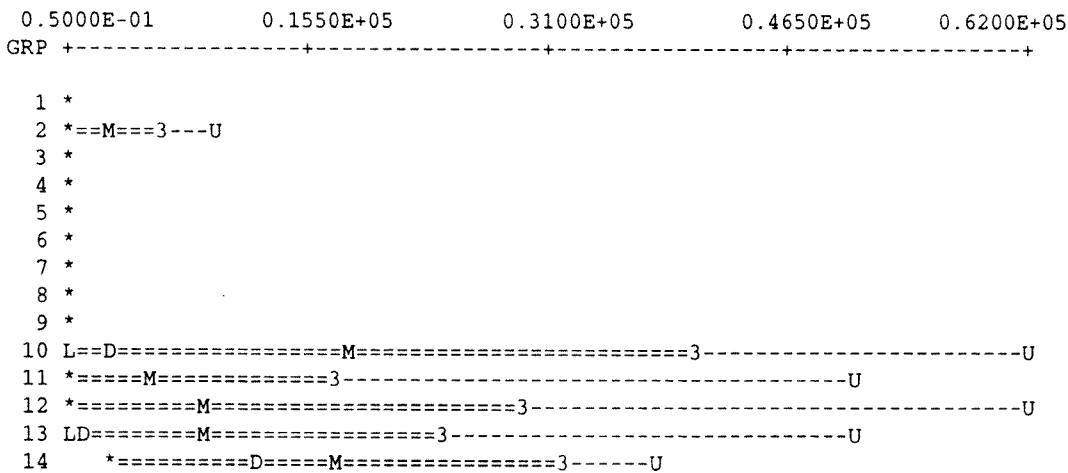
strong correlation with the broad habitat classification, again with the wetlands associated with major stream being the most diverse (Table 7). Turbidity and electrical conductivity of the wet season water body showed significance differences between site type means (Figure 4). The occurrence of claypans in site types 10 – 14 is highlighted by high mean turbidity values, and some of the saline water bodies had slightly elevated turbidity (Figure 6). The water bodies associated with site types 1, 2, 3 and 6 were moderately to highly saline. A lesser saline influence can also be seen in site types 7, 10 and 13.

The highly saline site groups (groups 1, 2, 3 and 6) were largely restricted to the coastal belt except for a quadrat at Salt Creek near Gascoyne Junction (Figure 5). The hyper saline *Ruppia tuberosa* quadrats

of site group 3 were restricted to Shark Bay and the mangrove dominated quadrats (group 6) were restricted to Lake MacLeod. However, as was noted previously, the coastal mangrove communities were not sampled in this survey. Site groups 5, 8, 9, and 14 were found to be quite restricted, with group 8 being restricted to Mooka Springs area, group 9 to the Murchison and Wooramel Rivers and group 14 (cane grass swamps) to the area around Carnarvon (Figure 5). In contrast site groups 10 and 11 were widespread in the study area and group 13 was widespread in the northern half.

Many of the wetland areas had more than one site group present and this concentric zonation of the vegetation around the wetland was an obvious feature of the study area. At five of the 57 wetlands three different site groups were recorded, a further

Turbidity (NTU) Kruskal-Wallis: 45.819, df: 13, Probability < 0.0001



Electrical conductivity (mSm⁻¹) Kruskal-Wallis: 74.103, df: 13, Probability < 0.0001

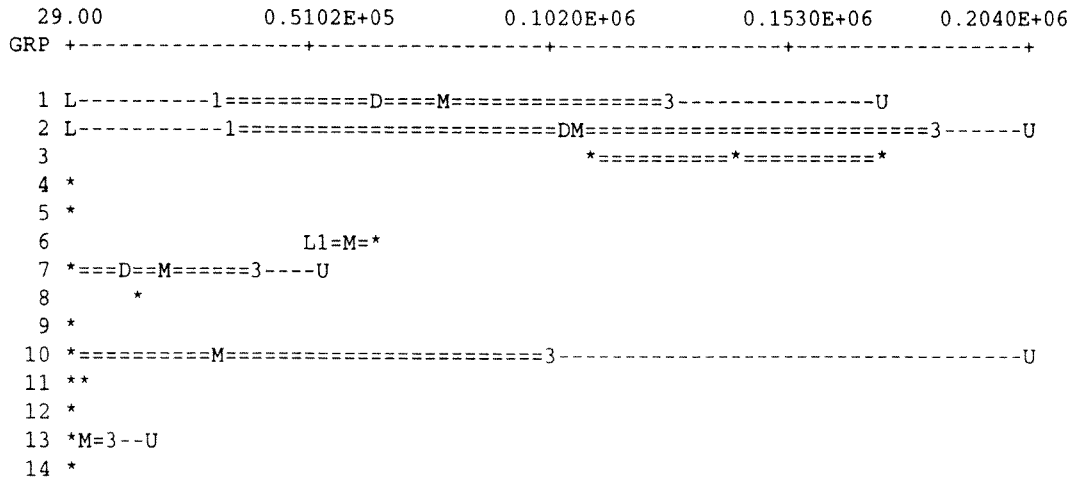


Figure 6 Turbidity (NTU) and electrical conductivity (mSm⁻¹) for the 14 site types. L = lower limit, 1 = Mean – 1 standard deviation, M = mean, D = Median, 3 = Mean + 1 standard deviation, U = upper limit, * = more than one symbol at print position.

19 had two distinct site groups and a single group was recorded from the remaining wetlands.

DISCUSSION

The present survey has improved on the poor state of knowledge of the flora and vegetation of the seasonal and permanent wetlands of the southern Carnarvon Basin. During the course of this work one apparently new species was collected, seven new populations of priority flora were located and major range extensions were recorded for a further 15 taxa (Appendix 1). The flora of the wetlands is largely arid (Jessop, 1985) but with both a significant temperate component (34 taxa reaching their northern range limit) and a significant tropical component (18 taxa reaching their southern limit).

The composition and affinities of the wetlands reported here do not accord with the recently published review of biogeography of freshwater plants, which concentrated almost entirely on wet temperate and tropical regions (Jacobs and Wilson, 1996). Our study area overlaps the northern edge of their south west Western Australian region but the affinities of the freshwater plants (defined in Jacobs and Wilson's study as plants that grow in or near water) in our study are largely with the arid zone (Jessop, 1985) and not with New Zealand. Jacobs and Wilson's (1996) work does indicate the lack of knowledge of the seasonal and permanent wetlands in the arid temperate zone (south of the Tropic) is not restricted to southern Carnarvon Basin but is true across Australia. With an increase in knowledge of the wetland systems of arid areas of both the temperate and tropical zones the very strong division between the tropical and temperate regions reported by them can be expected to break down.

Detailed quadrat-based floristic surveys of the Swan Coastal Plain, the coastal communities of the Warren bioregion (Thackway and Cresswell, 1995), and the Tingle forests of the high rainfall zone have all shown that there is a high proportion of naturally rare species in south west Western Australian ecosystems (Gibson *et al.*, 1994; Gibson and Lyons, unpublished data; Wardell-Johnson and Williams, 1996). In all three studies approximately 25% of total floras (1485 taxa in 509 quadrats; 901 taxa in 301 quadrats; and 857 taxa in 441 quadrats respectively) were only recorded at one site. Data from the present survey shows the same pattern with taxa being recorded at only one site comprising 55% of species at the individual wetland scale (58 wetland areas) and 46% at the 1 m² quadrat scale (124 quadrats). The regional vegetation survey of the southern Carnarvon Basin study area and a detailed study of the sandplain vegetation in the south of the study area show essentially similar trends (Keighery *et al.*, 2000;

Gibson *et al.*, 2000). This rare component of the floras adds significantly to the biodiversity but is not a predictable component of vegetation communities. The conservation status of this component of the flora will continue to be difficult to assess.

The highly variable nature of wetlands in south-west Western Australia has been reported both at the landscape scale (Churchward *et al.*, 1988) and plant and animal community scales (Gibson *et al.*, 1994; Wardell-Johnson and Williams, 1996; Wardell-Johnson and Horwitz, 1996). In the survey of the plant communities of the Swan Coastal Plain the seasonal wetlands were found to comprise 16 of the 30 groups defined (Gibson *et al.*, 1994), while in a study in high rainfall forest areas near Walpole wetlands comprised 22 of the 44 community types defined (Wardell-Johnson and Williams, 1996). The reasons for these high levels of heterogeneity are not clear but appear to result at least in part from differences in substrate and differences in period and depth of inundation. High levels of heterogeneity can be seen from the present study at both scales examined.

It could be argued that part of the reason for heterogeneity at the larger scale could be related to the obvious zonation of the vegetation around many of the wetlands. Vegetation zonation is commonly observed in wetlands across Western Australia (Hopper *et al.*, 1996; Halse *et al.*, 1993). However when sampled at a finer scale the wetland classification still showed a high level of heterogeneity, indicating factors other than zonation are involved.

While some of the community types in the seven group classification generally occur in a particular wetland habitat (e.g. birridas/samphires or claypans/ephemeral swamps), none were restricted to these habitats (Table 4). At the finer scale sampling there is a much stronger correlation between site groups and wetland habitat (Table 7). Even at this scale, however, some site groups are recorded from several wetland habitats. The most diverse wetland habitat was the riverine wetlands reflecting the heterogeneous nature of these areas with variation in substrate composition, texture, slope, degree of disturbance and salinity to which the floristic groups respond.

Examination of the distribution maps of the floristic groupings indicate only moderate biogeographic patterning (Figures 3 and 6). In the seven group wetland classification, the saline community type is generally restricted to the coastal belt but with an outlier near Gascoyne Junction and type 7 is restricted to wetlands at the base of the Kennedy Range south to Wooramel River. The other community types (with the exception of type 3 which are highly disturbed) are widespread across the region, although community type 4 only occurs

in the north of the study area (Figure 3).

At the finer scale of analysis of the 14 site groups, much stronger biogeographic patterning is seen. Eight site groups (groups 1, 2, 3, 5, 6, 8, 9 and 14 – Figure 5) have a restricted distribution, while site groups 10, 11 and 13 are widespread. This increased patterning results from the finer subdivisions possible in the larger dataset.

While most wetlands visited were not obviously impacted by grazing, the use of two springs in the Kennedy Range as cattle yards had resulted in the total removal of the understorey (wetland community type 6). Grazing impacts could also be seen in the claypans and riverine areas of wetland community type 3. These sites were generally dominated by *Asphodelus fistulosus*, a weed indicative of over grazing (Parsons and Cuthbertson, 1992), and were typically quite species poor.

The seasonal and permanent wetlands of the southern Carnarvon Basin have a diverse and poorly known flora. The present study has shown that patterns in species distribution and species richness are similar to those reported for wetlands in higher rainfall area of the southwest, however as in the southwest, the causal factors operating are still poorly understood.

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Appendix 1

List of taxa found in the 57 wetlands in the southern Carnarvon Basin study area, showing aquatic taxa (taxa restricted or almost restricted to aquatic habitats), habitat, the endemic taxa, range ends and geographic limits of the 265 taxa recorded. (Aquatic taxa – EAq emergent aquatic; Aq submerged or floating aquatic. Habitat – EW ephemeral wetlands; HW heavy soil wetlands; R riverine; R/F riverine or fringing; S saline. Range ends – N northern; S southern. * indicates an introduced species).

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	Family: Aizoaceae				
	<i>Gunniopsis septifraga</i>				
	<i>Tetragonia cristata</i>				
	<i>Tetragonia diptera</i>				
EAq	Family: Amaranthaceae				
	<i>Alternanthera nodiflora</i>	EW			
	<i>Hemichroa diandra</i>				
	<i>Ptilotus gaudichaudii</i>				
	<i>Ptilotus macrocephalus</i>				
	<i>Ptilotus murrayi</i>				
	Family: Anthericaceae				
	<i>Dichopogon tyleri</i>		endemic		Shark Bay to Lake McLeod
	Family: Apiaceae				
	<i>Apium annuum</i>				
	<i>Apium prostratum</i>				
	<i>Daucus glochidiatus</i>				
	<i>Neosciadium glochidiatum</i>			N	Dirk Hartog Island
	<i>Trachymene glaucifolia</i>				
	Family: Asphodelaceae				
	* <i>Asphodelus fistulosus</i>				
	Family: Asteraceae				
	<i>Actinobole uliginosum</i>				
	<i>Angianthus tomentosus</i>				
	* <i>Bidens bipinnata</i>				
	<i>Brachyscome ciliaris</i>				
	<i>Brachyscome iberidifolia</i>				
	<i>Calotis hispidula</i>				
	<i>Calotis multicaulis</i>				
	<i>Centipeda cunninghamii</i>	HW		N	Rocky Pool, Gascoyne River
	<i>Centipeda minima</i>	HW		S	Carnarvon
	<i>Centipeda thespidioides</i>	HW		S	Gascoyne River
	<i>Chthonocephalus pseudevax</i>			N	40 km N Gascoyne Junction
	<i>Cotula cotuloides</i>	HW		N	Dirk Hartog Island
	<i>Decazesia hecatocephala</i>			S	93 km N Carnarvon
	<i>Gnephosis arachnoidea</i>				
	<i>Gnephosis brevifolia</i>				
	<i>Gnephosis eriocephala</i>			N	56 km N Carnarvon
	<i>Isoetopsis graminifolia</i>				
	<i>Minuria integerrima</i>				
	<i>Myriocephalus gascoynensis</i> ms		endemic		Carnarvon area
	<i>Myriocephalus guerinae</i>			N	Gascoyne River
	<i>Myriocephalus nudus</i>	HW			
	<i>Myriocephalus pygmaea</i>				
	<i>Pluchea rubelliflora</i>	HW		S	Rocky Pool, Gascoyne River
	<i>Podolepis lessonii</i>				
	<i>Pogonolepis muelleriana</i>				
	<i>Pogonolepis stricta</i>			N	Three Rivers Station, Gascoyne R.
	* <i>Pseudognaphalium luteoalbum</i>				
	<i>Rhodanthe chlorocephala</i> subsp. <i>splendia</i>				
	<i>Rhodanthe margarethae</i>				

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	<i>Rhodanthe stricta</i> <i>Senecio glossanthus</i> * <i>Sonchus oleraceus</i> <i>Streptoglossa tenuiflora</i> <i>Trichanthodium skirrophorum</i> * <i>Urospermum picroides</i>	HW		S	Boolathana
EAq	Family: Avicenniaceae <i>Avicennia marina</i>				
	Family: Boraginaceae <i>Heliotropium curassavicum</i> <i>Plagiobothrys plurisepalus</i>	EW		N	Coolcalalaya
	Family: Brassicaceae * <i>Brassica tournefortii</i> * <i>Coronopus didymus</i> <i>Lepidium oxytrichum</i> <i>Lepidium pseudoruderale</i> <i>Lepidium rotundum</i> <i>Menkea australis</i> <i>Menkea villosula</i> * <i>Sisymbrium erysimoides</i> <i>Stenopetalum pedicellare</i> <i>Stenopetalum sphaerocarpum</i>	EW			
	Family: Caesalpinaceae <i>Senna</i> sp. Austin (A. Strid. 20210)				
Aq	Family: Callitrichaceae * <i>Callitriche stagnalis</i>				
	Family: Campanulaceae <i>Wahlenbergia preissii</i> <i>Wahlenbergia tumidifructa</i>			N	Coolcalalaya
	Family: Caryophyllaceae <i>Gypsophila australis</i> * <i>Polycarpon tetraphyllum</i> * <i>Spergularia rubra</i>				
	Family: Casuarinaceae <i>Casuarina obesa</i>	R/F			
	Family: Centrolepidaceae <i>Centrolepis eremica</i> <i>Centrolepis humillima</i>			N	Wooramel River
	Family: Chenopodiaceae <i>Atriplex holocarpa</i> <i>Atriplex lindleyi</i> subsp. <i>inflata</i> <i>Atriplex paludosa</i> subsp. <i>moquiniana</i> <i>Atriplex semilunaris</i> <i>Atriplex vesicaria</i> <i>Chenopodium auricomum</i> <i>Chenopodium cristatum</i> <i>Dysphania glomulifera</i> subsp. <i>eremaea</i> <i>Dysphania platycarpa</i> <i>Dysphania rhadinostachya</i> <i>Halosarcia halocnemoides</i> <i>Halosarcia indica</i> <i>Halosarcia pruinosa</i> <i>Halosarcia pterygosperma</i> subsp. <i>denticulata</i>	S EW EW S S S S S S S		N N	Lake MacLeod Flats near Gascoyne River

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	<i>Maireana aphylla</i>				
	<i>Maireana oppositifolia</i>			N	Yaringa
	<i>Maireana stipitata</i>			S	Tamala
	<i>Osteocarpum acropterum</i> var. <i>acropterum</i>			N	Boolathana
	<i>Salsola kali</i>				
	<i>Sarcocornia quinqueflora</i>	R/F			
	<i>Sarcocornia</i> sp.				
	<i>Sclerolaena diacantha</i>				
	<i>Sclerolaena recurvicauspis</i>				
	<i>Tecticornia verrucosa</i>	HW			
	<i>Threlkeldia diffusa</i>				
	Family: Clusiaceae				
	<i>Hypericum gramineum</i>				
	<i>Hypericum japonicum</i>				
	Family: Colchicaceae				
	<i>Wurmbea murchisoniana</i>	EW		N	Coolcalalaya
	Family: Crassulaceae				
	<i>Crassula colorata</i>				
	<i>Crassula exserta</i>				
Aq	* <i>Crassula natans</i>				
	<i>Crassula pedicellosa</i>				
	Family: Cymodoceaceae				
	<i>Halodule uninervis</i>	EW			
	Family: Cyperaceae				
EAq	<i>Baumea articulata</i>	R			
	<i>Cyperus</i> aff. <i>cunninghamii</i>				
	<i>Cyperus bifax</i>	R/F;		S	Talisker
	<i>Cyperus gymnocaulos</i>	R			
	* <i>Cyperus hamulosus</i>				
	<i>Cyperus rigidellus</i>	EW			
	<i>Cyperus squarrosus</i>	EW		S	50 km S Carnarvon
	<i>Cyperus vaginatus</i>	R			
EAq	<i>Eleocharis acuta</i>			N	Carnarvon
EAq	<i>Eleocharis geniculata</i>			S	Mooka Creek, range extension
	<i>Eleocharis pallens</i>	EW			
	<i>Isolepis congrua</i>			N	Kennedy Range, Boolathana
	<i>Isolepis cyperoides</i>			N	Coolcalalaya, range extension
	<i>Lipocarpus microcephala</i>				
	<i>Schoenoplectus lateriflorus</i>	EW		S	Cardilya Ck, Carey Downs, range extension
EAq	<i>Schoenoplectus subulatus</i>			S	Murchison River
	<i>Schoenus elegans</i>				
	<i>Schoenus humilis</i>			N	Wooramel River
	Family: Droseraceae				
	<i>Drosera indica</i>	EW			
	Family: Elatinaceae				
	<i>Bergia auriculata</i>	EW			
	<i>Bergia perennis</i> subsp. <i>obtusifolia</i>	EW			Range extension
Aq	<i>Elatine gratioloides</i>	EW			Range extension
	Family: Frankeniaceae				
	<i>Frankenia cinerea</i>				
	<i>Frankenia laxiflora</i>			N	Talisker
	<i>Frankenia pauciflora</i>				
	Family: Gentianaceae				
	<i>Centaurium spicatum</i>				

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	* Family: Geraniaceae <i>Erodium cicutarium</i>				
	Family: Goodeniaceae <i>Goodenia berardiana</i> <i>Goodenia corynocarpa</i> <i>Goodenia maideniana</i> <i>Goodenia neogoodenia</i> <i>Goodenia pinnatifida</i> <i>Velleia hispida</i>				Range extension
	Family: Haloragaceae <i>Haloragis trigonocarpa</i> <i>Myriophyllum decussatum</i>			N	Doorawarrah
	Family: Hypoxidaceae <i>Hypoxis occidentalis</i>			N	Kalbarri
	Family: Isoetaceae <i>Isoetes muelleri</i> <i>Isoetes</i> sp.				
	Family: Juncaceae <i>Juncus aridicola</i> * <i>Juncus bufonius</i> <i>Juncus kraussii</i>			N	Cardilya Creek, Carey Downs
	Family: Juncaginaceae <i>Triglochin calcitrapum</i> <i>Triglochin centrocarpum</i> <i>Triglochin minutissimum</i> <i>Triglochin mucronatum</i>			N N N	Kennedy Range Boolathana Dirk Hartog Island
	Family: Lythraceae <i>Ammannia baccifera</i> <i>Ammannia multiflora</i> <i>Lythrum</i> sp. Towrana (RJC 2183) <i>Rotala diandra</i>		EW	S S S	Wooramel River, range extension Cardilya Creek, Carey Downs, range extension Carnarvon - Gascoyne Junction area Cardilya Creek, Carey Downs, range extension
	Family: Malvaceae <i>Abutilon</i> sp. <i>Lawrencia glomerata</i> <i>Lawrencia viridigrisea</i> * <i>Malva parviflora</i>				
	Family: Marsileaceae <i>Marsilea angustifolia</i> <i>Marsilea drummondii</i> <i>Marsilea</i> sp.	EW EW			
	Family: Mimosaceae <i>Acacia aneura</i>				
	Family: Myoporaceae <i>Eremophila oldfieldii</i> subsp. <i>oldfieldii</i> <i>Myoporum acuminatum</i>				
	Family: Myrtaceae <i>Eucalyptus camaldulensis</i> var. <i>obtusa</i>	R/F			

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	<i>Eucalyptus coolabah</i>	R/F			
	<i>Eucalyptus victrix</i>	R/F			
	<i>Melaleuca glomerata</i>	R/F			
	<i>Melaleuca leucadendra</i>	R/F			
	<i>Melaleuca linophylla</i>	R/F			
	<i>Melaleuca uncinata</i>				
	<i>Verticordia forrestii</i>				
Aq	Family: Najadaceae				
	<i>Najas marina</i>				
	Family: Nyctaginaceae				
	<i>Boerhavia coccinea</i>				
	Family: Ophioglossaceae				
	<i>Ophioglossum lusitanicum</i>				
	Family: Orchidaceae				
	<i>Prasophyllum gracile</i>			N	Tamala
	Family: Papilionaceae				
	<i>Lotus australis</i>				
	<i>Lotus cruentus</i>				
*	<i>Medicago polymorpha</i>				
*	<i>Medicago truncatula</i>				
	<i>Muelleranthus trifoliolatus</i>				
	<i>Rhynchosia minima</i>			S	Cardilya Creek, Carey Downs
	<i>Swainsona pterostylis</i>				
	<i>Swainsona</i> sp.				
	<i>Trigonella suavissima</i>				
	Family: Plantaginaceae				
	<i>Plantago drummondii</i>				
	Family: Plumbaginaceae				
	<i>Muellerolimon salicorniaceum</i>	S			
	Family: Poaceae				
	<i>Agrostis</i> sp.				
*	<i>Aira caryophyllea</i>				
	<i>Aristida holathera</i>				
	<i>Austrostipa trichophylla</i>				
*	<i>Avena barbata</i>				
	<i>Bromus arenarius</i>				
*	<i>Cenchrus ciliaris</i>				
	<i>Diplachne muelleri</i>				
*	<i>Ehrharta longiflora</i>				
	<i>Eragrostis australasica</i>	EW			
	<i>Eragrostis basedowii</i>				
	<i>Eragrostis cumingii</i>				
	<i>Eragrostis dielsii</i>				
	<i>Eragrostis leptocarpa</i>				
	<i>Eragrostis pergracilis</i>				
	<i>Eragrostis tenellula</i>				
	<i>Eragrostis xerophila</i>				
	<i>Eriachne aristidea</i>				
	<i>Eriachne flaccida</i>				
	<i>Eriachne ovata</i>				
	<i>Eriachne pulchella</i>				
	<i>Eriochloa procera</i>			S	Cardilya Creek, Carey Downs
	<i>Eulalia aurea</i>				
*	<i>Hordeum leporinum</i>				
	<i>Iseilema eremaeum</i>			N	Minilya

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	<i>Paractaenum novae-hollandiae</i>				
	* <i>Parapholis incurva</i>			N	Tamala, range extension
	* <i>Pentaschistis airoides</i>				
	* <i>Phalaris minor</i>				
	* <i>Polypogon monspeliensis</i>				
	<i>Psammagrostis wiseana</i>		endemic		Lake MacLeod area
	* <i>Rostraria pumila</i>				
	<i>Setaria dielsii</i>				
	<i>Sporobolus mitchellii</i>				
	<i>Tragus australianus</i>				
	Family: Polygonaceae				
	* <i>Emex australis</i>				
	<i>Muehlenbeckia cunninghamii</i>	EW			
	<i>Rumex crystallinus</i>	EW			Lyndon R. and McNeill Claypan, Gascoyne R. in WA
	* <i>Rumex vesicarius</i>				
	Family: Portulacaceae				
	<i>Calandrinia corrigioloides</i>				
	<i>Calandrinia eremaea</i>				
	<i>Calandrinia granulifera</i>				
	<i>Calandrinia polyandra</i>				
	<i>Calandrinia Ptychosperma</i>				
	<i>Calandrinia pumila</i>				
	<i>Calandrinia</i> sp. Coolcalalaya (GJK and NG 698)	EW	endemic		Coolcalalaya area
	<i>Calandrinia stagnensis</i>				
	<i>Portulaca oleracea</i>				
	Family: Potamogetonaceae				
Aq	<i>Potamogeton pectinatus</i>				
Aq	<i>Ruppia megacarpa</i>				
Aq	<i>Ruppia polycarpa</i>				
Aq	<i>Ruppia tuberosa</i>			N	Shark Bay
	Family: Primulaceae				
	* <i>Anagallis arvensis</i>				
	<i>Samolus junceus</i>				
	<i>Samolus repens</i>				
	Family: Ranunculaceae				
	<i>Ranunculus pumilio</i>			N	Boolathana, range extension
	<i>Ranunculus sessiliflorus</i>			N	Eurardy
	Family: Rubiaceae				
	<i>Oldenlandia galioides</i>	EW		S	Cardilya Creek, Carney Downs, range extension
	<i>Synaptantha tillaeacea</i>				
	Family: Sapindaceae				
	<i>Dodonaea petiolaris</i>				
	Family: Scrophulariaceae				
	<i>Elacholoma hornii</i>				Range extension
	<i>Glossostigma diandrum</i>	EW		N	Kennedy Range
	<i>Glossostigma drummondii</i>	EW		N	Doorawarra
	<i>Mimulus gracilis</i>	EW		S	McNeill claypan, Gascoyne River, range extension
	<i>Peplidium aithocheilum</i>	EW			
	<i>Peplidium muelleri</i>	EW			
	<i>Peplidium</i> sp. C (N.T. Burbidge and A. Kain 8152)	EW			

Aquatics	Taxon	Habitat	Endemics	Range ends	Geographic limits
	<i>Stemodia florulenta</i> <i>Stemodia grossa</i> <i>Stemodia viscosa</i>	EW			
	Family: Solanaceae <i>Nicotiana occidentalis</i> <i>Solanum lasiophyllum</i>				
	Family: Thymelaeaceae <i>Pimelea trichostachya</i>				Range extension
	Family: Tiliaceae <i>Corchorus walcottii</i>				
EAq	Family: Typhaceae <i>Typha domingensis</i>				
	Family: Urticaceae <i>Parietaria debilis</i>				
	Family: Zygophyllaceae <i>Zygophyllum ammophilum</i>				

[^] A recent (August 2000) taxonomic review of the genus *Lythrum* in WA (Lepschi, 2000, *Nutysia* 13: 273–282) has included this taxon in *Lythrum wilsonii* which is widespread across the arid and semi-arid regions of New South Wales, the Northern Territory, Queensland and South Australia.



Plate 1, satellite image of the lower reaches of the Gascoyne River, showing the outflow of sediment after Cyclone Bobby which crossed the Carnarvon Basin in late February 1995. The loss of surface soils is a significant problem in Australian rangelands (DOLA WA, SPOT © CNES (1995) - SPOT Imaging Services, Sydney).



Plate 2, the Gascoyne River has a wide sandy bed lined with river gums. This is typical of Carnarvon Basin rivers, which meander through generally flat landscapes (M. Lochman/Lochman Transparencies).



Plate 3, the eastern slopes of the Kennedy Range, the highest location of the study area (Andrew Burbidge).



4



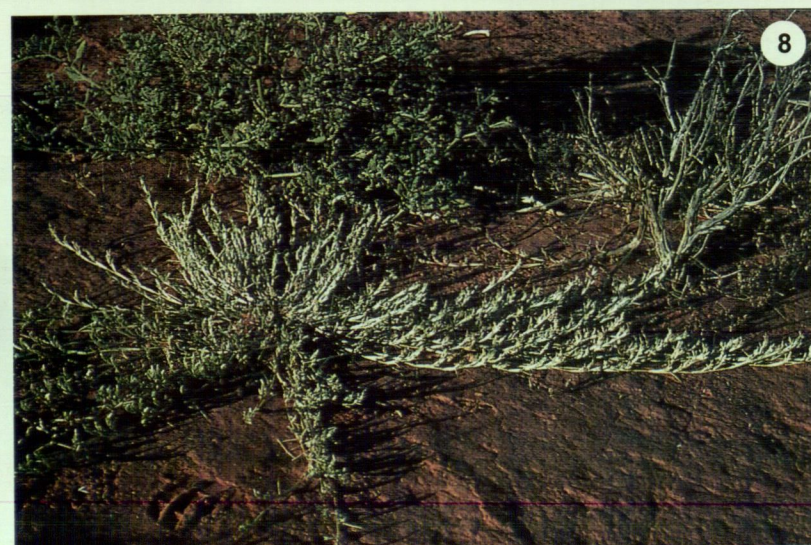
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Plate 4, *Eucalyptus roycei* is a spectacular rare mallee endemic to the tree heath south of Tamala in the Shark Bay World Heritage Area (G. Keighery).

Plate 5, a new subspecies of *Eremophila glabra*, confined to the Zuytdorp cliffs (G. Keighery).

Plate 6, dry claypan dominated by *Calandrinia polyandra* (Parakeelya) at Talisker Station (N. Gibson).

Plate 7, a coastal species, *Pileanthus limacis* is largely confined to the Shark Bay World Heritage Area (N. Gibson).

Plate 8, *Psammogrostis wiseana* is a spreading low annual grass. It is the only genus of plant endemic to the Carnarvon Basin (G. Keighery).

Plate 9, a common tall shrub of coastal sandplains, *Banksia ashbyi* has a disjunct occurrence on the dunefields of the Kennedy Range (Andrew Burbidge).



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Figure 10, *Caleana lyonsii* ms. is a new orchid discovered during the survey on Nerren Nerren Station (G. Keighery).

Figure 11, *Calandrinia* sp. nov. is a new *Parakeelya* discovered during the survey. It is the only member of the genus with yellow flowers (N. Gibson).

Figure 12, coastal heath vegetation on cliffs at Zuytdorp National Park (G. Keighery).

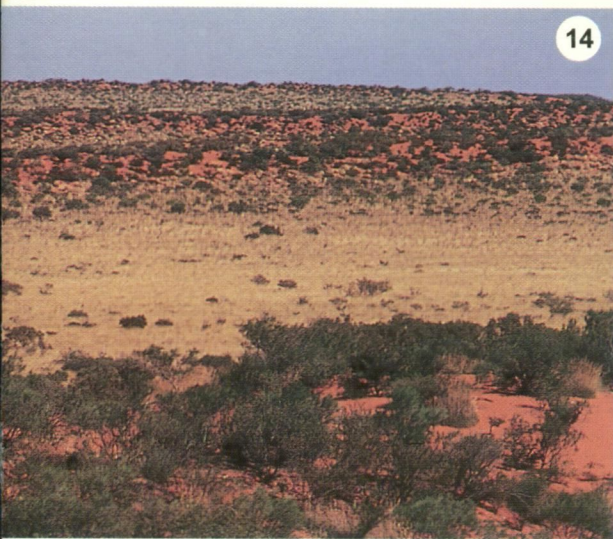
Figure 13, flowering *Cephalopterum drummondii* herbfield on the Yaringa Pastoral Lease (G. Keighery).

Figure 14, a sand dune and swale system dominated by *Triodia basedowii* on Kennedy Range, in the vicinity of KE1 (M. Lochman/Lochman Transparencies).

Figure 15, *Brachycome latisquamea* is a common coastal floriferous shrub confined to the Carnarvon Basin. It normally has purple flowers, but in the Quobba area all flowers are white (G. Keighery).



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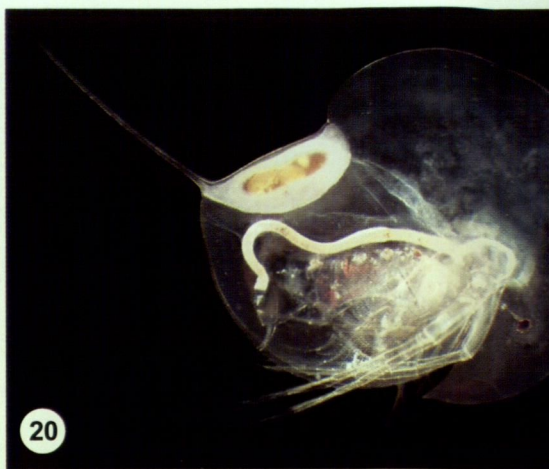
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Plate 16, a coastal birrida (site CB25), representative of Wetland Type I (see p. 565) (S. Halse).

Plate 17, a saline pool with fringing mangroves (site CB25), representative of Wetland type III (see p. 565) (S. Halse).

Plate 18, an inland birrida (site CB25), representative of Wetland Type II (see p. 565) (N. Gibson).

Plate 19, a freshwater claypan on the Murchison River floodplain (site CB6a), wetland type IV (see p. 565) (S. Halse).

Plate 20, *Daphnia cephalata*, a wide-bodied cladoceran was found at several sites (see p. 565) (J. McRae).

Plate 21, *Trigonocypris globulosa*, a filter-feeding ostracod found at one site on the Murchison River (J. McRae).

Plate 22, the nomadic Pink-eared Duck breeds in freshwater wetlands (S. Halse).



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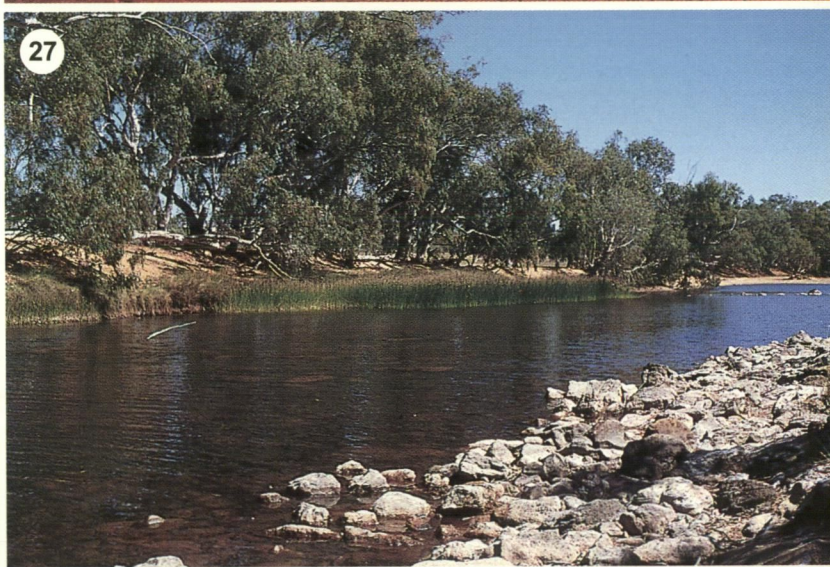
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Plate 23, a nymph of the widespread dragonfly *Hemianax papuensis*, which was common throughout freshwater wetlands of the study area (J. McRae).

Plate 24, *Eretes australis*, a dytiscid beetle that is widespread in wetlands of the northern Australian arid zone (J. McRae).

Plate 25, a stream section wetland (site CB62, Wetland Group V), associated with Mooka Spring, Kennedy Range, in August 1994 (see p. 565); (S. Halse).

Plate 26, Cattle Camp Pan, an ephemeral claypan (site CB75a) belonging to Wetland Group VIII (see p. 565) (S. Halse).

Plate 27, a large river rockpool on the Gascoyne River (site CB42, Wetland Group VI) (see p. 565) (S. Halse).

Plate 28, a small spring under the western slopes of the Kennedy Range used as a cattle yard (site CB67a, Wetland Group VII, see p. 565) (S. Halse).

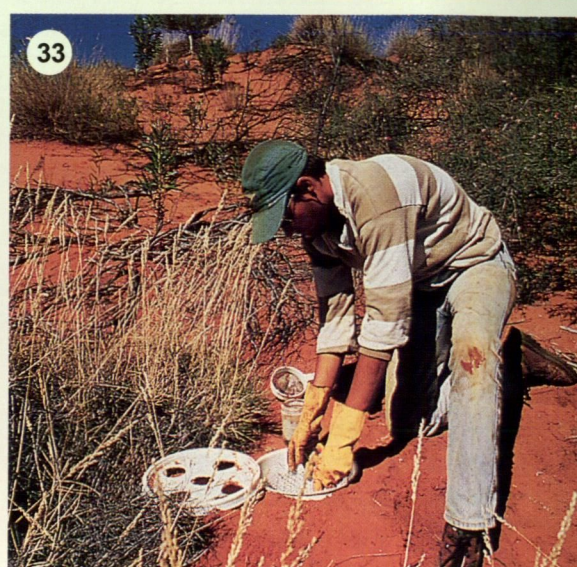
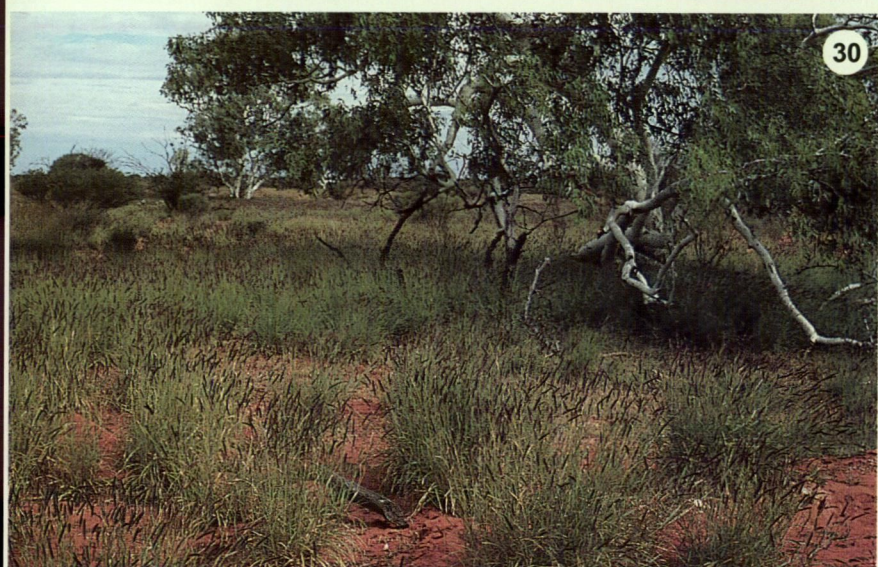


Plate 29, *Acacia* shrubland invaded by the introduced weed Prickly Turnip, *Brassica tournfortii* (G. Keighery).

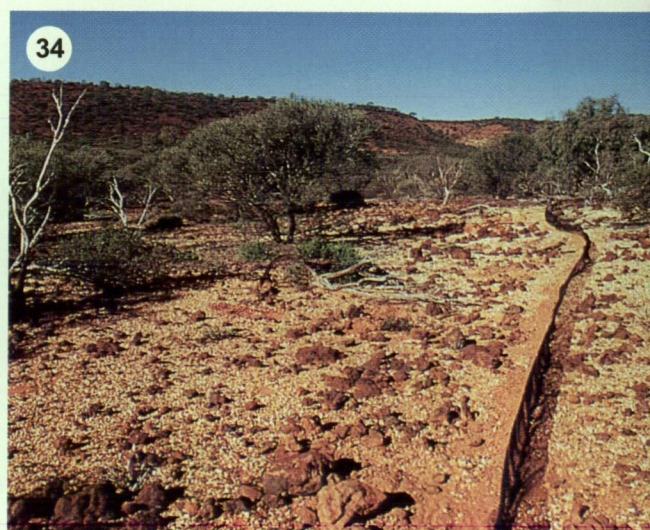
Plate 30, introduced Buffel Grass, *Cenchrus ciliaris*, has spread throughout the Carnarvon Basin, often dominating the ground layer (G. Keighery).

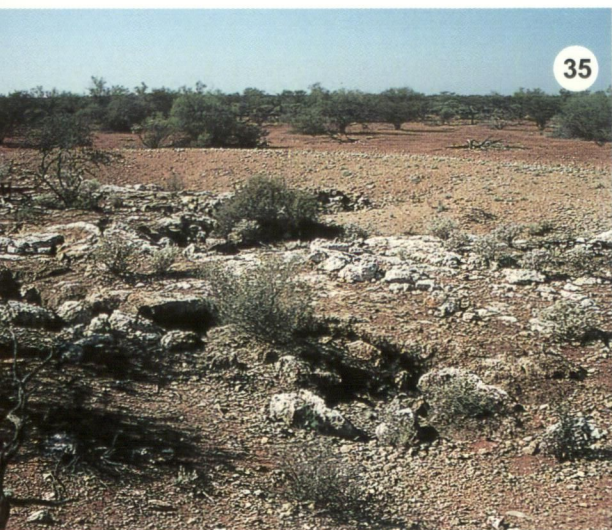
Plate 31, establishing a pit-line at the Pells Range (site GJ1) (Allan Burbidge).

Plate 32, reptiles and other ground-dwelling animals were sampled by hand at every terrestrial quadrat (site KE2) (J. Lochman/Lochman Transparencies).

Plate 33, terrestrial invertebrates were sampled over a 12-month period using 'wet' pitfall traps, such as this one on the Kennedy Range (site KE1) (J. Lochman/Lochman Transparencies).

Plate 34, terrestrial vertebrates were sampled using fenced pitfall traps, such as this line on the Kennedy Range (site KE3) (M. Lochman/Lochman Transparencies).





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Plate 35, abandoned warrens of the Boodie, *Bettongia lesueur*, now extinct on mainland Australia (Andrew Burbidge).

Plate 36, a river pool, Mundilya Pool (site CB34) on the Wooramel River, Meedo Station, at a time when the river was in flood following a summer cyclone (S. Halse).

Plate 37, Callytharra Spring (site CB93c), a permanent spring on the Wooramel River (S. Halse).

Plate 38, remains of a Greater Stick-nest Rat nest, comprising pebbles and charcoal bed, on Cenozoic calcrete surface of Carbla Plateau. *Acacia grasbyi* open shrubland (N. McKenzie).

Plate 39, *Acacia* woodlands on the western slopes of the Kennedy Range (Andrew Burbidge).



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Plate 40, the Long-tailed Dunnart, *Sminthopsis longicaudata*, inhabits rocky surfaces, and was abundant at site KE3, a scree slope of the Kennedy Range (Babs and Bert Wells / CALM).

Plate 41, Lesser Long-eared Bats, *Nyctophilus geoffroyi*, foraged within shrubland and woodland vegetations throughout the Carnarvon Basin (N. Speechley).

Plate 42, Jan's Banded Snake, *Simoselaps bertholdi*. This small banded snake is widespread in the study area (R. Johnstone).

Plate 43, *Dasykaluta rosamondae*, a small active predator in hummock grasslands of the Pilbara and northern Carnarvon Basin (J. Lochman/Lochman Transparencies).

Plate 44, once widespread throughout the southern arid zone, the Thick-billed Grasswren is now confined to a few localities, including the Shark Bay region (Babs and Bert Wells / CALM).



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Plate 45, *Egernia depressa* is a small spiny skink mostly found in hollow trees and logs in arid environments (R. Johnstone).

Plate 46, the gecko *Diplodactylus alboguttatus* occurs from Perth to Cape Cuvier, where it favours sandy coastal to sub-coastal habitats (B. Maryan).

Plate 47, the small, slender, sand-swimming skink, *Lerista humphriesi*, is endemic to the south-western portion of the Victoria Plateau (B. Maryan).

Plate 48, the endemic Western Australian frog *Neobatrachus wilsmorei* inhabits areas subject to seasonal flooding (B. Maryan).

Plate 49, the Sandhill Frog *Arenophryne rotunda* is a small burrowing frog endemic to the coastal sand dunes in the southern portion of the study area (R. Johnstone).

Plate 50, *Ctenotus schomburgkii* is a small predatory skink that forages in litter patches under shrubs and trees (B. Maryan).





Plate 51, the huntsman spider *Pediana tenuis* (Heteropodidae) occurs throughout the semi-arid regions of Western Australia (D. Elford).

Plate 52, the wolf spider *Lycosa bicolor* occurs throughout the arid zone of western Australia, where they construct open-mouthed burrows (B. Maryan).

Plate 53, the scorpion *Urodacus armatus* constructs burrows in sandy soils throughout arid Australia (B. Maryan).

Plate 54, the curtain web spider, *Cethegus* sp. (Dipluridae), constructs curtain-like webs at the bases of trees and shrubs (M. Harvey).

Plate 55, the mygalomorph spider *Gaius villosus* reaches its northern limits in the Carnarvon Basin (B. Maryan).





Plate 56, site ZU3, *Acacia rostellifera* / *Eucalyptus eudesmoides* tall shrubland on ferricrete mantled with deep yellowish and reddish sand of southern Victoria Plateau (N. Gibson).



Plate 57, site ZU4, *Actinostrobus* dominated heath on yellow sand surface of the southern Victoria Plateau (Allan Burbidge).



Plate 59, site NA3, *Eucalyptus eudesmoides* mallees and *Banksia* woodland over shrubs on undulating yellow sandplain, Peron Geomorphological Region (Allan Burbidge).



Plate 60, site ZU1, low heath on yellow sand shallowly mantling calcrete outcrop of Tamala Limestone on seaward margin of Victoria Plateau (N. Gibson).



Plate 58, site NE5, open *Eucalyptus mannensis* over *Acacia* shrubland on undulating yellowish sandplain of Victoria Plateau (Andrew Burbidge).



Plate 61, site WO1, *Acacia ramulosa* shrubland on red sandplain of northern Victoria Plateau (Allan Burbidge).



Plate 64, site BB5, mixed low shrubland on sheet of pale calcareous sand with silt fragments on Holocene supra-tidal plain of Carnarvon Coastal Plain (N. Gibson).



Plate 62, site NA4, mallees (*Eucalyptus eudesmoides* and *E. mannensis*) over shrubs and hummock grass (*Plectrachne bromoides*) on undulating sandplain with a linear bedform, Peron Geomorphological Region (N. Gibson).



Plate 65, site CU6, spinifex grassland on Holocene coastal dune of calcareous sand in the MacLeod Geomorphological Region (N. Gibson).



Plate 63, site EL2, low shrubland with hummock grass on crest of linear dune of brownish calcareous sand in Edel Geomorphological Region (N. Gibson).



Plate 66, site BB1, saltbush on alluvial plain of paleo-Gascoyne delta of Carnarvon Coastal Plain. Red aeolian lunette with *Acacia* and *Hakea* in background (Allan Burbidge).

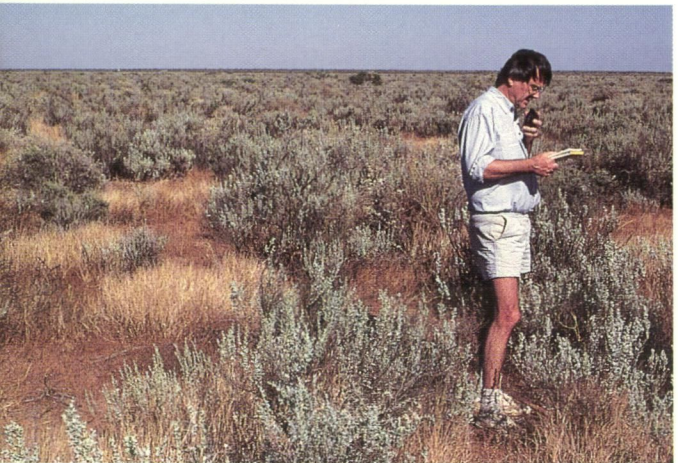


Plate 67, site BO1, Dr Karl-Heinz Wyrwoll standing in a saltbush (*Atriplex*) shrubland on a saline sandy surface over clay of a paleo-tidal flat on the eastern shore of Lake MacLeod in the MacLeod Geomorphological Region (N. McKenzie).



Plate 69, site GJ5, *Acacia tetragonophylla* and river gums on deep alluvial floodplain of Gascoyne River, Carnarvon Coastal Plain (Allan Burbidge).



Plate 70, site BB3, samphire on deep saline supra-tidal flat comprising loam over clay on the Carnarvon Coastal Plain (Allan Burbidge).



Plate 71, site PE1, samphire on elevated evaporite pan (birrida). Mixed gypsum and sand with raised crust, in Peron Geomorphological Region (N. Gibson).

Plate 68, site MD3, river gums and *Acacia* species on fine textured alluvium with patches of deep leaf litter on banks of the Wooramel River, Wooramel Geomorphological Region (N. Gibson).



Plate 72, site KE1, open shrubland including *Banksia ashbyi* and hummock grass on crest of red sand dune, on top of Kennedy Range, Kennedy Geomorphological Region (Andrew Burbidge).

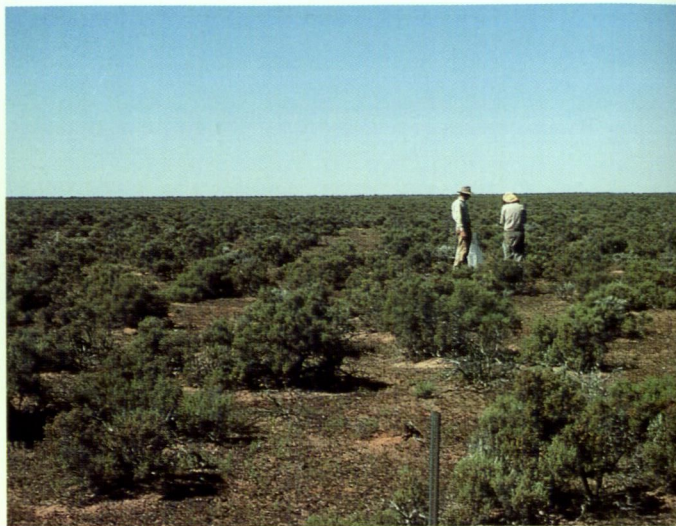


Plate 75, site BO2, samphire on paleo-tidal flat on the western margin of Lake MacLeod in the MacLeod Geomorphological Region. Saline sandy loam over clay (N. Gibson).



Plate 73, site CU3, hummock grass with emergent *Acacia coriacea* on crest of red calcareous sand dune in the MacLeod Geomorphological Region (Allan Burbidge).



Plate 76, site NA1, samphire on a supra-tidal flat of sandy loam over saline clay, Peron Geomorphological Region (N. Gibson).



Plate 74, site PE5, hummock grass with emergent *Acacia* shrubs on calcareous red sand dune, Peron Geomorphological Region (N. McKenzie).



Plate 77, site PE3, *Acacia* shrubland on undulating red calcareous sand sheet deeply mantling Peron Sandstone, Peron Geomorphological Region (Allan Burbidge).



Plate 78, site BO3, low shrubland on yellowish-red calcareous sand with carbonate at depth, on the eastern margin of Lake MacLeod, MacLeod Geomorphological Region (N. McKenzie).



Plate 79, site MD2, *Hakea*, *Eremophila* and *Scaevola* shrubland on the side of a red sandy lunette associated with a large claypan, Wooramel Geomorphological Region (Allan Burbidge).

Plate 82, site GJ4, shrubland, mainly *Acacia tetragonophylla*, *A. victoriae* and *Hakea preissii*, on a gentle, sandy-clay slope with a stony profile and a surface strewn with rocks, Carnarvon Coastal Plain (Allan Burbidge).



Plate 80, site GJ3, *Acacia* woodland on deep sandy alluvium of the Gascoyne River floodplain, Carnarvon Coastal Plain (N. Gibson).



Plate 81, site WO4, *Acacia grasbyi* shrubland on gravelly sand with abundant calcrete fragments, shallowly mantling the Cenozoic calcrete duricrust of the Carbla Plateau (N. Gibson).





Plate 83, site KE4, shrubland (*Acacia* and other species) on Permian siltstone footslopes of the Kennedy Range, with a soil profile comprising stony sand over clay, in the Kennedy Geomorphological Region (N. McKenzie).



Plate 86, site CU4, hummock grassland (*Triodia basedowii*) with *Acacia* shrubs on calcareous red sandy soils shallowly overlaying calcrete. Floor of an interdune corridor in the MacLeod Geomorphological Region (N. McKenzie).

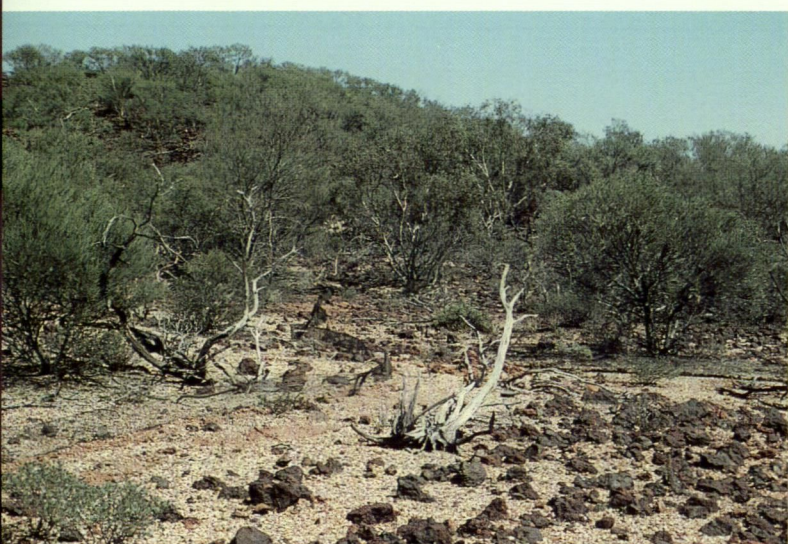


Plate 84, site KE3, scattered *Eucalyptus striatocalyx* over *Acacia* shrubs on a steep Permian siltstone hillslope of the Kennedy Range, Kennedy Geomorphological Region. The slope is shallowly mantled by tallus and alluvium (Andrew Burbidge).



Plate 87, site MR2, open mulga (*Acacia aneura*) woodland over hummock grassland (*Plectrachne rigidissima*) on red sandy interdune corridor, Mardathuna Geomorphological Region (Allan Burbidge).



Plate 85, site KE5, mulga (*Acacia aneura*) woodland on a red sandy plain overlying Cretaceous sandstone of the Kennedy Geomorphological Region (Andrew Burbidge).



Plate 88, site KE2, scattered *Eucalyptus lenziana* over hummock grassland (*Plectrachne schinzii*) on red sandy interdune floor deeply mantling sandstone basement on top of Kennedy Range, Kennedy Geomorphological Region. Linear sandridge in background (N. McKenzie).