Vegetation surveys near Lake MacLeod

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Abstract

Tyler, J. P. Vegetation surveys near Lake MacLeod. Kingia 1(1): 49-74 (1987). The vegetation adjacent to Lake MacLeod was assessed and documented from 1980-1984. A total of 269 flora species were collected from the area and are currently housed in the Dampier Salt Research Laboratory at Dampier.

The dynamics of the vegetation were assessed using permanent quadrats in four vegetatively distinct areas. For convenience of study, the vegetation was classified in three categories, namely herbs, shrubs less than 1 metre high, and shrubs greater than 1 metre high. The herbs exhibited a distinct annual pattern, with peak numbers of individuals and species occurring in early spring. The number of small shrub species fluctuated with rainfall regardless of the season. Large shrubs exhibited very slow growth rates and few recruitments or deaths.

The impact of grazing animals was assessed using exclosed and unexclosed areas. No significant grazing pressure was found. The Lake MacLeod shrublands were found to regenerate very slowly if degraded by fire. This is due to the inherently slow growth rates of the shrub species.

Introduction

Lake MacLeod is a 2000 km^2 natural coastal salina some 40 km north of Carnarvon. It is separated from the Indian Ocean to the south by a thirty metre high ridge of white sand dunes called the Bejaling Dunes. These are around 2 km wide. To the west of Lake MacLeod lies the Quobba Ridge, a barrier separating Lake MacLeod from the Indian Ocean. The red sand dunes of the Quobba Ridge run parallel to the coast and merge with the Bejaling Dunes. The dunes of the Quobba Ridge overlie limestone which is frequently exposed as rocky outcrops.

Lake MacLeod is in an arid region with an average rainfall of around 200 millimetres per year. It occurs in the major soil zone called desert-steppe. These soils show no characteristic profile due to an absence of leaching and high wind action, and are red to reddish-brown in colour (Prescott 1952). The scrub with associated saltbush, typical of these soils, is in evidence near Lake MacLeod.

There are few published accounts on the vegetation near Lake MacLeod and the area has not been extensively surveyed. This study concerns itself with the vegetation of the Quobba Ridge and the Bejaling Dunes. Both of these areas lie within the Quobba Station pastoral lease and are used as grazing land for sheep. The area also contains feral goats, rabbits and kangaroos.

The purpose of the study is to document the vegetation and floristics, and to assess the impact of grazing animals.

Materials and Methods

1. Vegetation classification

The vegetation was classified into three categories for convenience of study.

These were as follows:

(a) Shrubs greater than one metre high

These were well established shrubs and trees.

(b) Shrubs less than one metre high

These were distinctly woody plants less than one metre high. This category included a number of species such as *Stemodia grossa*, *Solanum lasiophyllum* and *Acanthocarpus preissii* which even when well established did not reach one metre in height. It also included woody annuals such as *Ptilotus* and *Olearia* and the seedlings of all the larger shrubs.

(c) Herbs

This category included all annual species with soft non-woody stems and all the grasses.

2. Permanent Quadrats

Three permanent quadrats were established in visually-assessed distinctive vegetation zones on the Quobba Ridge. A fourth was established in the Bejaling Dunes (Figure 1). The 20 m x 20 m permanent quadrats were pegged in July 1980 using surveyors pegs and marking tape.

Quadrat 1 Environs

Quadrat 1 was located on the Quobba Ridge, adjacent to the old salt haulage road previously used by Dampier Salt (Operations) Pty Ltd. This road was no longer in use and the area was remote from salt field activities. The quadrat was situated in an area of dense *Acacia* scrub. There were no sheep in the area due to a lack of drinking water, although goats and kangaroos had been sighted. The red sandy soils had a pH around 6.9.

Quadrat 2 Environs

Quadrat 2 was located in the Bejaling Dunes. The vegetation was mainly salt bush (*Atriplex* and *Rhagodia* spp.) interspersed with *Acacia* spp., *Banksia ashbyi* and *Thryptomene baeckeacea*. The white sandy soils were alkaline with a mean pH of 8.0. Sheep, feral goats and rabbits were present in the Bejaling Dunes.

Quadrat 3 Environs

Quadrat 3 was situated on the Quobba Ridge, north of the present salt haulage road from the Lake MacLeod mine site to Cape Cuvier. Like quadrat 1, some twenty kilometres to the north, it had neutral soils of pH 7.0. The vegetation was open *Acacia* scrub and *Triodia* grassland. A bore about a kilometre from the quadrat provided water for sheep and feral goats, which were plentiful in the area.

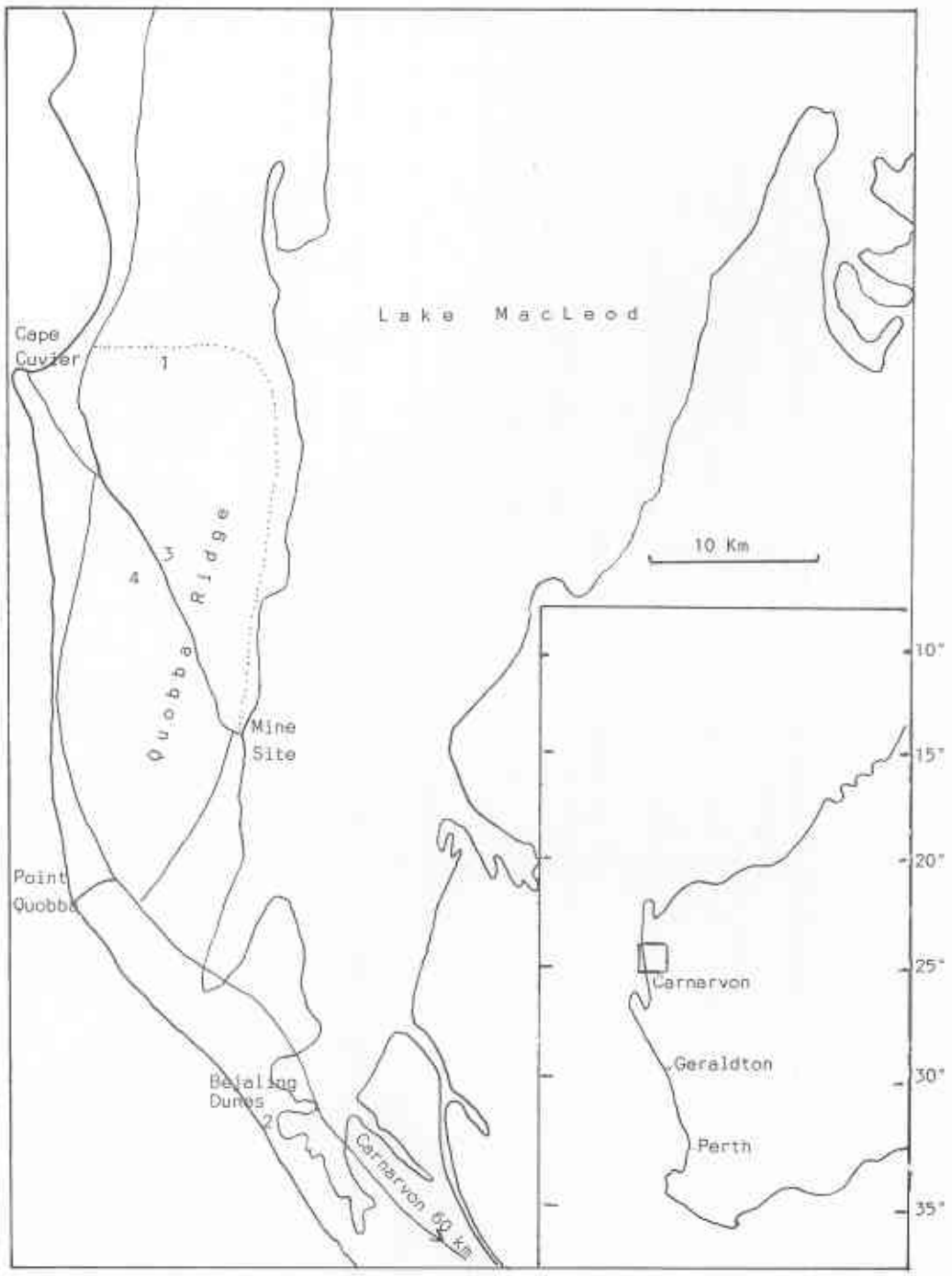


Figure 1. Locality map showing study areas.

Table 1. Rainfall Readings at Lake MacLeod Meteorological Station

(a) Monthly means from 1968-1982 (mm)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
13.0	11.6	21.0	10.1	24.7	43.7	44.7	13.9	5.2	5.1	3.75	0.68

(b) Average yearly rainfall (mm)

1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Mean
78.1	—	273.3	175.6	147.7	339.8	331.8	198.3	130.4	223.4	67.5	249.8	176.5	181.2	198

(c) Total monthly rainfall (mm) during study period

1980						1981											
July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
14.1	15.0	1.3	9.1	0	0	4.0	14.7	18.4	0	34.5	42.1	24.2	17.2	18.8	0.6	0.4	1.6

1982									
Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
93.8	8.1	23.8	0	13.3	23.1	0	10.3	7.3	1.2

Table 2. Number and change in number of shrub species greater than 1 m high recorded in 20 x 20 m permanent quadrats from 1980 to 1982.

	Quadrat 1			Quadrat 2			Quadrat 3			Quadrat 4		
	1980	1982	Changes	1980	1982	Changes	1980	1982	Changes	1980	1982	Changes
Acacia coriacea					2	2	0					
Acacia ligulata				9	7	−2	3	4	+1			
Acacia sclerosperma	1	1	0									
Acacia tetragonophylla	8	9	+1	3	5	+2				1	1	0
Atriplex cinerea				1	2	+1						
Banksia ashbyi				1	1	0						
Corchorus walcottii							2	4	+2			
Dodonaea amblyophylla							3	2	Merged			
Exocarpos aphyllus				1	2	+1	3	3	0			
Grevillea wickhamii	2	4	+2									
Heterodendrum oleaefolium	3	3	0				1	2	+1			
Pimelea microcephala				2	2	+1, −1	1	1	0			
Rhagodia baccata	1	1	0	0	1	+1						
Santalum lanceolatum				1	3	+2						
Scaevola crassifolia				2	2	0						
Scaevola spinescens	16	15	−2, +1	3	3	0						
Scaevola tomentosa	0	1	+1	0	1	+1	5	5	−1, +1			
Stylobasium spathulatum				5	4	−1						
Thryptomene baeckeacea	1	1	0									
Total No. Shrubs	32	35	+3	30	35	+5	18	21	+3	1	1	0
Total No. Species	7	8	+1	11	13	+2	7	7	0	1	1	0

Quadrat 4 Environs

Quadrat 4 was situated less than fifty metres from quadrat 3, but on the southern side of the salt haulage road. A fire in 1979 only burnt the area south of the haul road. The soil and vegetation type were similar to those of quadrat 3, but with far fewer shrubs. A number of plant species common on the north side of the road in a good season, had not been sighted in the previously burnt area. These included *Thysanotus speckii*, *Dichopogon* sp. and *Dianella revoluta*.

The following information was recorded once monthly for 26 months.

(a) The area covered by shrubs greater than one metre in height was mapped onto graph paper. The positioning of the shrubs and their sizes were obtained by pacing. The maps illustrate recruitment and death of shrubs.

(b) A list of all shrubs species less than one metre high in the quadrat was compiled.

(c) All herb species present in the quadrat were listed.

3. Exclosure Experiments

One chicken wire exclosure 3 m x 3 m x 1 m was established in each survey area adjacent to the 20 m x 20 m permanent quadrat. Unexclosed control quadrats were pegged adjacent to the exclosures. A once monthly survey of all quadrats was undertaken. The area covered by shrubs greater than one metre high was mapped. Shrub species less than one metre high and herb species were listed and quantified.

4. Flora List

A list of all flowering plants present on the Quobba Ridge and the Bejaling Dunes was compiled over four years from 1980 to 1984. Plants were mainly collected on the monthly quadrat survey, but extra surveys were undertaken following any period of heavy rain. Occasional specimens were collected on daily journeys to and from the salt field. A habit photograph of most species was taken and pressed specimens of each species are housed in the company herbarium. Specimens were identified using published keys, with doubtful identifications being verified at the Western Australian Herbarium (PERTH). All plant species are listed in Appendix 1. Nomenclature follows Green (1985).

Table 3. Presence of shrubs greater than 1 m high over the whole study period (1980-1982) and similarity of the four permanent quadrats based on species presence.

	Quadrat			
	1	2	3	4
Chenopodiaceae				
Atriplex aff. *cinerea*		+		
Rhagodia baccata	+	+	+	
Goodeniaceae				
Scaevola crassifolia		+		
Scaevola spinescens	+	+		
Scaevola tomentosa	+	+	+	
Mimosaceae				
Acacia coriacea		+		
Acacia ligulata		+	+	
Acacia sclerosperma	+			
Acacia tetragonophylla	+	+	+	+
Myrtaceae				
Thryptomene baeckeacea	+			

Table 3 (continued). Presence of shrubs greater than 1 m high over the whole study period (1980-1982) and similarity of the four permanent quadrats based on species presence.

	Quadrat 1	2	3	4
Proteaceae				
Banksia ashbyi		+		
Grevillea wickhamii	+			
Santalaceae				
Exocarpos aphyllus		+	+	
Santalum lanceolatum		+		
Sapindaceae				
Dodonaea amblyophylla			+	
Heterodendrum oleaefolium	+		+	
Solanaceae				
Solanum orbiculatum			+	
Surianaceae				
Stylobasium spathulatum		+		
Tiliaceae				
Corchorus walcottii			+	
Thymelaeaceae				
Pimelea microcephala		+	+	
Total Number Per Quadrat:	8	13	10	1

All species with the exception of *Rhagodia baccata* and *Scaevola tomentosa* in Quadrat 2 were present in the quadrats for the whole of the study period.

$$\text{Similarity index} = \frac{\text{Number in common}}{\text{total number in both}} \times 2 \times 100$$

The maximum possible similarity between two samples is 100%

Quadrat 1/Quadrat 2 = 38.1% Quadrat 2/Quadrat 3 = 52.2%
Quadrat 1/Quadrat 3 = 44.4% Quadrat 2/Quadrat 4 = 14.3%
Quadrat 1/Quadrat 4 = 22.2% Quadrat 3/Quadrat 4 = 18.2%

Table 4. Presence of shrubs less than 1 m high over the whole study period (1980-1982) and similarity of the four permanent quadrats based on species presence.

	Quadrat 1	2	3	4
Amaranthaceae				
Ptilotus obovatus	+	+	+	+
Ptilotus villosiflorus		+		
Ptilotus sp. 1 (J.P.T. 133 Dampier)	+			
Ptilotus sp. 2 (J.P.T. 134 Dampier)	+			
Asteraceae				
Olearia imbricata				+
Boraginaceae				
Halgania preissiana			+	
Caesalpiniaceae				
Cassia oligophylla		+	+	
Chenopodiaceae				
Chenopodium desertorum		+		+
Einadia nutans		+		
Enchylaena tomentosa	C8m	C9m	C12m	
Maireana tomentosa	+			
Rhagodia baccata	+	+	+	+
Salsola kali		+		

Table 4 (continued). Presence of shrubs less than 1 m high over the whole study period (1980-1982) and similarity of the four permanent quadrats based on species presence.

	Quadrat 1	2	3	4
Dasypogonaceae				
Acanthocarpus preissii	C13m	C+	+	
Euphorbiaceae				
Euphorbia atoto	+			
Goodeniaceae				
Dampiera incana	+	+		C
Scaevola crassifolia		+		
Scaevola restiacea				+
Scaevola spinescens	+	+		
Scaevola tomentosa	+	+	+	+
Scaevola sp. (J.P.T. 235 Dampier)			+	
Loranthaceae				
Amyema sp. (J.P.T. 157 Dampier)		+		
Malvaceae				
Abutilon geranioides			+	
Hibiscus drummondii				C
Mimosaceae				
Acacia coriacea		+		
Acacia ligulata		+	+	+
Acacia tetragonophylla	+	+	+	
Myrtaceae				
Thryptomene baeckeacea	+	C	+	+
Phormiaceae				
Dianella revoluta		+	+	
Proteaceae				
Grevillea wickhamii		+		
Hakea stenophylla				+
Santalaceae				
Exocarpos aphyllus		+	+	+
Santalum lanceolatum		+		
Sapindaceae				
Diplopeltis eriocarpa				+
Dodonaea amblyophylla			+	+
Heterodendrum oleaefolium			+	
Scrophulariaceae				
Stemodia grossa	+	C15m		
Solanaceae				
Solanum lasiophyllum			C9m	C9m
Solanum orbiculatum			C6m	+
Surianaceae				
Stylobasium spathulatum		+	+	
Thymelaeaceae				
Pimelea microcephala	+	+	+	+
Tiliaceae				
Corchorus elachocarpus	+	C7m	+	+
Corchorus walcottii	+		C	C
Total Number per Quadrat	19	24	22	21

Species designated C were present in the quadrat continuously since the beginning of the study.

Species designated Cxm were present continuously for the final x months of the study.

$$\text{Similarity index} = \frac{\text{Number in common}}{\text{total number in both}} \times 2 \times 100$$

The maximum possible similarity between two samples is 100%

Quadrat 1/Quadrat 2 = 55.8%	Quadrat 2/Quadrat 3 = 56.5%
Quadrat 1/Quadrat 3 = 53.7%	Quadrat 2/Quadrat 4 = 48.9%
Quadrat 1/Quadrat 4 = 50.0%	Quadrat 3/Quadrat 4 = 69.8%

Table 5. Presence of herbs over the whole study period (1980-1982) and similarity of the four permanent quadrats based on species presence.

	Quadrat 1	2	3	4
Aizoaceae				
Disphyma crassifolium		+		
Anthericaceae				
Dichopogon sp. (J.P.T. 98 Dampier)			+	
Apiaceae				
Trachymene pilosa			+	+
Asteraceae				
Angianthus cunninghamii				+
Brachycome iberidifolia	+	+	+	
Brachycome latisquamea	+	+	+	+
Calocephalus brownii		+		
Gnephosis gynotricha			+	+
Helipterum humboldtianum		+		
Podotheca angustifolia		+		
Senecio lautus		+	+	
Sonchus oleraceus			+	
Waitzia acuminata	+			+
Boraginaceae				
Heliotropium paniculatum				+
Brassicaceae				
Sisymbrium irio			+	
Campanulaceae				
Wahlenbergia gracilis		+		
Chenopodiaceae				
Dysphania plantaginella			+	+
Euphorbiaceae				
Euphorbia drummondii		+	+	+
Gentianaceae				
Centaurium tenuiflorum			+	
Geraniaceae				
Erodium cygnorum	+		+	
Goodeniaceae				
Goodenia berardiana	+			
Lauraceae				
Cassytha aurea	+			
Lobeliaceae				
Lobelia heterophylla	+		+	+

Table 5 (continued). Presence of herbs over the whole study period (1980-1982) and similarity of the four permanent quadrats based on species presence.

	Quadrat 1	2	3	4
Papilionaceae				
Glycine clandestina	+			
Glycine tabacina		+		+
Indigofera georgei		+		+
Lotus australis		+		
Swainsona kingii		+		
Poaceae				
Aristida contorta		+	+	+
Cenchrus ciliaris		+	+	+
Eragrostis australasica	+	+		
Eragrostis eriopoda	+		+	+
Eragrostis japonica	+	+	+	+
Eulalia fulva			+	+
Sorghum plumosum	+	+	+	
Triodia basedowii	+		+	+
Triodia pungens	+		+	+
Triodia sp.		+		
Triraphis sp. (J.P.T. 109 Dampier)		+		+
Portulacaceae				
Calandrinia polyandra	+	+	+	
Solanaceae				
Nicotiana simulans		+	+	+
Stackhousiaceae				
Stackhousia sp. 1 (J.P.T. 159 Dampier)		+		
Zygophyllaceae				
Zygophyllum fruticulosum		+	+	+
Total Number per Quadrat	14	24	24	22

$$\text{Similarity index} = \frac{\text{Number in common}}{\text{total number in both}} \times 2 \times 100$$

The maximum possible similarity between two samples is 100%

Quadrat 1/Quadrat 2 = 26.3% Quadrat 2/Quadrat 3 = 45.8%
Quadrat 1/Quadrat 3 = 47.4% Quadrat 2/Quadrat 4 = 47.8%
Quadrat 1/Quadrat 4 = 38.9% Quadrat 3/Quadrat 4 = 69.6%

Table 6. Changes in number of shrubs less than 1 m high in exclosed and unexclosed quadrats from spring, 1983 to summer, 1984.

(a) Site 1

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Acanthocarpus preissii	1	1	1	1
Corchorus walcottii	1	0	0	0
Ptilotus sp. (J.P.T. 133 Dampier)	23	11	0	0
Unknown sp.	1	1	1 (dying)	1
New emergent	1	0	0	0
Total	27	14	2	2

(b) Site 2

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Enchylaena tomentosa	1	5	dying	dying (clump
Rhagodia baccata	0	¾ cover of quadrat	0	¾ cover of quadrat
Salsola kali	1	3	0	3
Stemodia grossa	9	4	3	3
Total (excluding *Rhagodia*)	11	12	5	6

(c) Site 3

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Enchylaena tomentosa	1	0	2	2
Ptilotus obovatus	3	2	0	0
Rhagodia baccata	3	0	1	1
Scaevola tomentosa	1	1	0	0
Stemodia grossa	1 (large clump)	0	1 (large clump)	0
Total	9	3	4	3

(d) Site 4

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Acacia ligulata	0	1	0	0
Corchorus elachocarpus	0	1	0	1
Dampiera incana	4	9	6	8
Diplopeltis eriocarpa	1	1	1	1
Melaleuca cardiophylla	1	0	2	0
Scaevola restiacea	0	2	0	1
Solanum lasiophyllum	3	0	2	0
Unknowns	3	0	2	0
Total	12	14	11	11

Table 7. Changes in number of herbs in exclosed and unexclosed quadrats from spring, 1983 to summer, 1984.

(a) Site 1

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Calandrinia polyandra	43	32	0	0
Goodenia berardiana	1	0	0	0
Gnephosis gynotricha	2	11	0	0
Lobelia heterophylla	11	4	0	0
Sonchus oleraceus	0	1	0	0
Triodia pungens	8	6	9	5
Total	65	54	9	5

(b) Site 2

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Calandrinia polyandra	17	7	0	0
Calocephalus brownii	90	60	0	0
Eragrostis japonica	Sparse covering	Sparse covering	0	0
Ptilotus villosiflorus	15	4	0	0
Total (excluding *Eragrostis*)	122	71	0	0

(c) Site 3

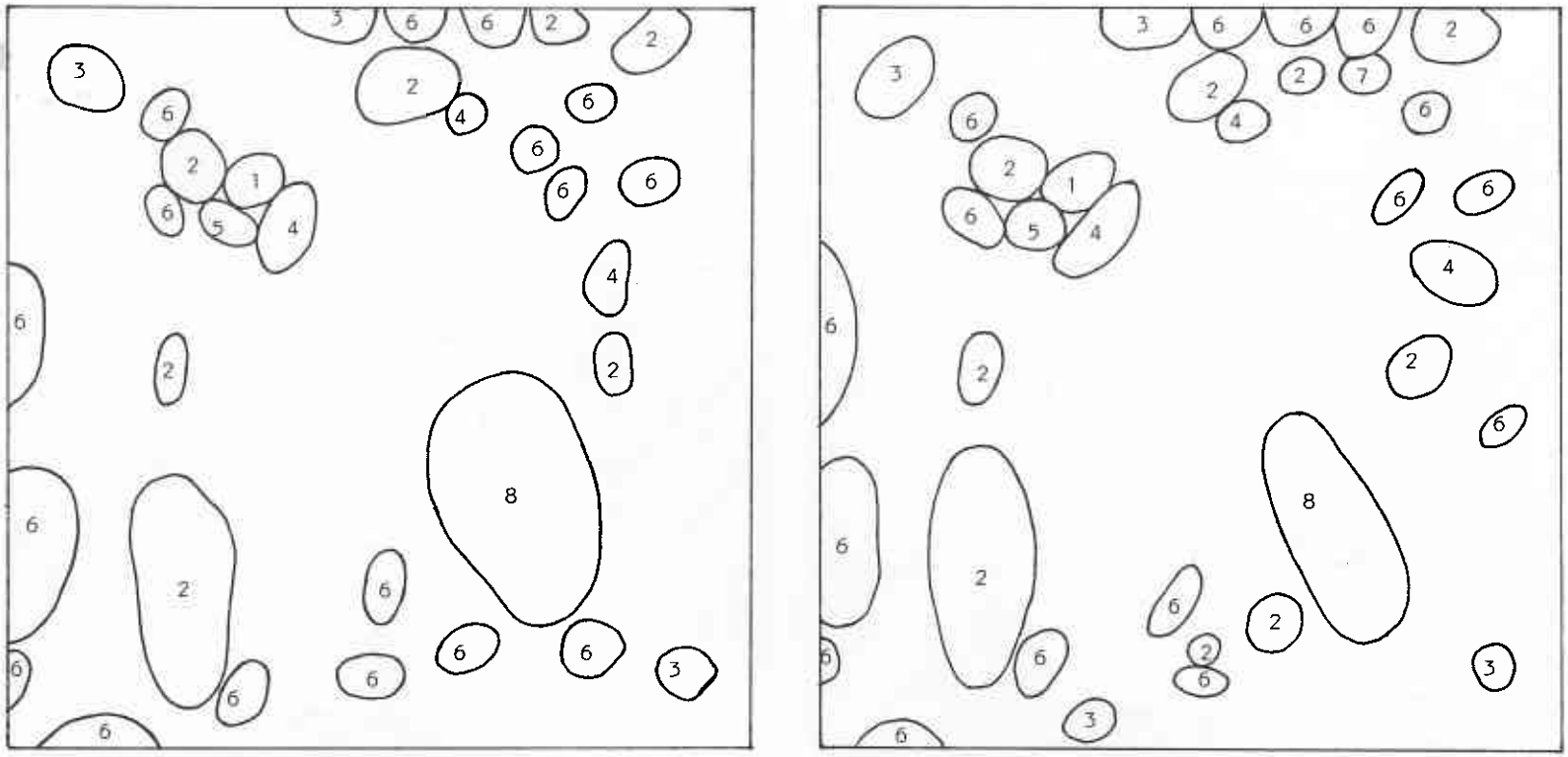
Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Brachycome latisquamea	9	4	0	0
Cenchrus ciliaris	80% cover	20% cover	dying	absent
Gnephosis gynotricha	5	0	0	0
Nicotiana simulans	3	0	0	0
Sonchus oleraceus	0	1	0	0
Sorghum plumosum	0	7	0	0
Triodia pungens	4	4	0	0
Triodia wiseana	0	0	8	10
Zygophyllum fruticulosum	0	3	0	0
Total (excepting *Cenchrus*)	12	19	8	10

(d) Site 4

Species	06.09.83 Exclosed	06.09.83 Unexclosed	15.02.84 Exclosed	15.02.84 Unexclosed
Eragrostis eriopoda	0	4	0	0
Euphorbia drummondii	0	4	0	0
Gnephosis gynotricha	11	3	0	0
Indigofera georgei	4	1	0	0
Lobelia heterophylla	1	1	0	0
Triodia pungens	3	0	5	0
Triodia wiseana	23	25	35	30
Zygophyllum fruticulosum	1	1	0	0
Total	43	39	40	30

Results and Discussion

Quadrat 1 was situated in an area of dense *Acacia* scrub. Grazing pressure in this area was very low due to a lack of nearby drinking water. Low grazing pressure was confirmed by the exclosure experiment which showed no obvious changes in the vegetation of the unexclosed plot without corresponding changes within the exclosure (Tables 6 and 7). The species diversity of the large shrubs within Quadrat 1 increased by 1 during the study period, and the number of individual shrubs increased by 3 (Table 2). There was no appreciable change in the area covered by any of the large shrubs, illustrating very slow growth rates (Figure 2).

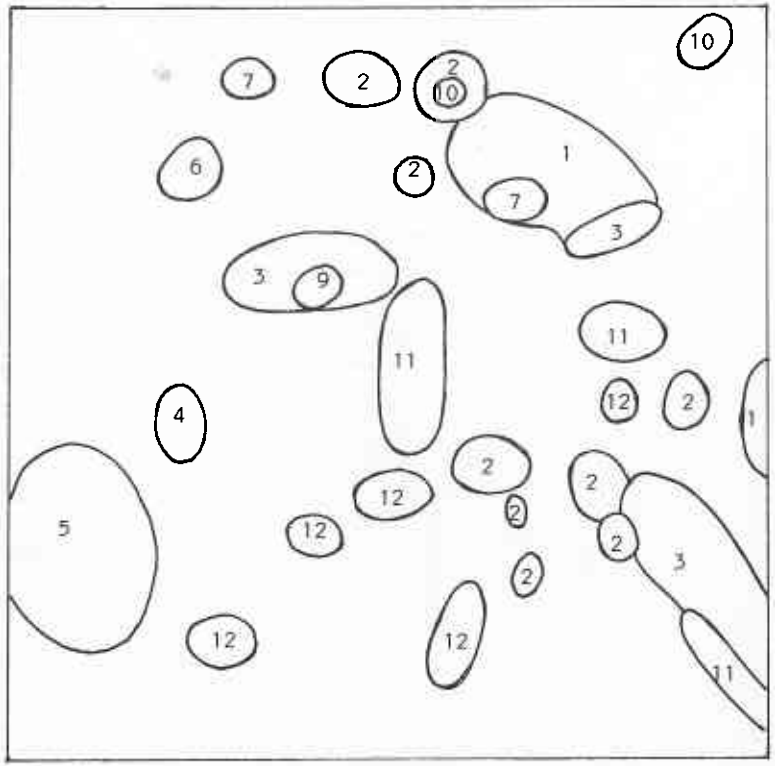


August 1980

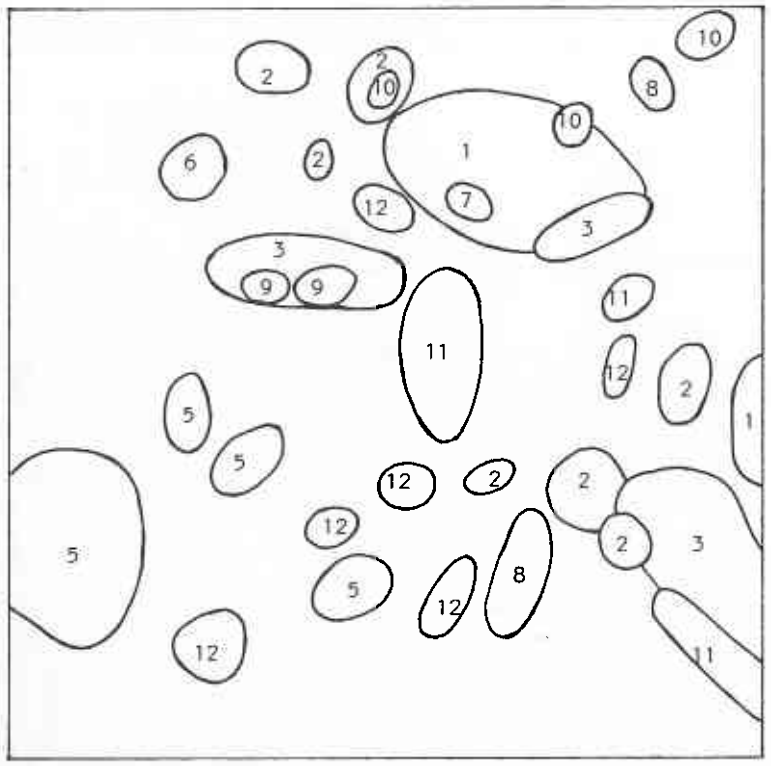
October 1982

1 *Acacia sclerosperma*
2 *Acacia tetragonophylla*
3 *Grevillea wickhamii*
4 *Heterodendrum oleaefolium*
5 *Rhagodia baccata*
6 *Scaevola spinescens*
7 *Scaevola tomentosa*
8 *Thryptomene baeckeacea*

Figure 2. Location and size of shrubs greater than 1m high in permanent quadrat 1 during August, 1980 and October, 1982.



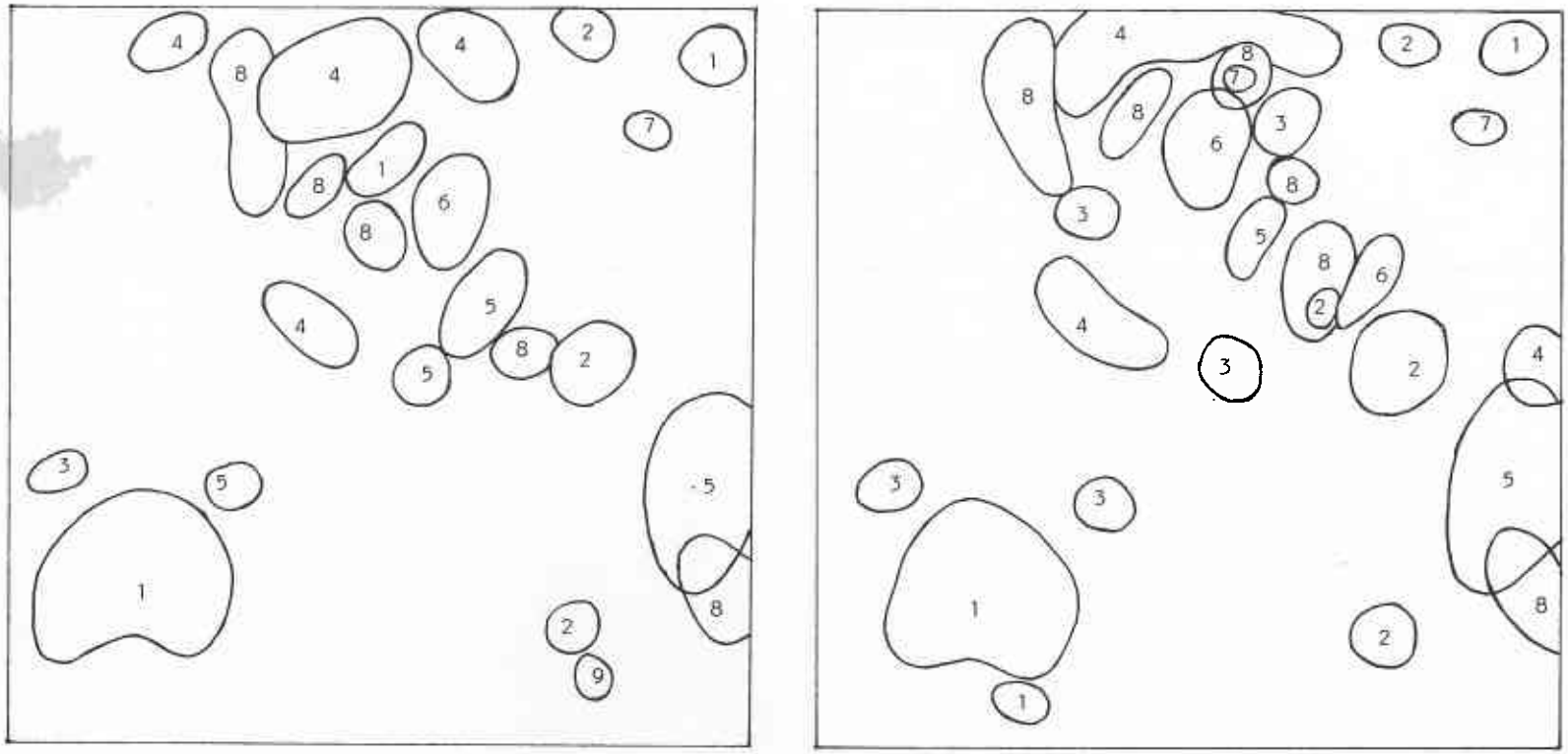
August 1980



October 1982

1 *Acacia coriacea*
2 *Acacia ligulata*
3 *Acacia tetragonophylla*
4 *Atriplex cinerea*
5 *Banksia ashbyi*
6 *Exocarpos aphyllus*
7 *Pimelea microcephala*
8 *Rhagodia baccata*
9 *Santalum lanceolatum*
10 *Scaevola crassifolia*
11 *Scaevola spinescens*
12 *Stylobasium spathulatum*

Figure 3. Location and size of shrubs greater than 1m high in permanent quadrat 2 during August, 1980 and October, 1982.

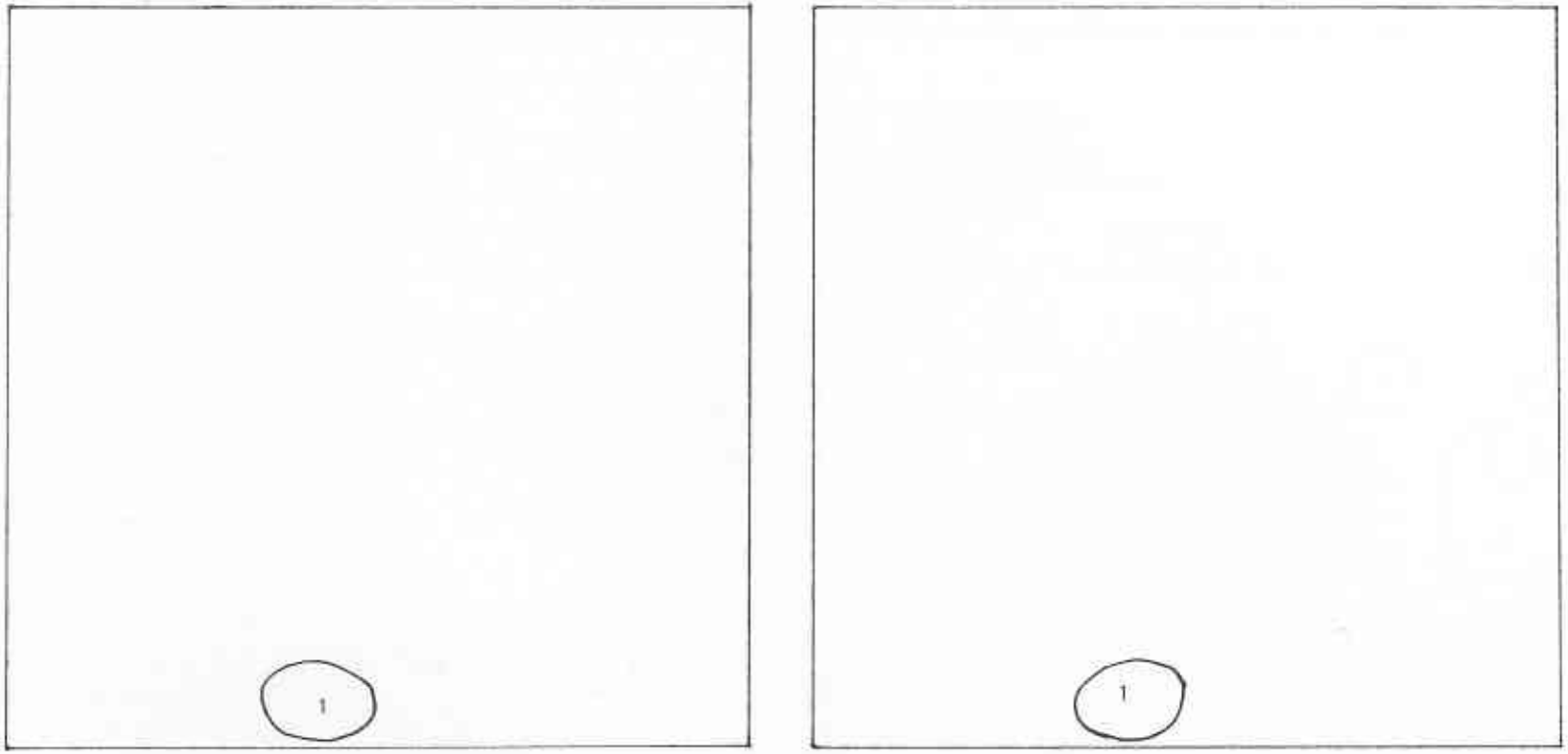


August 1980

October 1982

1 *Acacia ligulata*
2 *Acacia tetragonophylla*
3 *Corchorus walcottii*
4 *Dodonaea amblyophylla*
5 *Exocarpos aphyllus*
6 *Heterodendrum oleaefolium*
7 *Pimelea microcephala*
8 *Scaevola tomentosa*
9 *Solanum orbiculatum*

Figure 4. Location and size of shrubs greater than 1m high in permanent quadrat 3 during August, 1980 and October, 1982.



August 1980 October 1982

1 *Acacia tetragonophylla*

Figure 5. Location and size of shrubs greater than 1m high in permanent quadrat 4 during August, 1980 and October, 1982.

Quadrat 2 was situated in the Bejaling Dunes. Sheep, goats and kangaroos were all seen near the quadrat during the study, but grazing pressure remained low. With the exception of a sheep trail through the unexclosed plot near Quadrat 2, there was no obvious influence of grazing animals on the vegetation. Changes within the unexclosed plot paralleled those within the exclosure (Tables 6 and 7). Five individual shrubs were recruited into the large shrub category in Quadrat 2 over the study period (Table 2). These included *Scaevola tomentosa* and *Rhagodia baccata,* species which were not previously present in the large shrub category. The growth rates of large shrubs in the Bejaling Dunes were slow (Figure 3).

Quadrat 3 was subjected to intermittent grazing pressure due to the proximity of water. This grazing pressure affected the herbaceous plants, such as *Cenchrus ciliaris* but not the shrubs (Tables 6 and 7). All the *Cenchrus ciliaris* within the unexclosed plot disappeared within three months, while the floor of the exclosure had an 80% covering of this species. There was no evidence of grazing pressure on shrubs over the study period, and an additional three individual large shrubs became established within Quadrat 3 (Table 2). Quadrant 3 also demonstrated very slow growth rates for large shrubs (Figure 4).

Quadrat 4 was situated less than 50 metres from Quadrat 3, but on the other side of the road. A fire in 1979 had destroyed all but one of the large shrubs in this area. There was no recruitment of large shrubs within this quadrat during the study period despite the presence of seedlings of many of the larger shrub species, e.g. *Acacia ligulata, Pimelea microcephala, Dodonaea amblyophylla* and *Exocarpos aphyllus* (Tables 2 and 4). The area was 70% similar to Quadrat 3 in the category of shrubs less than 1 metre high. The slow rate of recovery can be considered a function of the slow growth rates of the shrubs (Figure 5). The only evidence of grazing in this area was on soft spinifex (*Triodia pungens*) (Table 7). This was completely absent from the unexclosed plot but there were five plants within the exclosure.

The number of shrub species less than 1 metre high fluctuated broadly with rainfall regardless of the seasons (Table 1, Figures 6 and 7). Some of the plants were woody annuals such as *Olearia* and *Ptilotus* which would germinate, flower and set seed very quickly following rain, and then die off in the drier weather. The majority of the perennial small shrub species that were present continuously in the quadrats were represented by individuals that were well established from the start. These included *Acanthocarpus preissii* and *Thryptomene baeckeacea* in Quadrat 2; *Corchorus walcottii* in Quadrat 3; and *Acanthocarpus preissii, Corchorus walcottii, Dampiera incana* and *Hibiscus drummondii* in Quadrat 4. As only the presence and absence of species was noted, it is not possible to ascertain whether any new individuals of these species became established during the study period. A number of other perennial shrubs species were present continuously for six months or more at the end of the study. These included *Acanthocarpus preissii* in Quadrat 1; *Enchylaena tomentosa* in Quadrats 1, 2 and 3; *Corchorus elachocarpus* in Quadrat 2; *Solanum lasiophyllum* in Quadrats 3 and 4; *Solanum orbiculatum* in Quadrat 3; and *Stemodia grossa* in Quadrat 2.

The number of herb species in the permanent quadrats fluctuated seasonally with maximum numbers occurring around September (Figures 6 and 7). About 25% of the herb species were composites and most of these, presumably for similar reasons to those found by Mott (1972), would only germinate and flower during winter. About 25% of the herb species were grasses. These would germinate at any time of the year following rain. They were the major component of the summer herb population following rain and, with the composites, formed the major component of the winter population of herbs. Unlike the Murchison area examined by Mott (1972), there was no obvious winter dormancy exhibited by the grasses. One possible reason was the higher winter temperatures of the area around Lake MacLeod. Most of the remaining species were also winter annuals.

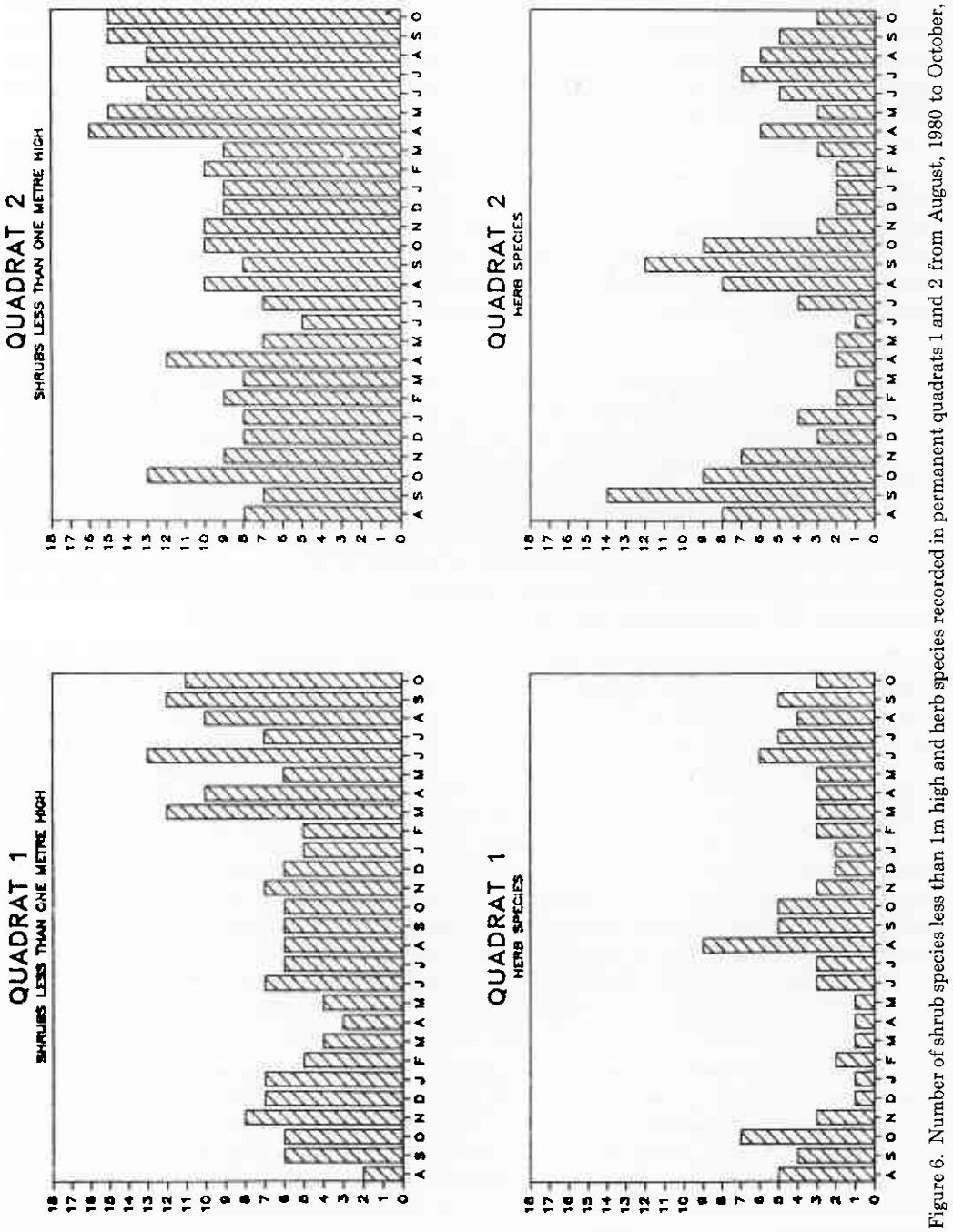


Figure 6. Number of shrub species less than 1m high and herb species recorded in permanent quadrats 1 and 2 from August, 1980 to October, 1982.

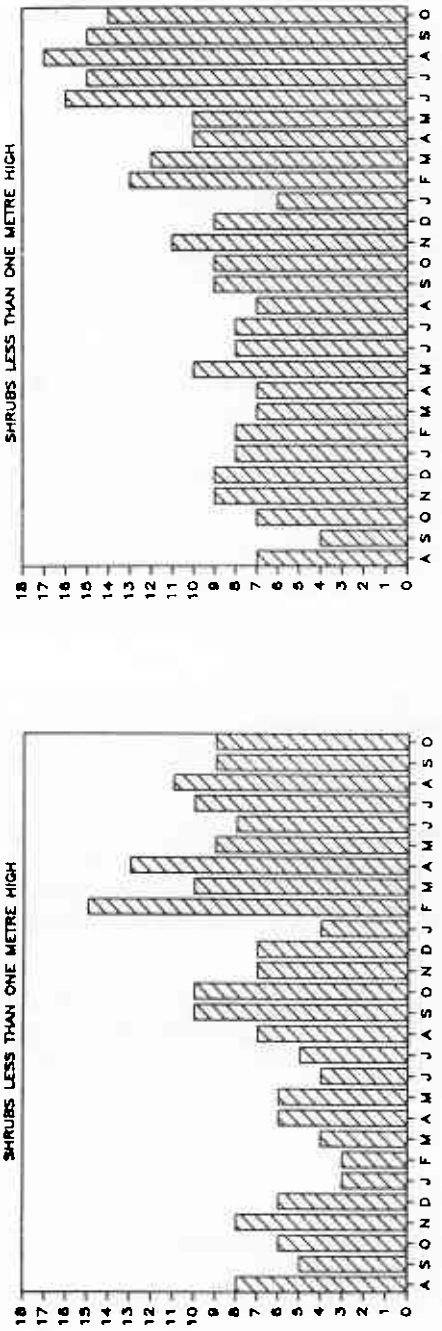


Figure 7. Number of shrub species less than 1m high and herb species recorded in permanent quadrats 3 and 4 from August, 1980 to October, 1982.

One exception was *Lobelia heterophylla* which would germinate and flower between September and December each year. Another exception was *Zygophyllum fruticulosum* which would quickly appear following uniform light rain, and was often the only herb species present in the quadrats during dry summer periods.

The lower than normal number of herb species in the 1982 winter period was probably due to the exceptionally dry weather. July had no rain at all and all other months had rainfall below the monthly average (Table 1). The minimum water requirement for the germination of many of the winter annuals did not seem to have been reached.

A comparison of species similarity between quadrats is included in Tables 3, 4 and 5. The highest similarity in both the small shrub and herb categories occurred between Quadrats 3 and 4 which had about 70% similarity in both these categories. This is to be expected as the quadrats were very close to one another geographically and shared similar soils. These quadrats, however, show a low similarity with respect to large shrubs because of a recent fire at the site of Quadrat 4.

Over one third of all small shrub species (8) occurred in all four quadrats at some stage during the study, although very few of these became established (Table 4). These shrubs largely accounted for the 50% similarity obtained between all quadrats in this vegetation category with the exception of Quadrats 3 and 4. The similarity indices for the large shrub category, with the exception of Quadrats 2 and 3 which also had around 50% similar, tended to be lower than for the small shrub category.

The herb category exhibited the greatest variation in similarity indices, with geographical separation apparently playing a major role. Quadrats 3 and 4 were adjacent and had a similarity index of 69.6% whilst the widely separated Quadrats 1 and 2 were only 26.3% similar.

A large number of species in all vegetation categories were present in Quadrat 2 but were not found in any other quadrat. This is possibly a function of the alkaline, white sandy soils in Quadrat 2 which were of more recent origin than the reddish neutral soils of Quadrats 1, 3 and 4 on the Quobba Ridge.

In general undisturbed *Acacia* shrublands are stable areas and only slightly susceptible to erosion. Once this type of vegetation is degraded it is slow to recover, and serious erosion can occur (Condon 1972). Very little regeneration has occurred in western New South Wales where large areas of mulga (*Acacia aneura*) have died due to overgrazing, coupled with tree lopping during drought.

This study demonstrated that the Lake MacLeod shrublands regenerate very slowly if degraded by fire. This is due to the inherently slow growth rates of the shrub species. There was no evidence of overgrazing in the study areas but recovery rates are likely to be slow if this should occur.

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Appendix 1. Tentative list of plant species

* denotes introduced species

Aizoaceae
* *Carpobrotus aequilaterus* (Haw.) N.E.Br.
* *Mesembryanthemum crystallinum* L.

Amaranthaceae
Alternanthera sp.
Amaranthus pallidiflorus F. Muell.
Ptilotus alexandri Benl
Ptilotus exaltatus Nees
Ptilotus obovatus (Gaudich.) F. Muell.
Ptilotus spathulatus (R.Br.) Poiret
Ptilotus villosiflorus F. Muell.
Ptilotus sp. 1 (J.P.T. 133 Dampier)
Ptilotus sp. 2 (J.P.T. 134 Dampier)

Anthericaceae
Dichopogon tyleri N.H. Brittan
Murchisonia volubilus N.H. Brittan
Thysanotus speckii N.H. Brittan

Apiaceae
Daucus glochidiatus (Labill.) Fisher, C. Meyer & Ave-Lall.
Trachymene pilosa Smith

Asclepiadacae
Sarcostemma australe R.Br.

Asphodelaceae
**Asphodelus fistulosus* L.

Asteraceae
Angianthus cunninghamii (DC.) Benth.
**Aster subulatus* Michaux
Asteridea aff. *athrixioides* (Sonder & F. Muell.) G. Kroner
Brachycome iberidifolia Benth.
Brachycome latisquamea F. Muell.
Brachycome sp. (J.P.T. 240, 245 Dampier)
Calocephalus angianthoides (Steetz) Benth.
Calocephalus brownii (Cass.) F. Muell.
Calotis aff. *multicaulis* (Turcz.) Druce
Cephalipterum drummondii A. Gray
Chthonocephalus pseudevax Steetz
Craspedia sp. (J.P.T. 277 Dampier)
Gnephosis brevifolia (A. Gray) Benth.
Gnephosis gynotricha Diels
Helipterum corymbosum (A. Gray) Benth.
Helipterum humboldtianum (Gaudich.) DC.
Helipterum hyalospermum F. Muell. ex Benth.
Helipterum involucratum (F. Muell.) Benth.
Helipterum strictum (Lindley) Benth.
Helipterum splendidum Hemsley
Helipterum sp. (J.P.T. 263 Dampier)
Lagenifera huegelii Benth.
Millotia myosotidifolia (Benth.) Steetz
Olearia axillaris (DC.) F. Muell. ex Benth.
Olearia imbricata (Turcz.) Benth.
Olearia sp. (J.P.T. 219 Dampier)
Pluchea squarrosa Benth.
Podolepis auriculata DC.
Podolepis canescens Cunn. ex DC.
Podolepis gardneri G. Davis
Podolepis lessonii (Cass.) Benth.
Podolepis sp. (J.P.T. 87 Dampier)
Podotheca angustifolia (Labill.) Less.
Podotheca pygmaea A. Gray
Schoenia cassiniana (Gaudich) Steetz
Senecio glossanthus (Sonder) Belcher
Senecio lautus G. Forster ex Willd. subsp. *maritimus* Ali
Senecio lautus G. Forster ex Willd. subsp. *dissectifolius* Ali

Sonchus oleraceus L.
Streptoglossa liatroides (Turcz.) C.R. Dunlop
Waitzia acuminata Steetz
Waitzia sp. 1 (J.P.T. 130 Dampier)
Waitzia sp. 2 (J.P.T. 297 Dampier)

Avicenniaceae
Avicennia marina (Forsskal) Vierh.

Boraginaceae
Halgania preissiana Lehm.
Heliotropium paniculatum R.Br.
Heliotropium undulatum M. Vahl
Trichodesma zeylanicum (Burm. f.) R.Br.

Brassicaceae
* *Diplotaxis tenuifolia* (L.) DC.
Lepidium aff. *rotundum* (Desv.) DC.
* *Sisymbrium irio* L.
Sisymbrium sp. (J.P.T. 54, 55 Dampier)

Caesalpiniaceae
Cassia oligophylla F. Muell.
Cassia sturtii R.Br.
Labichea eremaea C. Gardner

Campanulaceae
Wahlenbergia gracilis A.DC.

Capparaceae
Capparis spinosa L.

Caryophyllaceae
* *Spergularia rubra* (L.) J.S. Presl & C. Presl

Chenopodiaceae
Atriplex aff. *cinerea* Poiret
Atriplex nummularia Lindley
Atriplex paludosa R.Br.
Atriplex spongiosa F. Muell.
* *Chenopodium ambrosioides* L.
Chenopodium desertorum (J. Black) J. Black
Didymanthus roei Endl.
Dysphania plantaginella F. Muell.
Einadia nutans (R.Br.) A.J. Scott
Enchylaena tomentosa R.Br.
Eriochiton sclerolaenoides (F. Muell.) F. Muell. ex A.J. Scott
Halosarcia halocnemoides (Nees) Paul G. Wilson
Halosarcia indica subsp. *bidens* (Nees) Paul G. Wilson
Halosarcia pruinosa (Paulsen) Paul G. Wilson
Maireana appressa (J. Black) Paul G. Wilson
Maireana planifolia (F. Muell.) Paul G. Wilson
Maireana polypterygia (Diels) Paul G. Wilson
Maireana scleroptera (J. Black) Paul G. Wilson
Maireana tomentosa Moq.
Rhagodia baccata (Labill.) Moq.
Rhagodia crassifolia R.Br.
Rhagodia latifolia (Benth.) Paul G. Wilson
Salsola kali L.
Sarcocornia quinqueflora (Bunge ex Ung.-Sternb.) A.J. Scott
Sclerolaena eurotioides (F. Muell.) A.J. Scott
Sclerolaena aff. *forrestiana* (F. Muell.) Domin
Sclerolaena tridens (F. Muell.) Domin
Sclerolaena uniflora R.Br.
Sclerolaena sp. (J.P.T. 334 Dampier)
Sclerostegia disarticulata Paul G. Wilson
Suaeda australis (R.Br.) Moq.

Chloanthaceae
Pityrodia loxocarpa (F. Muell.) Druce

Colchicaceae
Wurmbea odorata T.D. Macfarlane

Convolvulaceae
Porana sericea (Gaudich.) F. Muell.

Crassulaceae
Crassula colorata (Nees) Ostenf.

Cucurbitaceae
Mukia maderaspatana (L.) M. Roemer

Cyperaceae
Cyperus sp. 1 (J.P.T. 21 Dampier)
Cyperus sp. 2 (J.P.T. 22 Dampier)
Cyperus sp. 3 (J.P.T. 123 Dampier)
Cyperus sp. 4 (J.P.T. 106 Dampier)

Dasypogonaceae
Acanthocarpus preissii Lehm.

Euphorbiaceae
Adriana tomentosa Gaudich
Euphorbia atoto G. Forster
Euphorbia drummondii Boiss.
Phyllanthus sp. 1 (J.P.T. 199 Dampier)
Phyllanthus sp. 2 (J.P.T. 317 Dampier)

Frankeniaceae
Frankenia ambita Ostenf.
Frankenia pauciflora DC.

Gentianaceae
* *Centaurium spicatum* (L.) Fritsch ex Janchen
* *Centaurium tenuiflorum* (Hoffsgg. & Link) Fritsch ex Janchen

Geraniaceae
Erodium cygnorum Nees

Goodeniaceae
Dampiera incana R.Br.
Goodenia berardiana (Gaudich.) Carolin
Scaevola aff. *collaris* F. Muell.
Scaevola crassifolia Labill.
Scaevola glandulifera DC.
Scaevola restiacea Benth.
Scaevola spinescens R.Br.
Scaevola tomentosa Gaudich.
Scaevola sp. (J.P.T. 235 Dampier)

Gyrostemonaceae
Codonocarpus cotinifolius (Desf.) F. Muell.
Gyrostemon sp. (J.P.T. 222 Dampier)

Juncaginaceae
Triglochin calcitrapa Hook.

Lauraceae
Cassytha aurea J.Z. Weber

Lobeliaceae
Lobelia heterophylla Labill.

Loranthaceae
Amyema sp. (J.P.T. 157 Dampier)
Lysiana exocarpi (Behr) Tieghem

Malvaceae
Abutilon geranioides (DC.) Benth.
Abutilon leucopetalum (F. Muell.) F. Muell. ex Benth.
Gossypium australe F. Muell.
Hibiscus drummondii Turcz.
Hibiscus sturtii Hook.
Lawrencia densiflora (E.G. Baker) Melville
Lawrencia glomerata Hook.
Sida intricata F. Muell.
Sida sp. (J.P.T. 268 Dampier)

Mimosaceae
Acacia bivenosa DC.
Acacia coriacea DC.
Acacia farnesiana (L.) Willd.
Acacia gregorii F. Muell.
Acacia idiomorpha Cunn. ex Benth.
Acacia ligulata Cunn. ex. Benth.
Acacia linophylla W. Fitzg.
+ *Acacia morrisonii* Domin
Acacia murrayana F. Muell. ex Benth.
Acacia pyrifolia DC.
Acacia ramulosa W. Fitzg.
Acacia sclerosperma F. Muell.
Acacia spathulifolia Maslin
Acacia tetragonophylla F. Muell.
Acacia victoriae Benth.
Acacia xiphophylla E. Pritzel
Acacia sp. (J.P.T. 340 Dampier)

+ may be conspecific with *A. pyrifolia* DC.

Moraceae
Ficus platypoda (Miq.) Cunn. ex Miq.

Myoporaceae
Eremophila glabra (R.Br.) Ostenf.
Eremophila mackinlayi F. Muell.
Eremophila oppositifolia R.Br.
Eremophila subfloccosa Benth.
Myoporum apiculatum A.DC.

Myrtaceae
Calothamnus chrysantherus F. Muell.
Calytrix brevifolia (Meissner) Benth.
Eucalyptus camaldulensis Dehnh.
Eucalyptus coolabah Blakely & Jacobs
Eucalyptus foecunda Schauer
Melaleuca cardiophylla F. Muell.
Melaleuca leucadendra (L.) L.
Pileanthus limacis Labill.
Thryptomene baeckeacea F. Muell.

Najadaceae
Najas marina L.

Nyctaginaceae
Boerhavia sp. (J.P.T. 33 Dampier)
Commicarpus australis Meikle

Papaveraceae
* *Argemone ochroleuca* Sweet

Papilionaceae
Brachysema aphyllum Hook.
Clianthus formosus (G. Don) Ford & Vick.
Crotalaria cunninghamii R.Br.
Daviesia divaricata Benth.
Glycine clandestina Willd.
Glycine tabacina (Labill.) Benth.
Glycyrrhiza acanthocarpa (Lindley) J. Black
Indigofera brevidens Benth.
Indigofera georgei E. Prtizel
Lotus australis Andrews
Swainsona kingii F. Muell.

Phormiaceae
Dianella revoluta R.Br.

Plumbaginaceae
Muellerolimon salicorniaceum (F. Muell.) Lincz.

Poaceae
Aristida browniana Henrard
Aristida contorta F. Muell.

* *Avellinia michelii* (Savi) Parl.
* *Axonopus* sp. (J.P.T. 20 Dampier)
* *Cenchrus ciliaris* L.
* *Ehrharta longiflora* Smith
Enteropogon acicularis (Lindley) Lazarides
Eragrostis australasica (Steudel) C.E. Hubb.
Eragrostis brownii (Kunth) Nees ex Steudel
* *Eragrostis curvula* (Schrader) Nees
Eragrostis eriopoda Benth.
Eragrostis japonica (Thunb.) Trin.
Eriachne aff. *aristidea* F. Muell.
Eulalia fulva (R.Br.) Kuntze
* *Lolium perenne* L.
Sorghum plumosum P. Beauv. ex Roemer & Schultes
Stipa elegantissima Labill.
Themeda australis (R.Br.) Stapf
* *Trachynia* sp. (J.P.T. 122 Dampier)
Triodia basedowii E. Pritzel
Triodia pungens R.Br.
Triraphis sp. (J.P.T. 109 Dampier)

Polygonaceae
* *Emex australis* Steinh.
Muehlenbeckia sp.
Polygonum sp. (J.P.T. 13 Dampier)

Portulacaceae
Calandrinia granulifera Benth.
Calandrinia polyandra Benth.
Portulaca oleracea L.

Potamogetonaceae
Ruppia sp.

Primulaceae
Samolus junceus R.Br.

Proteaceae
Banksia ashbyi E.G. Baker
Grevillea eriostachya Lindley
Grevillea stenobotrya F. Muell.
Grevillea wickhamii Meissner.
Grevillea sp.
Hakea stenophylla Cunn. ex R.Br.

Santalaceae
Exocarpos aphyllus R.Br.
Santalum acuminatum (R.Br.) A.DC.
Santalum lanceolatum R.Br.
Santalum spicatum (R.Br.) A.DC.

Sapindaceae
Diplopeltis eriocarpa (Benth.) Hemsley
Dodonaea amblyophylla Diels
Dodonaea ptarmicaefolia Turcz.
Heterodendrum oleaefolium Desf.

Scrophulariaceae
Stemodia grossa Benth.
Stemodia viscosa Roxb.

Solanaceae
Anthocercis gracilis Benth.
Anthocercis littorea Labill.
Lycium australe F. Muell.
* *Nicotiana glauca* Graham
Nicotiana occidentalis Wheeler subsp. *occidentalis*
Nicotiana simulans N. Burb.
Solanum esuriale Lindley
Solanum lasiophyllum Dunal ex Poiret
* *Solanum nigrum* L.
Solanum orbiculatum Dunal ex Poiret

Stackhousiaceae
Stackhousia sp. 1 (J.P.T. 159 Dampier)
Stackhousia sp. 2 (J.P.T. 203 Dampier)

Surianaceae
Stylobasium spathulatum Desf.

Thymelaeaceae
Pimelea ammocharis F. Muell.
Pimelea microcephala R.Br.

Tiliaceae
Corchorus elachocarpus F. Muell.
Corchorus walcottii F. Muell.

Tremandraceae
Tetratheca hirsuta Lindley

Zygophyllaceae
Tribulus terrestris L.
Zygophyllum fruticulosum DC.
Zygophyllum glaucum F. Muell.