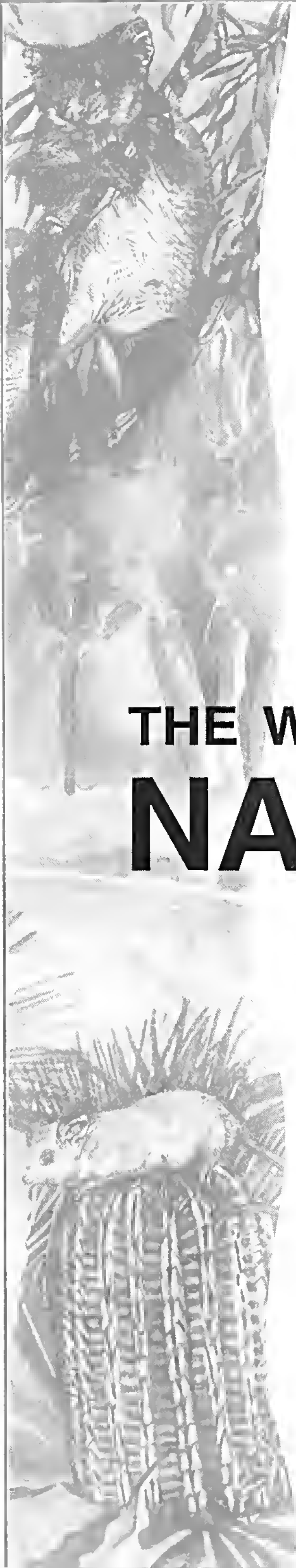

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Objects:
To encourage the study of Natural History in all its branches, and to endeavour to prevent the wanton destruction of native flora and fauna.

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THE FLORA AND AVIFAUNA OF THE PROPOSED CARNARVON RANGE CONSERVATION PARK, WESTERN AUSTRALIA, INCLUDING THE NEARBY BLUE HILL PASTORAL LEASE

PART 1 – BACKGROUND AND INTRODUCTION

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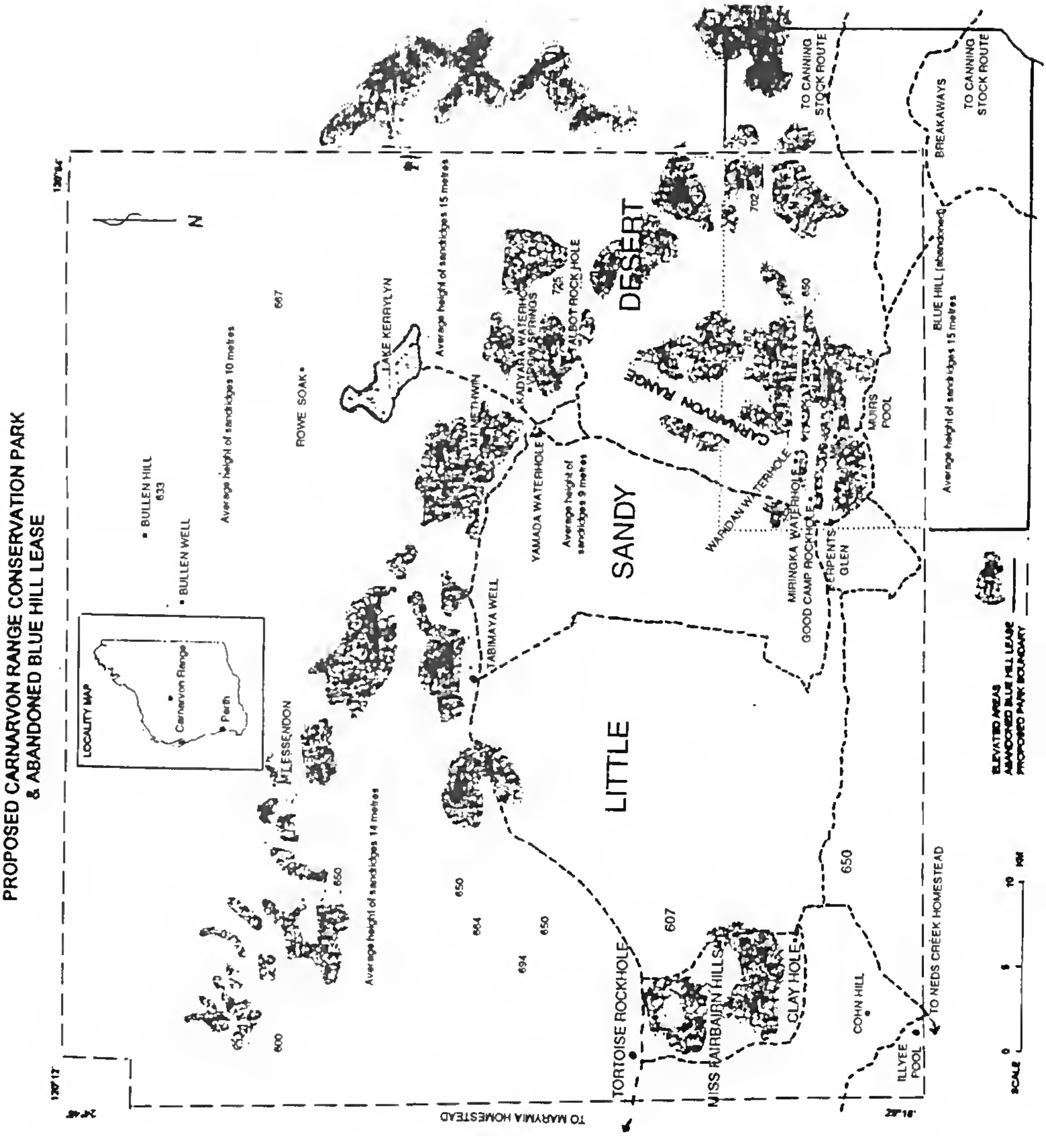
INTRODUCTION

The Carnarvon Range lies in the southwestern portion of the Little Sandy Desert and within the Bangemall Basin, a pre-Cambrian sedimentary basin of the Western Shield situated between the Great Northern Highway and the Canning Stock Route. It runs in a broad band from Mt Essendon (914m elevation) the highest point in the northwest, to Mt Methwin (903m) and south to M6 (See Map 1).

The proposed Carnarvon Range Conservation Park, comprising of 391 000ha was suggested as a nature reserve by the Conservation Through Reserves Committee in 1974. The proposal was supported by the Environmental Protection Authority in 1975 (EPA 1975) and endorsed by Cabinet in 1976. Its status was later raised to Conservation Park and it is on the register of the National Estate. In 1999, the Western Australian Naturalists' Club made a submission to the then Minister of the Environment, Mrs Cheryl Edwardes, to have the abandoned Blue Hill Pastoral Lease included in the proposed Carnarvon Range Conservation Park. The Club was advised that under current native title claims, inclusion would only be possible under a co-operative management arrangement such as joint reserve management or an Indigenous Protected Area.



MAP 1. The Carnarvon Range area showing the proposed Carnarvon Range Conservation Park and location of places mentioned in text.

1. Wonyulgunna Sandstone near Good Camp Rockhole at the southern section of the Carnarvon Range, August 2001. Photo: Kevin Coate.

2. Western Australian Naturalists' Club members amidst stands of flowering *Grevillea eriostachys* in typical sandplain near M 6, August 1999. Photo: Kevin Coate.

3. Members of the August 1999 Western Australian Naturalists' Club long range excursion at Serpents Glen in the Carnarvon Range. Photo: Kevin Coate.

4. Breakaway country on the abandoned Blue Hill Pastoral Lease, 1998. Photo: Kevin Coate.

The geology consists of cross-bedded red sandstone (named Wonyulgunna sandstone – after a hill south-east of Kumarina) of middle to upper Proterozoic age (Photo 1). This sandstone takes the form of low, gently undulating hills, with occasional steep cliffs and gullies containing a few semi-permanent pools. Red sand ridges and plains (Photo 2) occur at the base of the hills. Lake Kerrylyn is the only major salt lake in the area and was named in 1976 after a local resident. Also in the southwest of the proposed park are the Miss Fairbairn Hills. They are banded ironstone, low, rounded and undulating – the only occurrence of this geological formation in the area. There are two areas of granitoid rocks, which have eroded into lateritic breakaway country. Soils have been mapped at 1:2000,000 by Northcote *et al.* (1968).

The climate of the region has been described by Beard (1990) as arid, hot and dry with erratic summer rainfall, with an annual precipitation of about 200–250mm, mainly dependent on cyclones.

The park is traditionally home to the Wardal Aborigines, who have relocated to Wiluna. They still retain strong ties to the area. European impact has come from mining exploration and grazing of stock. As seen on Map 1, pastoral leases exist on the western, southwestern and southern boundaries. Mining exploration currently exists in the area. There are three granted "Exploration Licenses" and three in application. These cover approximately 10% of the proposed park (at February 2002). Historically much of the area has been explored for iron ore. A large part of the central area has been explored for diamonds. Although some indicator minerals were found, exploration failed to upgrade any prospects and most of the licences of this area have lapsed. The southwest area is being explored for lead and base metals in similar geology to that of exploration success further south on Nabberu. The northwest area is being explored for gold on extensions of geology from Marymia Station to the west. The central eastern area is probably being explored for diamonds, but may also be prospective for base metals. Sand cover and transported sediments make exploration difficult and expensive. Exploration activity is not considered very strong and none of the companies have made any announcements of significant success.

HISTORICAL

Prior to the coming of the European, Aboriginals lived in the Carnarvon Range area as evidenced by the numerous art sites and artifacts found scattered throughout.

Europeans first explored the area in 1874, when John Forrest named the range after Lord Carnarvon, 4th Earl and Secretary of State for the Colonies.

In 1893, Surveyor May undertook an extensive trigometric survey through the region. There is a series of 'M' trigs through the Carnarvon Range attributed to him – east to Mt Cecil Rhodes (outside the proposed park), north to Mt Essendon and south to M6. Good Camp Rockhole was possibly the rockhole located at traverse point "M10" by him in August 1893, and subsequently named in 1967 by government dogger, P Muir.

In 1895, Surveyor A. Newman carried out a traverse connection to M6.

The explorer Frank Hann visited the area in 1902 and named the Miss Fairbairn Hills, in honour of the daughter of the Resident Magistrate of Fremantle, and Cohn Hill in the southwest section of the proposed park after his riding horse.

Between 1907 and 1909, topographical surveyor H.W.B. Talbot carried out a geological assessment through the Carnarvon Range and the Miss Fairbairn Hills area, while on a geological survey in the country between Wiluna, Halls Creek and Tanami.

Until the 1960's there were few European visits apart from occasional explorers, prospectors, kangaroo shooters and doggers. During the latter part of the 1960's, P. Muir, under instruction from the Agriculture Protection Board, carried out dingo surveys naming and marking water points. Talbot Rockhole and Serpents Glen, although recognised as features, are not officially recorded in the Department of Land Administrations Geonoma database of 2000. These sites would also undoubtedly have an Aboriginal name.

In 1970, the geology master at Hale College, Mark de Graaf, had occasion to lead a party to the area for the purpose of studying geology. As a result of this excursion, a number of locally used names were discovered and recorded – including Tabimaya Well and Kadyara Waterhole.

During 1971–1972 tracks were established through the area by the Wiluna Shire, to facilitate mineral exploration by BHP (P. Strugnell, former Shire Clerk at Wiluna – *pers comm*).

A biological survey was undertaken by the Western Australian Wildlife Research Centre in November 1975 and March 1976 (McKenzie and Burbidge 1979). As part of the latter survey R.E. Johnstone from the Western Australian Museum visited the area from the 28–31 March 1976 (Johnstone *et al.* 1979). Since then periodic visits have been made to the area by Conservation and Land Management personnel. In September 1995 the Australian Nature Conservation Authority involving A.A. Burbidge, S. van Leeuwen *et al.* undertook a biological survey of the western Little Sandy Desert by helicopter, and touched on the northern end of the Carnarvon Range.

We independently visited the area in 1998. Members of the Western Australian Naturalists' Club (Photo 3), under the leadership of one of us (KHC), made extensive collections and recordings of flora and avifauna throughout the area including the nearby abandoned Blue Hill Pastoral Lease (Photo 4) in August 1999 and 2000 (see

Coate 1999). In August 2001 a *LANDSCOPE* Expedition (through the auspices of Department of Conservation and Land Management in association with The University of Western Australia Extension) under the leadership of botanist, Kevin Kenneally, also collected and recorded in the area. We were co-leaders on this expedition.

In the next two sections we present data on the plants and birds of the area.

ACKNOWLEDGEMENTS

We would like to express our appreciation to June and John Roach of "Mary,ia" and Esma and Ken Hall of "Neds Creek", for allowing access to the Carnarvon Ranges via roads on their property, Peter Strugnell, a kangaroo shooter (in the area during the 1950's and early 1960's) and later Wiluna Shire Clerk, for background knowledge and a better understanding of historical events, Brian Goodchild (Geographic Names Committee) and Jim Skates (Geodetic Data Services) of the Department of Land Administration for providing the origins of named features, Mark Thompson (Red Dog Prospecting P/L) for a mineral exploration summary. Special thanks to Yvonne Coate for preparing the text for publication. Finally, we would like to acknowledge members of the 1999 and 2000 Western Australian Naturalists' Club long-range excursion and the 2001 *LANDSCOPE* Expedition, for their enthusiasm and camaraderie in the field, while gathering data in this interesting area.

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THE FLORA AND AVIFAUNA OF THE PROPOSED CARNARVON RANGE CONSERVATION PARK, WESTERN AUSTRALIA, INCLUDING THE NEARBY BLUE HILL PASTORAL LEASE

PART 2 – VEGETATION

By DAPHNE CHOULES EDINGER
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SUMMARY

A comprehensive list of the 400 + vascular plants collected and recorded from the Carnarvon Range in August 1998, 1999, 2000 and 2001 is presented – plus 84 sight records of easily recognised common but uncollected plants. An analysis of the floristic composition of the vegetation of this range is given. Brief notes on the physical features, land use and climate of the range area are also provided.

The Carnarvon Range is at the southern limit of several plant species with a more northerly distribution.

METHODS

Because of the large area of the park and there being only one rough track through it, our collecting was necessarily opportunistic as we travelled and more concentrated at camp sites, mainly at rockholes. For location details and place names see Coate and Edinger (Part 1 this publication).

The park comprises five main areas:–

1. Miss Fairbairn Hills, low rounded hills of banded ironstone in the southwest.
2. Granitoid breakaway areas in the north of laterite.
3. The Carnarvon Ranges of Wonyulgunna Sandstone to 900+ metres.
4. Lake Kerrylyn, salt and mostly dry in the north-east and surrounds.
5. Red sandplain and sandridges to 9m running northeast and southwest.

VEGETATION OF CARNARVON RANGE

McKenzie and Burbidge (1979) have described the vegetation of the proposed park thus:

A. Vegetation of the range is tall open-shrubland of *Acacia aneura* with *Grevillea spinosa* and *Hakea rhombales*. Below the shrubs are scattered areas of hummock grassland (*Triodia basedowii*). There are scattered, emergent *Eucalyptus camaldulensis* and *Callitris glaucophylla*. Many areas of bare rock are present.

B. In the gullies which contain pools and ephemeral streams, coolibah (*Eucalyptus victrix*), to 15m form fringing formations, although *Callitris glaucophylla* is also common and *Ficus platypoda* is present, especially on steep areas.

C. Against the base of the southern side of the range are screes and gibbers with a tall shrubland to low woodland of mulga (*Acacia aneura*) and gidgee (*Acacia pruinocarpa*) or sometimes low open woodlands of *Corymbia deserticola* over low shrubs and grasses.

   To the south of the range are extensive red sandplains with occasional low dunes.

D. A low open woodland of corkwood (*Hakea lorea*) and scattered Acacia species over a hummock grassland of *Triodia basedowii* covers the plains.

E. The dunes have a low open-woodland of the sand-dune bloodwood (*Corymbia chippendalei*) with a scattered shrub layer of acacias and *Aluta* (formerly *Thryptomene*) *maisonnneuvei* over a hummock grassland (*Triodia* species). The desert grass tree (*Xanthorrhoea thorntoni*) occurs in patches on the plains and on some low dunes.

Beard (1974a, 1974b, 1976) has mapped the vegetation at 1:1,000,000.

At Good Camp Rockhole, while collecting water in a very dirty green pool, we collected a sample of the green slime and later sent it to Dr Stephen Skinner in Sydney. He identified it as containing *Spirogyra neglecta*, a desmid (*Pleurotaenium* sp.) and two species of Oedogonium. One of these, *Oedogonium silvaticum* proved to be a new species record for Australia and the other is an undescribed species.

DISCUSSION

A total of 400 species from 60 families (Appendix 1) were recorded for the area of which 4 were new species, 15 were priority species, one a range extension of 300km approximately (*Acacia hamersleyensis*) and one a first collection for the area (*Acacia marramamba*).

As stated before, the Carnarvon Range is at the southern limit of several plant species with a more northerly distribution, e.g. *Clerodendrum floribundum*.

A total number of genera and species of the major families are listed below:

Family	Genera	Species
Amaranthaceae	1	10
Asteraceae	27	44
Chenopodiaceae	9	25
Chloanthaceae	4	9
Euphorbiaceae	4	8
Goodeniaceae	5	27
Malvaceae	5	13
Mimosaceae	1	27
Myoporaceae	1	26
Myrtaceae	7	19
Papilionaceae	14	21
Poaceae	15	27
Proteaceae	2	9

ACKNOWLEDGEMENTS

I would like to thank Kevin Kenneally, Gilbert Marsh and Barbara and Bob Backhouse, who assisted greatly with the processing and identification of the specimens. To Paul Wilson and Bruce Maslin of the Western Australian Herbarium for identifications, and especially to Barbara Backhouse for typing the extensive species list so ably.

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APPENDIX 1. LIST OF FLORA.

Location numbers and codes are:

1. Miss Fairbairn Hills (banded ironstone).
2. Breakaways (granitoid) laterite.
3. Carnarvon Range (Wonyulgunna sandstone).
4. Lake Kerrylyn, salt.
5. Red, sand plain & ridges.
6. Stony, quartzite ridge in the nearby abandoned Blue Hill Pastoral Lease.

Sr. Sight records.
H. In Western Australian Herbarium, but not collected by us.
P. Priority species.
KC. Kevin Coate's collection.
BH Blue Hill Pastoral Lease (abandoned)

Family	Genus	Species	subspecies	Location	Collection	Status
Acanthaceae	Harnieria	kempeana	subsp. muelleri	2		
Adiantaceae	Cheilanthes	lasiophylla		2		
Adiantaceae	Cheilanthes	sieberi	subsp. sieberi	1,2,3		
Aizoaceae	Gunniopsis	sp. nov.		6		
Amaranthaceae	Ptilotus	aervoides		1		
Amaranthaceae	Ptilotus	beardii		6		P3
Amaranthaceae	Ptilotus	exaltatus			Sr	
Amaranthaceae	Ptilotus	fusiformis			Sr	
Amaranthaceae	Ptilotus	helipteroides	var. helipteroides	1		
Amaranthaceae	Ptilotus	obovatus	var. obovatus	2		
Amaranthaceae	Ptilotus	polystachyus	var. polystachyus		Sr	
Amaranthaceae	Ptilotus	roei		2		
Amaranthaceae	Ptilotus	schwartzii		1,2		
Amaranthaceae	Ptilotus	sp.Blue Hill (DJE Nats 66)		6		

Anthericaceae	Thysanotus	manglesianus		2	
Anthericaceae	Thysanotus	sp.(bud only)		3	
Apiaceae	Daucus	glochidiatus			Sr
Apiaceae	Trachymene	bialata		3	
Apiaceae	Trachymene	glaucifolia			Sr
Apiaceae	Trachymene	ornata			Sr
Asclepiadaceae	Rhyncharrhena	linearis			Sr
Asclepiadaceae	Sarcostemma	viminale	subsp. australe		Sr
Asteraceae	Actinobole	uliginosum			Sr
Asteraceae	Bidens	bipinnata		1	
Asteraceae	Brachyscome	ciliaris			Sr
Asteraceae	Brachyscome	ciliocarpa			Sr
Asteraceae	Calocephalus	?beardii		1,3	
Asteraceae	Calocephalus	multiflorus		3	
Asteraceae	Calotis	hispidula			Sr
Asteraceae	Calotis	multicaulis			Sr
Asteraceae	Chrysocephalum	puteale		2	
Asteraceae	Chthonocephalus	pseudevax			Sr
Asteraceae	Chthonocephalus	viscosus		1	
Asteraceae	Dielitzia	tysonii		2	
Asteraceae	Erymophyllum	ramosum	subsp. ramosum	2	
Asteraceae	Gilberta	?tenuifolia			Sr
Asteraceae	Gnephosis	tenuissima		3	
Asteraceae	Helipterum	craspedioides			Sr
Asteraceae	Lawrencella	davenportii		1	
Asteraceae	Leucochrysum	fitzgibbonii		2,3,6	
Asteraceae	Leucochrysum	stipitatum		2,3	
Asteraceae	Myriocephalus	rudallii		3	
Asteraceae	Olearia	stuartii		2,3	
Asteraceae	Othonna	gregorii		2	
Asteraceae	Pluchea	dentex		2,3,5	
Asteraceae	Podolepis	canescens			Sr
Asteraceae	Podolepis	capillaris			Sr

Family	Genus	Species	subspecies	Location	Collection	Status
Asteraceae	Podolepis	gardneri		2		
Asteraceae	Podolepis	kendallii		2		
Asteraceae	Podolepis	sp. Carnarvon Range (DJE Nats 33)		3		
Asteraceae	Podolepis	sp. GVD(A.S. George 8219)		1,3		
Asteraceae	Rhodanthe	charsleyae		1,3		
Asteraceae	Rhodanthe	floribunda		1,2		
Asteraceae	Rhodanthe	humboldtiana		1		
Asteraceae	Rhodanthe	propinqua		1,2,3		
Asteraceae	Rhodanthe	sterilescens		2		
Asteraceae	Schoenia	ayersii		1		
Asteraceae	Schoenia	cassiniana			Sr	
Asteraceae	Sonchus	oleraceus			Sr	
Asteraceae	Streptoglossa	liatroides		6		
Asteraceae	Taplinia	saxatilis		3		
Asteraceae	Vittadinia	eremaea		3,5		
Asteraceae	Waitzia	acuminata		3		
Boraginaceae	Halgania	gustafsenii	var. compactus	5		
Boraginaceae	Trichodesma	zeylanica			Sr	
Brassicaceae	Lepidium	aff. pedicellosum (Mary Mia) DE sn		2		
Brassicaceae	Lepidium	oxytrichum		1,3		
Brassicaceae	Lepidium	phlebopetalum		1		
Brassicaceae	Lepidium	platypetalum			KC	
Brassicaceae	Menkea	sphaerocarpa		1		
Brassicaceae	Stenopetalum	anfractum		1		
Caesalpiniaceae	Petalostylis	cassioides		3		
Caesalpiniaceae	Petalostylis	labichioides		5		
Caesalpiniaceae	Senna	artemisioides	subsp helmsii	2		
Caesalpiniaceae	Senna	artemisioides	spp. x sturtii	1,2		

Caesalpiniaceae	Senna	pleurocarpum			Sr
Caesalpiniaceae	Senna	symonii		1	
Campanulaceae	Wahlenbergia	tumidifructa		3	
Caryophyllaceae	Polycarpaea	holtzei		3	
Centrolepidaceae	Centrolepis	eremica		2,3	
Chenopodiaceae	Atriplex	codonocarpa			Sr
Chenopodiaceae	Atriplex	vesicaria		6	
Chenopodiaceae	Chenopodium	saxatile		2	
Chenopodiaceae	Dysphania	kalpari		3	
Chenopodiaceae	Dysphania	rhadinostachya		3	
Chenopodiaceae	Enchylaena	tomentosa		1	
Chenopodiaceae	Halosarcia	calyptrata		6	
Chenopodiaceae	Maireana	aff planifolia		1,2	
Chenopodiaceae	Maireana	carnosa(cottony bluebush)			Sr
Chenopodiaceae	Maireana	convexa		3	
Chenopodiaceae	Maireana	georgei		2	
Chenopodiaceae	Maireana	prosthecochaeta			RP Fence
Chenopodiaceae	Maireana	thesioides		2	
Chenopodiaceae	Maireana	triptera		6	
Chenopodiaceae	Maireana	villosa		2	
Chenopodiaceae	Sclerolaena	cornishiana		1	
Chenopodiaceae	Sclerolaena	eriacantha			Sr
Chenopodiaceae	Sclerostegia	sp.Blue Hill (DJE Nats 61)		6	
Chloanthaceae	Dicrastylis	cordifolia	var. barnettii	3	
Chloanthaceae	Dicrastylis	cordifolia	var. cordifolia	3,5	
Chloanthaceae	Dicrastylis	georgei		3,5	
Chloanthaceae	Dicrastylis	sp.Kumarina(A.A. Mitchell 623)		5	
Chloanthaceae	Dicrastylis	tomentosa ms		5	
Chloanthaceae	Newcastelia	bracteosa		5	
Chloanthaceae	Newcastelia	cephalantha		5	

Family	Genus	Species	subspecies	Location	Collection	Status
Chloanthaceae	Pityrodia	loxocarpa		5		
Chloanthaceae	Spartothamnella	teucriiflora		1		
Clusiaceae	Hypericum	japonicum		2,3		
Colchicaceae	Wurmbea	deserticola(juvenile only)& seeds		3		
Convolvulaceae	Bonamia	?erecta		3		
Convolvulaceae	Bonamia	rosea			Sr	
Convolvulaceae	Ipomoea	plebeia		1		
Crassulaceae	Crassula	colorata	var. tuberculata		Sr	
Cupressaceae	Callitris	glaucophylla			Sr	
Cyperaceae	Carex	?inversa		2		
Cyperaceae	Cyperus	centralis		3		
Cyperaceae	Cyperus	rigidellus		3		
Cyperaceae	Cyperus	squarrosus		3		
Cyperaceae	Isolepis	congrua		2,3		
Cyperaceae	Lipocarpha	microcephala		3		
Dasypogonaceae	Lomandra	leucocephala	var. robusta	5		
Droseraceae	Drosera	burmanni		3		
Droseraceae	Drosera	indica		3		
Euphorbiaceae	Euphorbia	australis			Sr	
Euphorbiaceae	Euphorbia	boophthona (Gascoyne spurge)		3		
Euphorbiaceae	Euphorbia	drummondii			Sr	
Euphorbiaceae	Euphorbia	tannensis(desert spurge)	var. eremophila	3		
Euphorbiaceae	Monotaxis	luteiflora		3		
Euphorbiaceae	Phyllanthus	lacunellus		3		
Euphorbiaceae	Phyllanthus	maderaspatensis			Sr	
Euphorbiaceae	Poranthera	microphylla		3		
Frankeniaceae	Frankenia	fecunda		6		
Frankeniaceae	Frankenia	glomerata		6		P1

Frankeniaceae	Frankenia	sessilis		6		
Geraniaceae	Erodium	cygnorum			Sr	
Goodeniaceae	Brunonia	australis		3	Sr	
Goodeniaceae	Dampiera	atriplicina		5		P2
Goodeniaceae	Dampiera	dentata		3,5		
Goodeniaceae	Dampiera	ramosa		5		P2
Goodeniaceae	Goodenia	centralis		2,3		
Goodeniaceae	Goodenia	havilandii		2,3		
Goodeniaceae	Goodenia	macroplectra		3		
Goodeniaceae	Goodenia	mimuloides			Sr	
Goodeniaceae	Goodenia	mueckeana		3,5		
Goodeniaceae	Goodenia	prostrata		2		
Goodeniaceae	Goodenia	stellata		3		P3
Goodeniaceae	Goodenia	tenuiloba		2		
Goodeniaceae	Goodenia	triodiophila		1,5		
Goodeniaceae	Goodenia	wilunensis		2		
Goodeniaceae	Scaevola	basedowii		5		
Goodeniaceae	Scaevola	browniana	subsp. browniana	1,3		
Goodeniaceae	Scaevola	collaris		5		
Goodeniaceae	Scaevola	parvifolia		5,6		
Goodeniaceae	Scaevola	spinescens			Sr	
Goodeniaceae	Velleia	glabrata		2,3,5		
Goodeniaceae	Velleia	hispida		2		
Goodeniaceae	Velleia	rosea			Sr	
Gyrostemonaceae	Gyrostemon	racemigera			Sr	
Gyrostemonaceae	Gyrostemon	ramulosus		5		
Haloragaceae	Gonocarpus	ephemerus		3		P2
Haloragaceae	Gonocarpus	nodulosus		2		
Haloragaceae	Haloragis	odontocarpa (mulga spinach)		1		
Haloragaceae	Haloragis	sp nov.		3		
Haloragaceae	Haloragis	trigonocarpa			Sr	
Juncaginaceae	Triglochin	calcitrapum (spurred arrowgrass)		3		

Family	Genus	Species	subspecies	Location	Collection	Status
Juncaginaceae	Triglochin	nana		3		
Lamiaceae	Microcorys	macredieana		5		P3
Lamiaceae	Prostanthera	wilkieana			Sr	
Lobeliaceae	Isostoma	petraea			Sr	
Loranthaceae	Amyema	gibberula		3		
Loranthaceae	Amyema	maidenii			Sr	
Loranthaceae	Amyema	miquelii		5		
Loranthaceae	Lysiana	murrayi		3		
Malvaceae	Abutilon	amplum		3		
Malvaceae	Abutilon	cryptopetalum		1		
Malvaceae	Abutilon	fraseri		1		
Malvaceae	Abutilon	leucopetalum		3		
Malvaceae	Alyogyne	pinoniana		5		
Malvaceae	Hibiscus	coatesii		3,5		
Malvaceae	Hibiscus	gardneri		2		
Malvaceae	Lawrencia	squamata		6		
Malvaceae	Sida	calyxhymenia			Sr	
Malvaceae	Sida	excedentifolia		2		
Malvaceae	Sida	fibulifera			Sr	
Malvaceae	Sida	spodochroma		2		
Marsileaceae	Marsilea	drummondii(nardoo)			2	
Mimosaceae	Acacia	abrupta		1,5		
Mimosaceae	Acacia	aneura	var. aneura(mulga)	1,2,3		
Mimosaceae	Acacia	ayersiana		6		
Mimosaceae	Acacia	ayersiana x minyura		3		
Mimosaceae	Acacia	burkittii		1		
Mimosaceae	Acacia	citrinoviridis		2		
Mimosaceae	Acacia	cuthbertsonii	subsp. cuthbertsonii	3		
Mimosaceae	Acacia	cyperophylla			Sr	
Mimosaceae	Acacia	daviesioides		1,5		

Mimosaceae	Acacia	dictyophleba (whipstick wattle)	5		
Mimosaceae	Acacia	grasbyi		Sr	
Mimosaceae	Acacia	hamersleyensis	3		R g e
ext 300 km					
Mimosaceae	Acacia	jamesiana		H	
Mimosaceae	Acacia	kempeana	2		
Mimosaceae	Acacia	ligulata	3,4		
Mimosaceae	Acacia	linophylla		Sr	
Mimosaceae	Acacia	maitlandii	5		
Mimosaceae	Acacia	marramamba	1		1st coll
LSD					
Mimosaceae	Acacia	melleodora	5		
Mimosaceae	Acacia	minyura	1		
Mimosaceae	Acacia	pachyacra	5		
Mimosaceae	Acacia	prainii	5		
Mimosaceae	Acacia	pruinocarpa(black gidgee)		Sr	
Mimosaceae	Acacia	rhodophloia	3,5	Sr	
Mimosaceae	Acacia	tetragonophylla		Sr	
Mimosaceae	Acacia	victoriae		Sr	
Moraceae	Ficus	opposita		Sr	
Moraceae	Ficus	platypoda		Sr	
Myoporaceae	Eremophila	aff compacta	2		
Myoporaceae	Eremophila	aff gilesii	1		
Myoporaceae	Eremophila	aff glabra	3,4		
Myoporaceae	Eremophila	anomala ms	3		Pl
Myoporaceae	Eremophila	citrina ms	1		
Myoporaceae	Eremophila	clarkei(turpentine bush)	3		
Myoporaceae	Eremophila	decipiens	4		
Myoporaceae	Eremophila	drummondii	2		
Myoporaceae	Eremophila	eriocalyx	1,5		

Family	Genus	Species	subspecies	Location	Collection	Status
Myoporaceae	Eremophila	exilifolia		2		
Myoporaceae	Eremophila	foliosissima		1,2		
Myoporaceae	Eremophila	forrestii		1		
Myoporaceae	Eremophila	fraseri			Sr	
Myoporaceae	Eremophila	gilesii				
Myoporaceae	Eremophila	hughesii		2		
Myoporaceae	Eremophila	latrobei	var. latrobei	1,2,5		
Myoporaceae	Eremophila	oppositifolia	subsp. oppositifolia	2		
Myoporaceae	Eremophila	ostrina ms		H		P1
Myoporaceae	Eremophila	platythamnos		4		
Myoporaceae	Eremophila	punctata		6		
Myoporaceae	Eremophila	sp nov. orange-red		4		
Myoporaceae	Eremophila	sp nov. pink		6		
Myoporaceae	Eremophila	sp nov. purple		2		
Myrtaceae	Aluta	maisonneuvei (Syn. Thryptomene)	subsp.maisonneuvei	5		
Myrtaceae	Calytrix	carinata		3		
Myrtaceae	Calytrix	praecipua			H	P3
Myrtaceae	Corymbia	deserticola	subsp. deserticola	1		
Myrtaceae	Corymbia	lucasii(Barlee box)			H	
Myrtaceae	Corymbia	opaca		1		
Myrtaceae	Eucalyptus	camaldulensis			Sr	
Myrtaceae	Eucalyptus	eremicola	subsp. sublucida		H	
Myrtaceae	Eucalyptus	gamophylla			H	
Myrtaceae	Eucalyptus	gypsophila			H	
Myrtaceae	Eucalyptus	kingsmillii	subsp.kingsmillii		H	
Myrtaceae	Eucalyptus	oldfieldii			Sr	
Myrtaceae	Eucalyptus	rameliana			H	P4
Myrtaceae	Eucalyptus	trivalvis			H	
Myrtaceae	Melaleuca	lasiandra		3		
Myrtaceae	Micromyrtus	flaviflora		5		

Myrtaceae	Thryptomene	wittweri		H	DRF
Papilionaceae	Crotalaria	cunninghamii		Sr	
Papilionaceae	Daviesia	arthropoda	5		Pl
Papilionaceae	Daviesia	grahamii	3		
Papilionaceae	Galactia	aff tenuiflora	1		
Papilionaceae	Gastrolobium	grandiflorum (wallflower poison)			H
Papilionaceae	Glycine	canescens	3		
Papilionaceae	Gompholobium	polyzygum	3		
Papilionaceae	Indigofera	georgei	1		
Papilionaceae	Indigofera	monophylla	3		
Papilionaceae	Isotropis	forrestii	1,2		
Papilionaceae	Kennedia	prorepens	4	Sr	
Papilionaceae	Leptosema	chambersii	1		
Papilionaceae	Mirbelia	rhagodioides	2		
Papilionaceae	Swainsona	kingii	3,5		
Papilionaceae	Swainsona	pedunculata	2		
Papilionaceae	Swainsona	sp.(on loan)	1		
Pittosporaceae	Pittosporum	angustifolium ms		Sr	
Poaceae	Aristida	contorta(wind grass)		Sr	
Poaceae	Dicanthium	sp.(on loan)		?	
Poaceae	Elytrophorus	spicatus(spike grass)	2		
Poaceae	Enneapogon	caerulescens (limestone grass)	1		
Poaceae	Eragrostis	cumingii	2,3		
Poaceae	Eragrostis	desertorum	4		
Poaceae	Eragrostis	dielsii(love grass)	?		
Poaceae	Eragrostis	eriocarpa(wooll butt grass)		Sr	
Poaceae	Eragrostis	eriopoda	2		
Poaceae	Eragrostis	falcata(sickle lovegrass)	4		
Poaceae	Eragrostis	lacunaria	3		

Family	Genus	Species	subspecies	Location	Collection	Status
Poaceae	Eragrostis	lanipes			Sr	
Poaceae	Eragrostis	leptocarpa (drooping lovegrass)			2,3	
Poaceae	Eriachne	aristidea(false wanderriegrass)		2		
Poaceae	Eriachne	pulchella		2		
Poaceae	Eulalia	aurea(silky browntop)		3		
Poaceae	Eulalia	fulva		3	Sr	
Poaceae	Monachather	paradoxa (bandicoot grass)			Sr	
Poaceae	Neurachne	minor		2		
Poaceae	Paractaenum	novae-hollandiae		4		
Poaceae	Paractaenum	refractum		3		
Poaceae	Sporobolus	indicus		3		
Poaceae	Themeda	triandra(kangaroo grass)		2		
Poaceae	Thyridolepis	mitchelliana(window mulga grass)		2		
Poaceae	Triodia	basedowii(hard spinifex)		2,3		
Poaceae	Tripogon	loliiformis(five minute grass)		2		
Polygalaceae	Comesperma	viscidulum		5		P2
Portulacaceae	Calandrinia	eremaea		2,6		
Portulacaceae	Calandrinia	granulifera		3		
Portulacaceae	Calandrinia	polyandra			Sr	
Portulacaceae	Calandrinia	ptychosperma		3		
Portulacaceae	Calandrinia	stagnensis		2		
Proteaceae	Grevillea	deflexa		2		
Proteaceae	Grevillea	eriostachya		3		

Proteaceae	Grevillea	juncifolia	subsp. juncifolia		Sr	
Proteaceae	Grevillea	leucoptera			Sr	
Proteaceae	Grevillea	spinosa			Sr, KC	
Proteaceae	Grevillea	stenobotrya			Sr	
Proteaceae	Grevillea	wickhamii	subsp. aprica		Sr	
Proteaceae	Hakea	lorea			Sr	
Proteaceae	Hakea	rhombales		5		
Rubiaceae	Pomax	rupestris		3		Pl
Rubiaceae	Pomax	sp. Desert(A.S. George 11968)		3		
Rubiaceae	Psydrax	latifolia(Syn. Canthium)			Sr	
Rubiaceae	Synaptantha	tilaeacea		3		
Santalaceae	Anthobolus	leptomerioides		1		
Santalaceae	Santalum	acuminatum (quandong)			Sr	
Santalaceae	Santalum	lanceolatum			Sr	
Santalaceae	Santalum	spicatum (sandalwood)			Sr	
Sapindaceae	Dodonaea	angustissima			KC	
Sapindaceae	Dodonaea	petiolaris			Sr	
Sapindaceae	Dodonaea	viscosa		3		
Scrophulariaceae	Peplidium	?muelleri		2		
Scrophulariaceae	Peplidium	sp. C(Flora Cent.Aust.)		2		
Scrophulariaceae	Stemodia	viscosa		2	Sr	
Solanaceae	Duboisia	hopwoodii(Pituri)		2		
Solanaceae	Nicotiana	benthamiana		3		
Solanaceae	Nicotiana	rosulata	subsp. rosulata	1		
Solanaceae	Solanum	centrale		1		
Solanaceae	Solanum	lasiophyllum			Sr	
Stackhousiaceae	Macgregoria	racemigera(snow flower)			Sr	

Family	Genus	Species	subspecies	Location	Collection	Status
Stackhousiaceae	Stackhousia	intermedia		1		
Stackhousiaceae	Stackhousia	megaloptera		5		
Sterculiaceae	Brachychiton	gregorii			Sr	
Sterculiaceae	Keraudrenia	integrifolia		3		
Sterculiaceae	Rulingia	sp.		2		
Stylidiaceae	Levenhookia	chippendalei		6	Sr	
Stylidiaceae	Stylidium	desertorum		2		
Stylidiaceae	Stylidium	humphreysii		5		
Stylidiaceae	Stylidium	inaequipetalum		3		
Thymelaeaceae	Pimelea	ammocharis			Sr	
Tremandraceae	Tetratheca	chapmanii		3		Pl
Verbenaceae	Clerodendrum	floribundum			Sr	
Violaceae	Hybanthus	aurantiacus		3		
Xanthorrhoeaceae	Xanthorrhoea	thorntonii			Sr	
Zygophyllaceae	Tribulus	platypterus			Sr	
Zygophyllaceae	Tribulus	suberosus			H	
Zygophyllaceae	Zygophyllum	aurantiacum		5		
Zygophyllaceae	Zygophyllum	idiocarpum		1		
Zygophyllaceae	Zygophyllum	ovatum			Sr	
Zygophyllaceae	Zygophyllum	sp.		6		

THE FLORA AND AVIFAUNA OF THE PROPOSED CARNARVON RANGE CONSERVATION PARK, WESTERN AUSTRALIA, INCLUDING THE NEARBY BLUE HILL PASTORAL LEASE

PART 3 - ANNOTATED BIRD SPECIES LIST

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SUMMARY

This paper is based mainly on data gathered during visits by members of the Western Australian Naturalists' Club in August 1998, August 1999, June 2000, and August 2000 to the proposed Carnarvon Range Nature Reserve and the nearby abandoned Blue Hill pastoral lease in the Little Sandy Desert in Western Australia. Also included are data from the August 2001 *Landscope* Expedition and some historical records from Conservation and Land Management (CALM) personnel.

Reference is made of Black Honeyeater eating ash, the occurrence of Painted Finch, Mallee Fowl not previously recorded in the area and birds likely to be found when conditions are favourable. A total of eighty-nine species of bird are recorded, thirty-three non-passerine and fifty-six passerine species. Many of these were poorly or not previously recorded in the area. Breeding records are included. Nomenclature follows Johnstone (2001).

CASUARIIDAE

Emu – *Dromaius novaehollandiae*

Uncommon to common on all visits. Many with young chicks (1–9) up to 70cm high in August 1999.

MEGAPODIDAE

Malleefowl – *Leipoa ocellata*

Rare or uncommon. Reported near Virgin Springs in 1974–1975 (anecdotal to Kenny Farmer, an Aboriginal from Wiluna with strong ties to the area (A. Chapman, pers. comm.).

ANATIDAE

Australian Shelduck – *Tadorna tadornoides*

Uncommon. One recorded at Clayhole in July 1991 (A. Chapman, pers. comm.).

Grey Teal – *Anas gracilis*

Uncommon. Two pairs at Clayhole in July 1991 (A. Chapman pers. com.).

ACCIPITRIDAE

Black-shouldered Kite – *Elanus caeruleus*

Scarce. Two on sand ridge about 1km west of Serpents Glen in August 2000.

Square-tailed Kite – *Hamirostra isura*

Scarce. One near Virgin Springs in August 1999.

Black-breasted Buzzard – *Hamirostra melanosternon*

Uncommon. Two, one carrying nesting material, in a grove of *Eucalyptus camaldulensis* close to 25°17'59" 120°22'20" in August 2000.

Whistling Kite – *Haliastur sphenurus*

Scarce. One on two consecutive days at Serpents Glen in August 2001.

Brown Goshawk – *Accipiter fasciatus*

Uncommon. One seen several times at Virgin Springs in August 1999; one near Illyee Pool (south-western section of proposed park); one at Serpents Glen and two at Blue Hill breakaways in August 2001.

Collared Sparrowhawk – *Accipiter cirrocephalus*

Scarce. One recorded several times at Virgin Springs in August 1999.

Little Eagle – *Aquila morphnoides*

Scarce. One at southern end of Carnarvon Range in November 1975 (Johnstone *et al.* 1979).

Wedge-tailed Eagle – *Aquila audax*

Uncommon. Single birds observed in August 1998 and 1999; and a pair at Serpents Glen in August 2001.

Spotted Harrier – *Circus assimilis*

Scarce. Two above profusely flowering *Grevillea eriostachya* on sandplain at the southern end of Carnarvon Range near M6 in August 1999.

FALCONIDAE

Brown Falcon – *Falco berigora*

Uncommon in ones and twos. Recorded near Miss Fairbairn Hills and southern end of Carnarvon Range.

Australian Kestrel – *Falco cenchroides*

Moderately common in ones, twos and threes. Nest with young at Serpents Glen in August 1999.

Australian Hobby – *Falco longipennis*

Uncommon. One at Serpents Glen and one at Blue Hill, where it was observed to catch a Hooded Robin in August 1999.

Peregrine Falcon – *Falco peregrinus*

Uncommon. Two at breakaways south of Blue Hill in August 1998, one at Serpents Glen in August 2001. Two white downy chicks were in a nest at Blue Hill breakaways (25°19'00" 120°52'56") in August 1999. The nest was on a ledge of a cliff face two metres from the base. Several piles of Crested Pigeon feathers were nearby on top of the breakaway.

OTIDIDAE

Australian Bustard – *Otis australis*

Uncommon. Single birds recorded at Tabimaya Well and Blue Hill in August 1998 and 1999; remains of a recently killed, half-grown bird near Peregrine Falcon nest at Blue Hill breakaways in August 1999; three on the eastern boundary in August 2000 and one close to Clay Hole, south of Miss Fairbairn Hills in August 2001.

TURNICIDAE

Little Button-quail – *Turnix velox*

Uncommon. Mainly in small groups. Recorded near Good Camp Rockhole, southwest of Miss Fairbairn Hills and at Blue Hill breakaway.

CHARADRIIDAE

Black-fronted Dotterel – *Charadrius melanops*

Uncommon. Three at Clayhole in July 1991 (A. Chapman pers. comm.).

Inland Dotterel – *Peltohyas australis*

Scarce. One on flat stony area at Blue Hills in August 2001.

COLUMBIDAE

Common Bronzewing – *Phaps chalcoptera*

Moderately common in ones and twos throughout the area.

Crested Pigeon – *Ocyphaps lophotes*

Common around rockholes in August 1998 and 1999; uncommon in 2000 and 2001. Nest with 2 eggs in *Callitris glaucophlla* in an unburnt gully near Serpents Glen in August 2001.

Spinifex Pigeon – *Geophaps plumifera*

Rare or uncommon. About 12 recorded near Mt. Methwin in May 1975 (Reid 1976).

Diamond Dove – *Geopelia cuneata*

Common to moderately common around rockholes and breakaways e.g. up to 100 at Good Camp Rockhole in August 1999 and Talbot Rockhole in 2001. Uncommon elsewhere.

PSITTACIDAE

Galah – *Cacatua roseicapilla*

Moderately common in small numbers in August 1998, 1999 and 2000; otherwise scarce, two at Serpents Glen in August 2001.

Little Corella – *Cacatua sanguinea*

Uncommon. Breeding in a grove of *Eucalyptus camaldulensis* trees on the southwest boundary near 25°17'57" 120°22'20" in August 2000.

Ring-necked Parrot – *Platycercus zonarius*

Moderately common near creeks and rockholes on all visits. Breeding at Serpents Glen in August 1999.

Mulga Parrot – *Platycercus varius*

Common in mulga woodland in August 1998, 1999 and 2000 otherwise scarce in unburnt areas of mulga woodland. Breeding at Serpents Glen in August 1999.

Budgerigar – *Melopsittacus undulatus*

Common in small flocks throughout the area in August 1999; scarce in small flocks (5–6) near Miss Fairbairn Hills and at Blue Hill breakaway in August 2001.

Bourke's Parrot – *Neophema bourkii*

Moderately common in small flocks (up to 8). Recorded at Tabimaya Well, Blue Hill and nearby breakaways and south of Miss Fairbairn Hills.

CUCULIDAE

Pallid Cuckoo – *Cuculus pallidus*

Moderately common throughout the area in August 1998 and 1999; uncommon in August 2000 and 2001.

Black-eared Cuckoo – *Chrysococcyx osculans*

Scarce. Two at southern end of Carnarvon Range in November 1975 (Johnstone *et al.* 1979).

Horsfield's Bronze-Cuckoo – *Chrysococcyx basalis*

Moderately common in August 1998 and 1999; uncommon, several between Serpents Glen and Talbot Rockhole in August 2001. A juvenile being fed by Chestnut-rumped Thornbill (*Acanthiza uropygialis*) at Good Camp Rockhole in August 1999.

STRIGIDAE

Boobook Owl – *Ninox novaeseelandiae*

Uncommon. One calling at Virgin Springs in August 1999.

TYTONIDAE

Barn Owl – *Tyto alba*

One at southern end of Carnarvon Range in March 1976 (Johnstone *et al.* 1979). One calling at night at Good Camp Rockhole in October 1993 (A. Chapman pers. comm.).

PODARGIDAE

Tawny Frogmouth – *Podargus strigoides*

Uncommon. Two flushed from small tree on steep slope below M6 and two at Blue Hill breakaways in August 2001.

CAPRIMULGIDAE

Spotted Nightjar – *Eurostopodus argus*

Uncommon. Heard at Serpents Glen in August 1998, 1999 and 2001.

AEGOTHELIDAE

Australian Owlet-nightjar – *Aegotheles cristatus*

Moderately common at rock holes and Serpents Glen in August 1998, 1999 and 2001. Two flushed from hollow limbs of *Eucalyptus camaldulensis* at Talbot Rockhole in August 2001. Young in nest at Kadyara Waterhole in August 1999.

HALCYONIDAE

Red-backed Kingfisher – *Todiramphus pyrrhopygia*

Uncommon. One pair near southwest boundary in August

2000 and one near Talbot Rockhole in August 2001.

CLIMACTERIDAE

White-browed Treecreeper – *Climacteris affinis*

Uncommon. One in tall Mulga woodland at Blue Hill in August 1999.

MALURIDAE

Variegated Fairy-wren – *Malurus lamberti*

Uncommon. One family group at Serpents Glen in August 1998; another near southwest boundary in August 2000; moderately common in *Triodia* sp. and *Aluta maisonneuvii* between Serpents Glen and Talbots Rockhole and in unburnt acacia woodland near M6 in August 2001.

White-winged Fairy-wren – *Malurus leucopterus*

Moderately common in heathlands.

Rufous-crowned Emu-wren – *Stipiturus ruficeps*

Moderately common in *Triodia* sp. and *Aluta maisonneuvii* between Serpents Glen and Talbots Rockhole (25°10'9" 120°41'2") in August 2001.

Striated Grasswren – *Amytornis striatus*

Scarce. One in spinifex at southern end of Carnarvon Range in May 1990 (A Chapman pers. com.); also reported between Serpents Glen and Talbot Rockhole in June 1991 (J. Blyth pers. comm.). Probably more common than indicated, due to their secretive nature.

PARDALOTIDAE

Red-browed Pardalote – *Pardalotus rubricatus*

Scarce. In ones and twos at Talbot Rockhole and Serpents Glen.

Striated Pardalote – *Pardalotus striatus*

Uncommon. Several at Serpents Glen in August 1998 and 2001, and near the southwest boundary in August 2000.

ACANTHIZIDAE

Weebill – *Smicrornis brevirostris*

Moderately common in small flocks in eucalyptus trees in gullies and near southwest boundary in August 1999, 2000 and 2001.

Western Gerygone – *Gerygone fusca*

Moderately common at Virgin Springs, Serpents Glen and Muir's Pool in August 1999 and also heard at Talbot Rockhole in August 2001.

Inland Thornbill – *Acanthiza apicalis*

Moderately common. Recorded at Serpents Glen, near southwest boundary and in unburnt areas between Serpents Glen and Talbots Rockhole.

Chestnut-rumped Thornbill – *Acanthiza uropygialis*

Moderately common in small groups (up to 8) on all visits.

Slaty-backed Thornbill – *Acanthiza robustirostris*

Moderately common in ones and twos on all visits. A pair feeding young just out of nest near southwest boundary in August 2000.

Yellow-rumped Thornbill – *Acanthiza chrysorrhoa*

Uncommon. Recorded in August 1999; and several in unburnt areas of mulga woodland between Serpents Glen and Talbot Rockhole in August 2001. Nest with small young at southern end of Carnarvon Range near M6 in August 1999.

Southern Whiteface – *Aphelocephala leucopsis*

Uncommon in August 1999; several at Blue Hill in August 2001. Breeding at Blue Hill in August 1999.

Banded Whiteface – *Aphelocephala nigricincta*

Scarce. Small flock at Blue Hill in August 2000.

MELIPHAGIDAE

Brown Honeyeater – *Lichmera indistincta*

Common on all visits. Attracted to thickets of flowering *Grevillea wickhamii* and *Grevillea spinosa* in gullies and around base of hills. Nest with 2 eggs near Good Camp Rockhole in August 1999 and nest with 2 eggs in *Acacia rhodophloia* near M6 in August 2001.

Black Honeyeater – *Certhionyx niger*

Moderately common in August 1998; common in August 1999; not recorded in August 2000; and scarce (2) between Serpents Glen and Talbot Rockhole in August 2001. Nest with 2 eggs on a dry limb about two metres up in a dead acacia tree near Serpents Glen in August 1999. Up to 3 females at one time observed over several days collecting ash and small lumps of charcoal from two old campfires and a campfire that contained glowing coals. Birds were observed swallowing ash while on the ground, but at other times would fly to a branch on an adjacent Mulga tree before swallowing. A fresh bird dropping, probably from a Black Honeyeater, on a tent close to where the birds were coming into the campfire, contained a small lump of charcoal in August 1999.

Pied Honeyeater – *Certhionyx variegatus*

Moderately common, especially around flowering grevillea in August 1998 and 1999; scarce; recorded near southern end of Carnarvon Range in August 2000; but not recorded in August 2001.

Singing Honeyeater – *Meliphaga virescens*

Moderately common in August 1999; uncommon in August 2000 and 2001.

Grey-headed Honeyeater – *Meliphaga keartlandi*

Moderately common in March 1976 and November 1975 (Johnstone *et al.* 1979).

Grey-fronted Honeyeater – *Meliphaga plumula*

Scarce. Several on Neds Creek track west of Carnarvon Range in August 2000.

White-plumed Honeyeater – *Meliphaga penicillata*

Moderately common. Juveniles at rockhole near M6 at 25'16.90' 120'41.42' in October 1993 (A Chapman pers. comm.); and moderately common in *Eucalyptus camaldulensis* woodland southwest boundary near 25'17'57" 120'22'20" in August 2000.

White-fronted Honeyeater – *Phylidonyris albifrons*

Very common throughout the area in August 1999. Attracted to flowering *Grevillea spinosa*, *Grevillea eriostachya* and *Grevillea juncifolia*; scarce; only one record, a bird attracted to flowering *Grevillea eriostachya* in August 2000. Common; and attracted to flowering *Hakea lorea* in unburnt areas between Serpents Glen and Talbot Rockhole in August 2001.

Yellow-throated Miner – *Manorina flavigula*

Moderately common on all visits.

Spiny-cheeked Honeyeater – *Acanthagenys rufogularis*

Very common in August 1999, attracted to flowering *Grevillea spinosa*, *Grevillea eriostachya* and *Grevillea juncifolia*; scarce in August 2000 and moderately common in August 2000 in unburnt areas.

Crimson Chat – *Epthianura tricolor*

Uncommon in small flocks (up to 30) often in company with Black-faced Woodswallow in August 1999. They appeared to be moving through the area in a northeasterly direction. Also several single birds at Blue Hill breakaway in August 2001.

Orange Chat – *Epthianura aurifrons*

Recorded at Lake Kerrylyn in June 1991 (J. Blyth pers. comm.).

EOPSALTRIIDAE

Red-capped Robin – *Petroica goodenovii*

Scarce to common in August 1999 and 2000; and moderately common in August 2001. 3 nests with eggs, 1 nest with young and 1 nest being built in August 1999.

Hooded Robin – *Petroica cucullata*

Uncommon to moderately common at Blue Hill (one seen taken by Australian Hobby); scarce elsewhere.

POMATOSTOMIDAE

Grey-crowned Babbler – *Pomatostomus temporalis*

Scarce; a small party at Blue Hill in August 1999 and 2001.

White-browed Babbler – *Pomatostomus superciliosus*

Uncommon to moderately common. Recorded at Serpents Glen and southwest boundary.

CINCLOSOMATIDAE

Chiming Wedgebill – *Psophodes occidentalis*

Scarce. Heard near Virgin Springs in August 1999.

Chestnut-breasted Quail-thrush – *Cinclosoma castaneothorax*

Moderately common near rocky areas; e.g. Miss Fairbairn Hills, Blue Hill breakaway, and on rocky area on the track west from Serpents Glen.

NEOSITTIDAE

Varied Sittella – *Daphoenositta chrysoptera*

Uncommon. Small flock of eight at southern end of Carnarvon Range in 1975 (Johnstone *et al.* 1979).

PACHYCEPHALIDAE

Crested Bellbird – *Oreoica gutturalis*

Moderately common on all visits.

Rufous Whistler – *Pachycephala rufiventris*

Moderately common in ones and twos throughout the area. Breeding at Serpents Glen in August 1999.

Grey Shrike-thrush – *Colluricincla harmonica*

Moderately common around rockholes and in gullies in the ranges.

DICRURIDAE

Willie Wagtail – *Rhipidura leucophrys*

Moderately common throughout the area.

Magpie Lark – *Grallina cyanoleuca*

Moderately common in August 1998, 1999 and 2000; uncommon in August 2001. A disused nest in *Eucalyptus camaldulensis* near 25°17'57" 120°22'20" in August 2000.

CAMPEPHAGIDAE

Black-faced Cuckoo-shrike – *Coracina novaehollandiae*

Common over much of the area in August 1998, 1999 and 2000; scarce in August 2001.

Ground Cuckoo-shrike – *Coracina maximal*

Uncommon to moderately common. A group of three and one of two on the track west of the Carnarvon Range in August 2000; and three south of Miss Fairbairn Hills, five at southern boundary near M6 and three at Blue Hill in August 2001.

White-winged Triller – *Lalage tricolor*

Moderately common in August 1998 and 1999; uncommon between Serpents Glen and Talbot Rockhole on flowering *Hakea lorea* in August 2001.

ARTAMIDAE

Masked Woodswallow – *Artamus personatus*

Moderately common. Small flocks at southern end of Carnarvon Range in November 1975 (Johnstone *et al.* 1979); also a small flock in transit at Blue Hill in August 2001.

Black-faced Woodswallow – *Artamus cinereus*

Common over much of the area in August 1998, 1999 and 2000 and several small flocks in August 2001.

Little Woodswallow – *Artamus minor*

Moderately common around cliff faces in August 1998 and 1999; scarce in August 2000 and 2001.

CRACTICIDAE

Grey Butcherbird – *Cracticus torquatus*

Moderately common on all visits. Large young in nest at Virgin Springs and Serpents Glen in August 1999.

Pied Butcherbird – *Cracticus nigrogularis*

Moderately common in August 1998, 1999 and 2000; uncommon, one at western end of the park and one near Serpents Glen and two at Blue Hill in August 2001.

Australian Magpie – *Cracticus tibicen*

Uncommon. Two at Blue Hill in August 1999; two near south-west boundary in August 2000; and two at Serpents Glen in August 2001.

CORVIDAE

Torresian Crow – *Corvus orru*

Uncommon. Recorded in August 1999 and 2001. A nest with small young in a *Eucalyptus camaldulensis* tree at Serpents Glen in August 1999, and an occupied nest in a *Eucalyptus camaldulensis* tree near southwest boundary in August 2000.

Little Crow – *Corvus bennetti*

Uncommon. Several in August 1999.

PTILONORHYNCHIDAE

Western Bowerbird – *Ptilonorhynchus maculatus*

Uncommon. Recorded at Virgin Springs, Serpents Glen (several in the vicinity of a bower) and at Blue Hill.

MOTACILLIDAE

Richards Pipit – *Anthus novaeseelandiae*

Moderately common throughout the area in August 1999; several on track near southwest boundary in August 2000; and moderately common at Blue Hill (not seen elsewhere) in August 2001.

PASSERIDAE

Zebra Finch – *Taeniopygia guttata*

Common in small flocks (up to 30) in August 1999; several small flocks up to fifteen at Blue Hill in 2001; scarce elsewhere with no more than seven recorded. Breeding profusely: Eggs and young at all stages in *Acacia tetragonophylla* trees close to southwest boundary near 25°17'57" 120°22'20" in August 2000.

Painted Finch – *Emblema pictum*

Moderately common at Good Camp Rockhole (flocks up to 20) in August 1999.

DICAEIDAE

Mistletoebird – *Dicaeum hirundinaceum*

Moderately common in August 1999, 2000 and 2001.

HIRUNDINIDAE

White-backed Swallow – *Cheramoeca leucosterna*

Scarce. Two flying above sand dunes west of Serpents Glen in August 2000, and several over Blue Hill breakaways in August 2001.

Tree Martin – *Hirundo nigricans*

Moderately common around groves of *Eucalyptus camaldulensis* trees close to southwest boundary in August 2000; scarce in August 2001. A number nesting in hollow limbs near 25°17'57" 120°22'20" in August 2000.

Fairy Martin – *Hirundo ariel*

Not recorded. Disused nests at Serpents Glen and Blue Hill breakaways in August 1999.

SYLVIIDAE

Rufous Songlark – *Cincloramphus mathewsi*

Uncommon. Several near southwest corner of park in August 2000, and one at Blue Hill in August 2001.

Brown Songlark – *Cincloramphus cruralis*

Scarce. One near Serpents Glen in August 1999.

DISCUSSION

During their reconnaissance of the area in August 1998 Kevin and Yvonne Coate found the country to be reasonably dry though most rock holes in the ranges were full of water. In August 1999 it would be difficult to imagine the area having more favourable conditions for birds. There was an abundance of water and flowering plants, especially over the sand plains and sand dunes where *Grevillea eriostachya* and *Grevillea juncifolia* were flowering profusely. In the sandstone ranges and rocky gullies *Grevillea spinosa*, various *Acacia* sp. and *Eremophila* sp. were also flowering at their peak. Nomadic birds, especially honeyeaters (e.g. White-fronted Honeyeater, Spiny-cheeked Honeyeater, Black Honeyeater) usually associated with these conditions were very obvious everywhere.

In August 2000 although conditions along the southern sections of the proposed park were excellent after good earlier rains, there was a marked scarcity of birds, especially nomadic honeyeaters. It may be that vegetation associated with earlier heavier rains to the north was more attractive (Kevin and Yvonne Coate and Robert and Maureen Skeet visited the Calvert Range approximately 300kms to the north-east in June 2000 where conditions were similar to the Carnarvon Range in 1999 and found the above mentioned honeyeaters abundant).

Female Black Honeyeater often appear to have a compulsive urge to eat ash and charcoal during their breeding season, the reason for which is unclear. In August 1999 while camped at Serpents Glen I closely observed birds eating ash and charcoal. Normally they are shy birds, they showed little fear of the close proximity to humans while eating the ash. This behaviour has been previously recorded (Coate 1985, 1987). It would be interesting for someone to research Black Honeyeater and determine what benefits they receive from this behaviour.

The occurrence of Painted Finch in reasonably good numbers in August 1999, was most likely due to the exceptional seasonal conditions. In exceptionally good seasons during 1973 and 1974 Painted Finch were recorded about 500 km to the south near Menzies and also near Leonora (Reid 1975).

Rufous-crowned Emu-wren and Striated Grasswren, normally rarely seen, may be more widely spread than indicated as the preferred spinifex and low shrubbery is reasonably plentiful.

Anecdotal evidence of Mallee Fowl reported near Virgin Springs in 1974 and 1975 suggest they may have been more widely spread than previously thought. Although they have not since been recorded and no sign of nesting mounds have been located, there are pockets of habitat where they could turn up in favourable seasons.

Visits by the Western Australian Naturalists' Club in mainly good seasons and the visit by *LANDSCOPE* Expeditions in 2001, after extensive areas near the range had been burnt eight months previously, have added to the understanding of the avifauna of this spectacular arid zone area. There is no doubt that there are many more species as yet unrecorded, particularly in some of the semi-permanent waterholes near Tabimaya Well in the north, and Illyee Pool and Clayhole south of Miss Fairbairn Hills on the south-western boundary. When filled with water, these areas would almost certainly attract waterfowl and waterbirds such as Australian Wood Duck (*Chenonetta jubata*), Pacific Black Duck (*Anas superciliosa*), Pink-eared Duck (*Malacorhynchus membranaceus*), Hard head (*Aythya australis*), Australasian Grebe (*Tachybaptus novaehollandiae*), Hoary-headed Grebe (*Poliocephalus poliocephalus*), White-faced Heron (*Ardea novaehollandiae*), Black-tailed Native-hen (*Gallinula ventralis*) and White-necked Heron (*Ardea pacifica*). Lake Kerrylyn, during rare occasions when it contains water, would most likely attract waders, such as Black-winged Stilt (*Himantopus himantopus*), Red-necked Avocet (*Recurvirostra novaehollandiae*) and Red-kneed Dotterel (*Erythrogonys cinctus*).

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PLANT REGENERATION FOLLOWING FIRE IN BUNGENDORE PARK, BEDFORDALE, WESTERN AUSTRALIA

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ABSTRACT

The results of a study of plant regeneration following fire in Bungendore Park, Bedfordale, Western Australia are presented. The seven-year study examined aspects of tree mortality, understorey species reappearance and effects on the orchid community. Mature Jarrah and Marri trees displayed epicormic regrowth within 6 months of the fire. Saplings regenerated from coppice 1–2 years later. Wandoo mortality exceeded that of Jarrah and Marri and was slower to regenerate. For all three tree species, saplings showed greater susceptibility to fire than mature trees and highest tree mortality was recorded in areas of highest fire intensity. Less than average post-fire rainfall probably accounted for low seedling numbers of Jarrah, Marri and Wandoo. *Allocasuarina fraseriana* regenerated very successfully via epicormic and crown regrowth regardless of age or size of tree. *Banksia grandis* displayed the greatest tree mortality with 31% of recorded trees failing to recover.

197 of the 352 species known from Bungendore Park reappeared at some time during the study period. Vegetation type, fire intensity and fire history influenced the type and density of species more than species diversity. Regenerating species were not widespread within the Park, only 6 % being recorded from seven or more quadrats. Species diversity peaked 2–3 years after the fire. Regeneration mechanisms for recorded understorey species are discussed (55 % are resprouters) and this is related to fire frequency and fire management strategies. Reappearing leguminous species were widespread and in high densities, but showed signs of dying off 6–7 years after the fire. Some understorey species took 2–3 years to reappear.

Within 12 months of the fire, sixteen new records of orchid species had been made and a greatly increased abundance of fire-stimulated orchid species was recorded. Orchid species numbers showed a steady decline in subsequent years to lower than pre-fire levels.

INTRODUCTION

Bungendore Park (↑A4561) is an "A" class reserve of approximately 500 hectares located about 5 kilometres by road from the City of Armadale along the Albany Highway. The park is situated on the western edge of the Darling Plateau and because it includes the upper parts of the Darling Scarp, displays a wide range of soils, topography and vegetation types resulting in a rich, diverse flora. It lies immediately to the north of Wungong Gorge and the Wungong Dam, already a major recreational resource in the area and, as a result, Bungendore Park forms a useful extension of this important natural feature. Bungendore, an aboriginal name meaning "Place of Gum Blossom", forms one of the attractions on the Heritage Country Tourist Drive – Route 205.

Whilst most of its 498 ha. is found on the undulating lateritic uplands of the plateau at elevations of up to 280 m, the western edge of the park encompasses the steep mid and upper slopes of the Darling Scarp. The park's northern boundary slopes gently towards Neerigen Brook and the eastern boundary forms part of the gentle slopes of the upper Wungong valley. To the south, the edge of the park is found at the top of the steep northern slope of the Wungong Gorge. In the areas around major drainage lines, especially Cooliabberra Spring, great variations in soil composition, depth and temperature (due to slope aspect and angle variations) occur resulting in a complex mosaic of vegetation types. Five major vegetation complexes based on Heddle *et al.* (1980) can be found within the park. Open Jarrah-Marri forest dominates (occupying about 80% of the park) and is found on gravelly soils of the gently undulating uplands of the lateritic plateau. Small areas of Wandoo-Marri woodland are located on the younger, shallower soils to the west on the slopes surrounding Cooliabberra Spring. Outcrops of granite on the lower slopes of this creek are surrounded by heath. Herbland covers the surface of the exposed granite. Finally, in the south-western corner is a low open woodland of Rock Sheoak (*Allocasuarina huegelii*), also associated with granite outcrops.

A survey of the flora of Bungendore Park was made between 1991 and 1993. A total of 352 species from 167 genera and 63 families was recorded representing about 44% of the total species occurring in the Jarrah forest of the south-west of Western Australia (Bell and Heddle 1989). One declared rare plant species and three listed "priority" species (Hopper *et al.* 1990) were recorded for the park.

On 9 December 1994, an uncontrolled wildfire swept into the park from the Wungong Gorge and moved rapidly through over 85% of the park, razing the understorey to an ash bed and reducing the dominant trees to blackened trunks. Flames were reported to have reached 10 to 15 metres above the trees. Many animals died in the fire and the destruction of much of the natural habitat meant that many animal species might never return. Local plant extinctions were also possible because fires occurring at the wrong times of year or with an inappropriate frequency destroy flowers and immature seeds and seedling germination is not stimulated (Australian House of Representatives 1984).

Fire, however, is an integral part of the Australian environment and is often essential in the maintenance of many of our ecosystems. Native plants have not only evolved mechanisms to cope with fire, but many have come to depend on high intensity fires for their survival (such as the hard-seeded leguminous species which need heat to germinate). Other fire adaptive traits include re-sprouting from stems and roots using epicormic shoots (e.g. Eucalypts, Banksias and sheoaks), lignotubers (and other underground storage organs), basal sprouts (e.g. Hibbertias, Leucopogons, Hakeas and Grevilleas) and large protected apical buds (Zamia and Balga) (Photo 1.). Some other plants rely on soil-stored seed, protective bark, woody fruits, or fire-stimulated flowering (e.g. orchids and Balga) (Burrows 1985). In forests such as that found in Bungendore Park about 70–75% of all understorey species re-sprout following fire; the remainder relying on soil- or canopy-stored seed (Burrows 1997).

South-Western Australia, with its dry Mediterranean climate, has been subjected to a relatively high natural fire frequency from lightning strikes (accounting for 194 fires in the SW forests between 1987 and 1992 (Ward and Sneeuwjagt 2000) and Aboriginal bush burning; the pre-European frequency estimated to be 3 to 4 fires per decade. Forty years ago, however, the newly formed Forests Department introduced a programme of prescribed and controlled fuel reduction burning as a measure of reducing the frequency and severity of wildfires (Burrows 1985). Since its introduction, no major bushfires of the type which devastated Dwellingup in 1961 have occurred (Burrows 2000 a.). It is known, however, that the frequency, intensity and season in which prescribed burns occur can have an effect on the ecology of an area, especially in small isolated areas of remnant bushland, resulting in the loss of some fire-sensitive species from the population and increased weed invasion (Australian House of Representatives. 1984). On the other hand, the health of a forest can be enhanced by an occasional hot burn which stimulates nitrogen fixing leguminous species to germinate from soil-stored seed (Shea *et al.* 1979) and cleanses and sterilizes the soil (Australian House of Representatives 1984). Modern fire management policies attempt to provide protection to life and property whilst being ecologically sustainable and enhancing biodiversity (Burrows 2000 b.).

Small sections of Bungendore Park have been subjected to prescribed burning on a rotational basis for many years now, resulting in a mosaic of fire

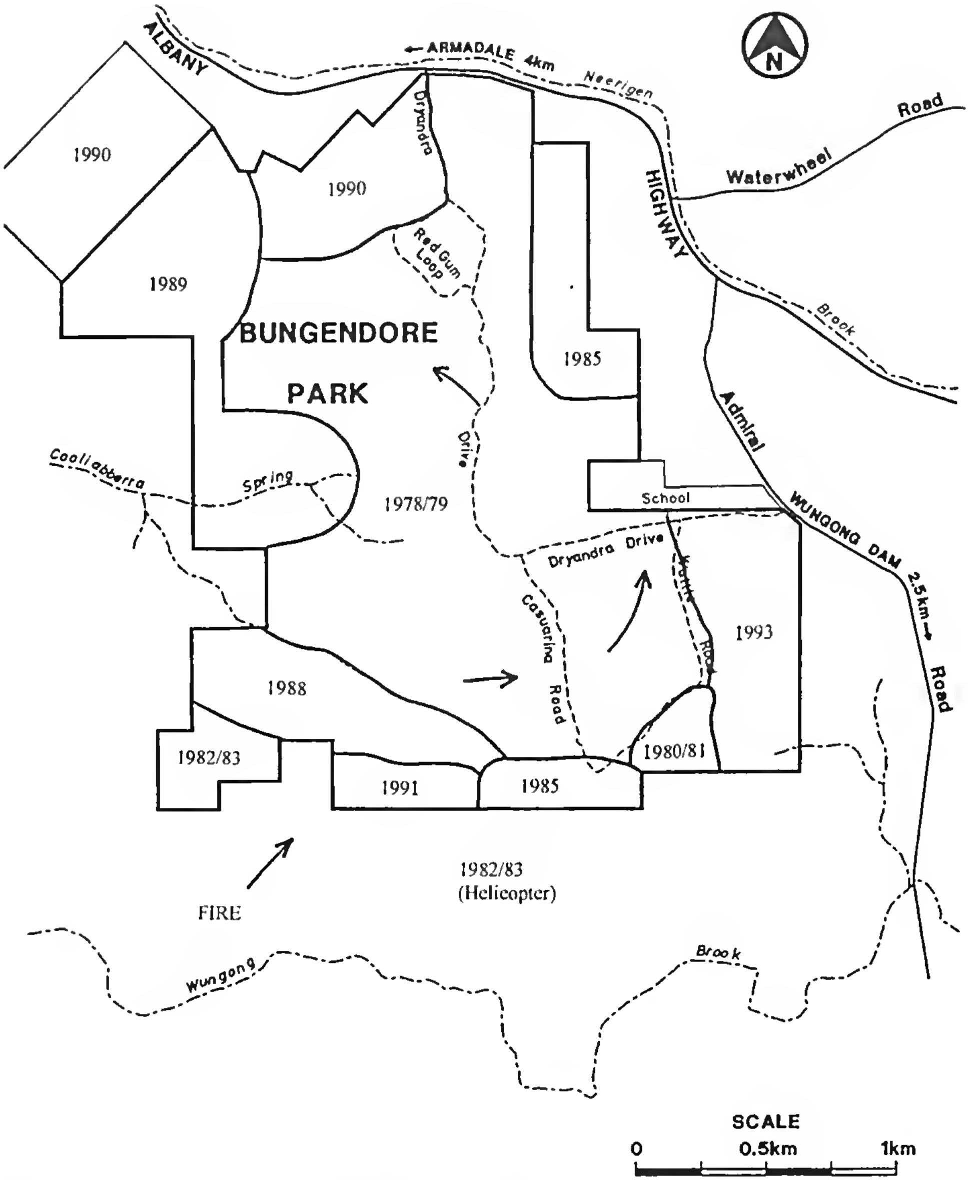

Figure 1. Fire History of Bungendore Park.

history in the park ranging from one year prior to the 1994 wildfire to 16 years (Figure 1). It is not known how long ago the last wildfire went through the park. This study looks at three aspects of vegetation regeneration in the park after the 1994 fire:

- Tree mortality
- Understorey species reappearance

• Effects of fire on the orchid community in the park

METHOD

TREE MORTALITY

The aim of this aspect of the study was to assess the effect of a wildfire on the survival of the main dominant and understorey tree species found in the park. A vegetation map based on Havel's site-vegetation type classification system, produced for my 1999 survey of Bungendore Park, (Figure 2) was used to plan the location of ten 100m x 100m

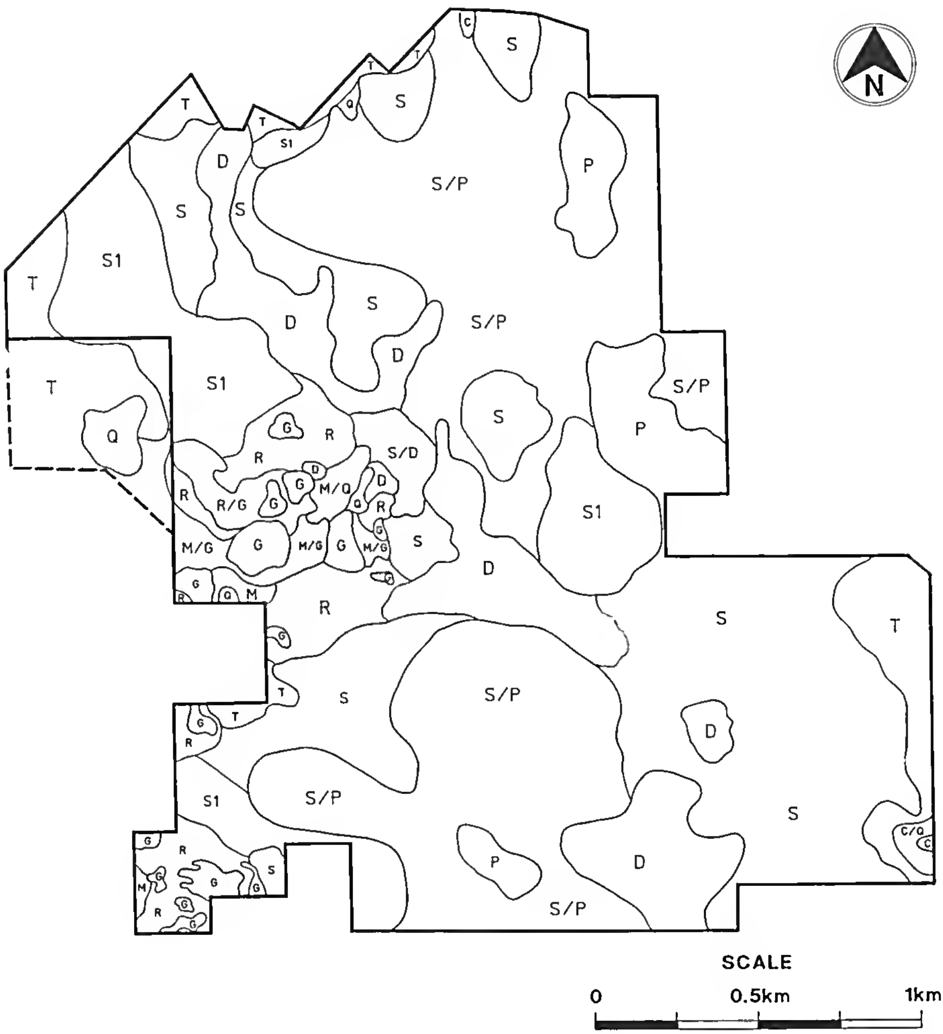

Figure 2. Distribution of Site-Vegetation Types (based on Havel 1975 a and b) (after Lewis 1999)

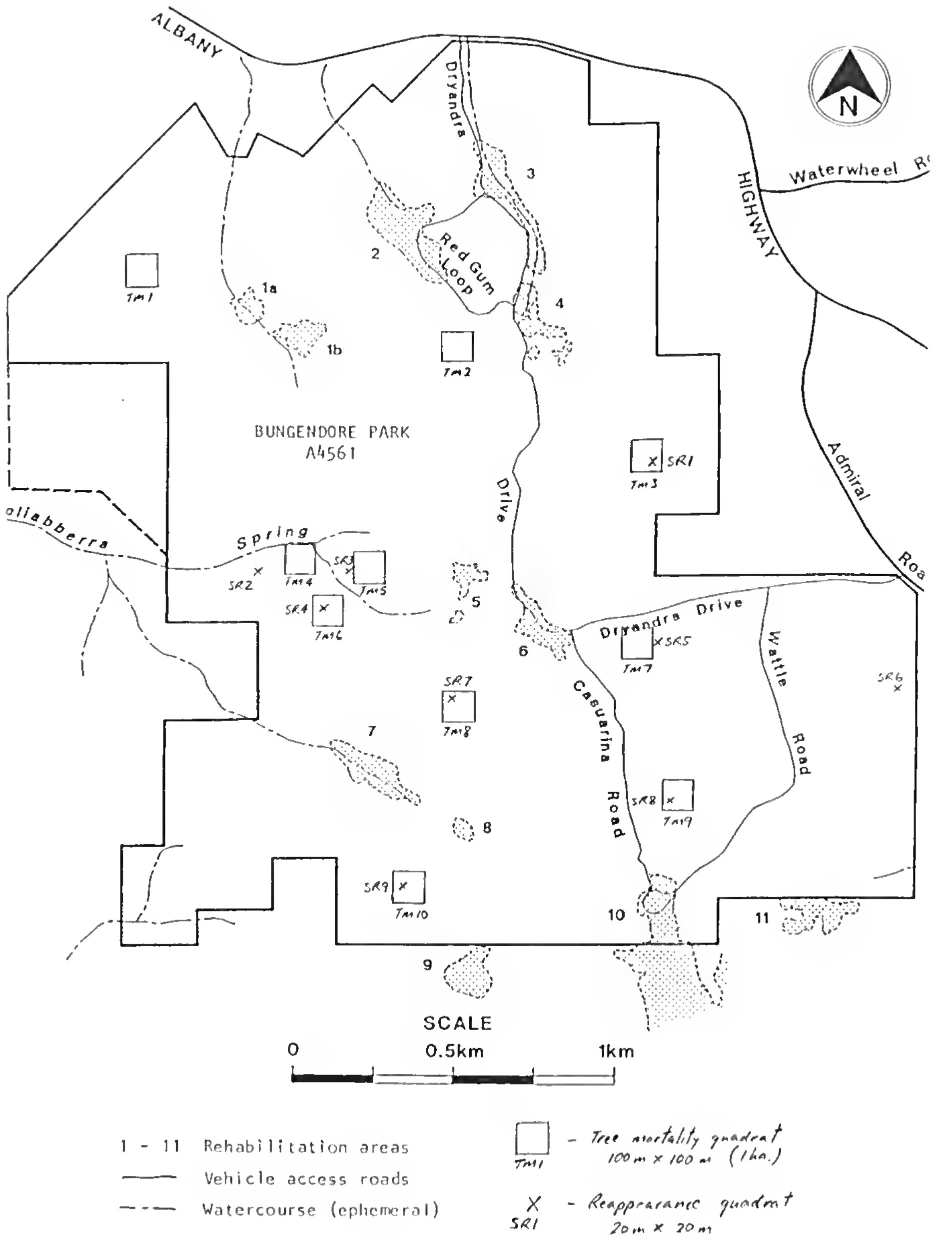

Figure 3. Tree Mortality and Species Reappearance Quadrat Locations.

quadrats in two of the three main vegetation types within the park (open Jarrah-Marri forest and Wandoo-Marri woodland). These ten quadrats were located widely throughout the park (Figure 3) in

Photo 1. Apical regrowth from *Xanthorrhoea preissii*

Photo 2. Deeply fissured Marri bark

Photo 3. Wandoo coppice regrowth.

Photo 4. Discarded epicormic regrowth on Jarrah.

Photo 5. Marri saplings showed greater mortality than mature trees.

Photo 6. Bark loss on mature Jarrah. (4 years after fire).

Photo 7. Wandoo sapling thicket

Photo 8. Epicormic regrowth on mature Wandoo.

Photo 9. *Allocasuarina* survive fire, but in poor condition.

Photo 10. Regrowth in *Allocasuarina* is by epicormic shoots.

Photo 11. Young Banksias survive fire better than mature trees.


Photos 12 and 13. Rapid high density regeneration of the legumes *Acacia pulchella* and *A. alata*

Photo 14. *Acacia alata* thicket (3 ½ years after fire)

Photo 15. Same thicket of *Acacia alata* dying off (6 years after fire).

Photo 16. *Acacia pulchella* dying off in species reappearance quadrat number 3. (6 years after fire).

Photo 17. Dense *Acacia lateriticola* regeneration in species reappearance quadarat number 9. (3 ½ years after fire).

Photo 18. Fire-stimulated flowering in *Xanthorrhoea preissii*.

Photo 19. Fire-stimulated flowering of redbeaks (*Pyrorchis nigricans*).

order to encompass a variety of fire history regimes. Each quadrat was visited on four occasions over a seven-year period. Tree mortality was assessed by determining the number of standing dead trees within each quadrat and recording their position so they could be relocated at a later date. For one of the ten quadrats, height, diameter at breast height and scorch height were also noted for each of the recorded dead trees. Records were made for the three dominant tree species found in the park – Jarrah (*Eucalyptus marginata*), Marri (*Corymbia calophylla*), and Wandoo (*Eucalyptus wandoo*). The understorey tree species *Allocasuarina fraseriana*, *Banksia grandis* and two species of *Persoonia* (*P. elliptica* and *P. longifolia*) were also recorded. Trees which showed neither basal sprouts nor epicormic regrowth were scored as dead on the initial visit. If, on subsequent visits, any form of regrowth was present, including coppice, the tree was recorded as having recovered. A total of 5882 trees were scored, mainly (4955 individuals) Jarrah, Marri and *Banksia grandis*.Tree mortality data were then examined to establish any relationships between tree deaths, tree species, regeneration method, fire intensity and vegetation type.

SPECIES REAPPEARANCE

This aspect of the study was designed to record the post-fire regeneration of understorey species and thus be able to assess the effect of a wildfire on the number (species density) and type (species diversity) of these species occurring in Bungendore Park. Nine permanent 20m x 20m quadrats were established in the park within three months of the December 1994 wildfire. Based on a vegetation map of the park, the quadrats were located to ensure that all three main vegetation types in the park (open Jarrah-Marri forest, Wandoo-Marri woodland and heath) were included at least twice (Figure 3). Each quadrat was visited on five separate occasions over a period of seven years following the fire (all quadrats twice in 1995, the year immediately after the fire). Each quadrat was subdivided into 400 1m x 1m units and presence of each understorey species appearing within each unit of the quadrat was recorded. In one quadrat, the total number of individuals of two of the more common species (*Hibbertia hypericoides* and *Acacia lateriticola*) was recorded. These data were entered onto a computer spreadsheet so that numerical information such as species diversity, species density, new records for subsequent visits and the disappearance of previously recorded species could easily be made. The post-fire regeneration strategy for each species was determined based on the categories established by Burrows (1994). Data were examined to identify any relationships between species re-appearance, fire intensity, vegetation type and regeneration strategy.

ORCHID SURVEY

A species list of orchids for Bungendore Park existed from a survey made prior to the 1994 wildfire. The effect of fire on orchid flowering, however, is well known and documented and so this fire presented an opportunity to collect data on fire-stimulated species which may occur in the park and to assess any long-term effects of a high intensity fire on the Park's orchid community. Information on the presence of orchid species in the park after the fire was collected from a variety of sources. Some orchid species were observed within the nine "species reappearance" quadrats. These quadrats, however, although being positioned in all major vegetation types within the park, represented a relatively small area of the 498 ha. reserve. Further records of post-fire orchid flowering were obtained from ground traverses in areas of the park known to have previously presented many orchid species plus anecdotal evidence from regular park visitors. Information collected was used to assess the effect of the wildfire on orchid species diversity and abundance, especially for fire-stimulated species. The appearance of orchid species known to flower only after fire was also recorded.

FIRE HISTORY AND INTENSITY

Records and anecdotal information provided by the local volunteer fire brigade headquarters were used to produce a fire history map of Bungendore Park. A colour aerial photograph taken 41 days after the wildfire of December 9 1994, along with ground observations, was then used to make a fire intensity map of the park using subjective categories (high, medium and low) (Figure 4). This provided information which could be used to relate fire intensity to fuel loads, vegetation types and any patterns which might emerge from data collected on tree mortality, species reappearance, density and diversity (richness).

RESULTS AND DISCUSSION

TREE MORTALITY

Eucalypts are well adapted to withstand fire. Their bark is a good insulator against heat and so bark thickness is of considerable importance (Hingston 1985). Variations occur in thickness, however, due to a rough texture and the presence of furrows. Both Jarrah and Marri have a thick rough outer bark layer. Marri bark, however, is deeply fissured (Photo 2) and would be expected to offer less protection to the sensitive underlying (living) cambial layer which is killed by temperatures as low as 65°C (Luke and McArthur 1978). Marri mortality would therefore be expected to be higher than Jarrah as was found by Kimber (1971) in a study carried out after the devastating 1961 Dwellingup fire (McCormick 1971). When considering all ten quadrats together, mortality numbers for

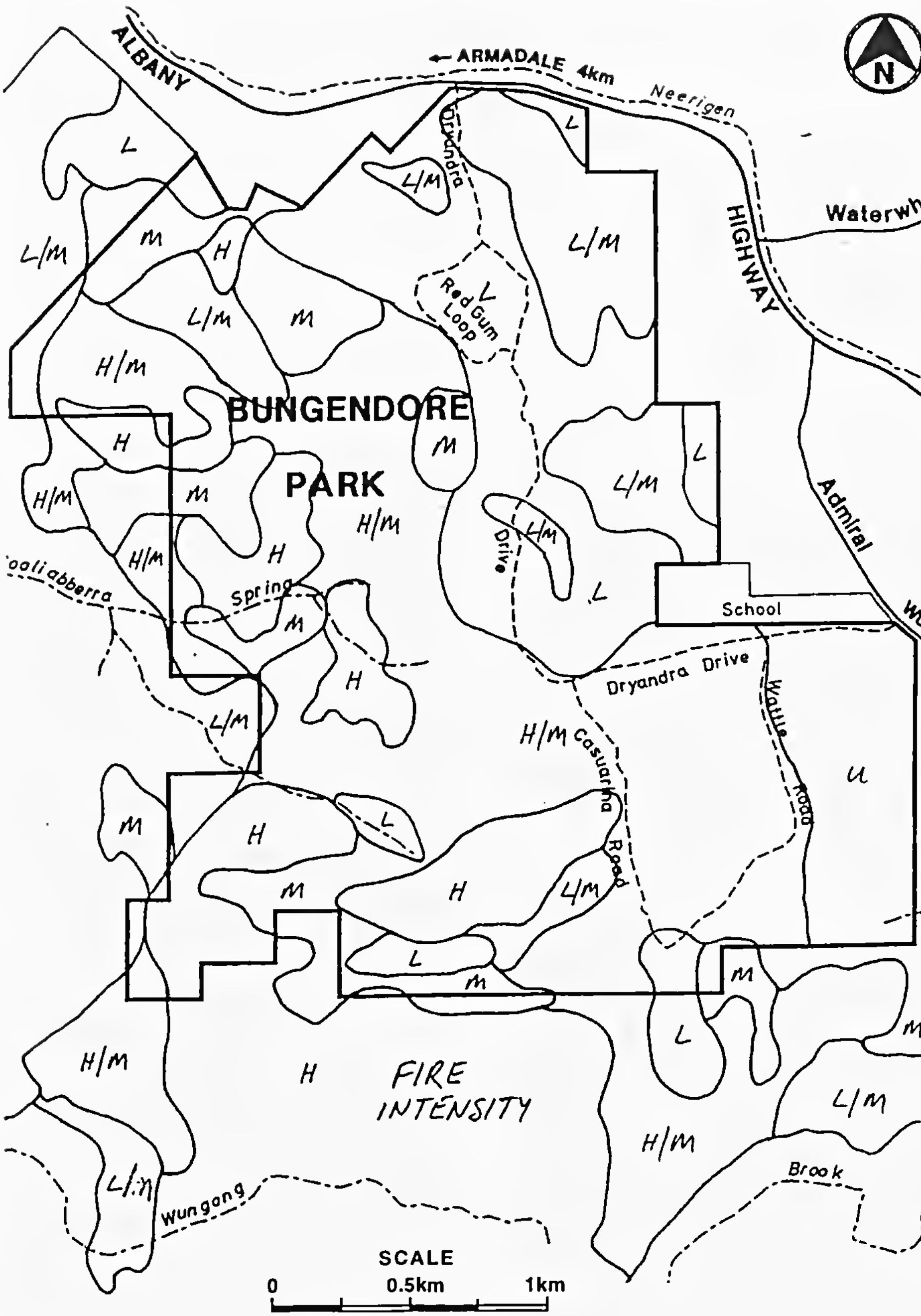

Figure 4. Fire Intensity (H = high, M = moderate, L = low, U = unburnt) Drawn from January 1995 aerial photograph.

Table 1. Tree Mortality (all quadrats combined)

	Species	Total No. trees recorded from ten 100m x 100m quadrats	% dead (<6 months after fire)	% dead (>12 months after fire)
a	*Corymbia calophylla*	1798	3.3	1.6
b	*Eucalyptus marginata*	1698	7.4	2.6
c	*Eucalyptus wandoo*	635	20.3	9
d	*Allocasuarina fraseriana*	280	5	0.7
e	*Banksia grandis*	1459	38	31
f	*Persoonia longifolia*	10	40	0
g	*Persoonia elliptica*	2	0	0

Jarrah exceed those for Marri (Table 1). If the quadrats are considered separately, however (Table 2), mortality numbers for only four of the ten quadrats were higher for Jarrah. Furthermore, re-sampling of all quadrats from 12 months up to 6 years after the fire showed a greater decrease in recorded dead trees for Jarrah than Marri as regeneration got underway. All tree species showed a decrease in recorded deaths in subsequent re-sampling of the quadrats.

In Jarrah and Marri, mature trees were the first to display regrowth (most within 6 months using epicormic shoots) whilst saplings regenerated mainly from coppice regrowth some time later (1–2 years). In Wandoo, only the larger, more mature trees displayed epicormic regrowth, most coppicing from the base (Photo 3). Epicormic shoots on many of the larger Marri and Jarrah trees died and fell off within 12 months (Photo 4) as if regeneration had begun but failed, possibly due previous tree damage or the fire occurring at the beginning of summer with no substantial rains to follow (Table 3).

Drought can affect regeneration (Hussey and Wallace 1993). Crown regrowth in most of these individuals, however, continued to flourish as epicormics lower on the tree serve only to maintain the tree in the short term while crown regrowth is established (Luke and McArthur 1978). One Wandoo was recorded dead two years after having displayed epicormic regrowth initially and then failing to maintain any crown or coppice foliage (Tree mortality quadrat TM 6).

Tree mortality decreases with size of tree (Williams 1995, and Burrows 1987). Consequently, saplings usually show greater mortality than larger trees (Shea *et al.* 1979) (Photo 5). Quadrat No. 6 had a large number of individual trees (1247), most of which were Marri (1035) and a high proportion with a diameter at breast height (dbh) of <10cm. Furthermore, this quadrat occurred towards the centre of the park which had not been burnt for 16 years and was in a high/moderate fire intensity region (estimated to be >4000

Table 2. Tree Mortality (individual quadrats)

	Quadrat Number														
	1			2			3			4			5		
Species	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
a	55	2	2	198	6	5	13	7	0	53	2	2	112	1.8	1.8
b	173	10	4	342	5	3	81	10	2.5	–			4	75	25
c	–			–			–			250	13	5	353	24	13
d	–			55	0	0	171	6	0	–			–		
e	339	21	9	153	55	46	6	0	0	–			–		
f	–			–			–			–			–		
g	–			–			–			–			–		

	Quadrat Number														
	6			7			8			9			10		
Species	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
a	1035	0.5	0.5	61	8	5.5	61	18	0	10	10	10	200	9.5	3
b	180	4.5	3	179	5	2	311	13	2.5	142	7	3	286	4.5	0.6
c	32	0	3	–			–			–			–		
d	–			–			54	5.5	3.7	–			–		
e	–			46	69	59	458	51	44	226	46	41	66	50	36
f	–			–			10	40	0	–			–		
g	–			–			2	0	0	–			–		

Legend:

A: Total Number of trees in quadrat

B: Percentage of trees recorded dead within 6 months

C: Percentage of trees recorded dead after 12 months

Species Key:

a. *Corymbia calophylla*
b. *Eucalyptus marginata*
c. *Eucalyptus wandoo*
d. *Allocasuarina fraseriana*
e. *Banksia grandis*
f. *Persoonia longifolia*
g. *Persoonia elliptica*

Table 3. Monthly rainfall for Bedfordale.

Month	Dec 1994	Jan 1995	Feb 1995	Mar 1995	Apr 1995	May 1995	June 1995	July 1995	Aug 1995	Sept 1995
Rainfall received (mm)	0.8	0.4	8.8	1.0	15.2	168.6	158.6	292.6	107.4	86.3
Average (last 8 years) (mm)	11.7	20.1	3.4	25.7	30.4	119.1	177.3	208.3	164.3	119.1

kW/m). Photo 6 provides further evidence of the fire intensity in this quadrat as large sheets of bark peel from a large Jarrah showing the extent of cambial damage during the fire (Abbott and Loneragn 1983). Baird (1977) reported that fire-induced cambial damage in Marri often took 3–4 years to become evident through bark loss. Tree mortality for this quadrat was very low (Marri = 0.5%, Jarrah = 3%). It should also be noted that very few saplings showed epicormic regrowth and regenerated only from rootstock coppice, indicating that the original bole was killed or severely damaged. Trees older than 5 years usually have lignotubers large enough to coppice successfully which appears to be the case in this quadrat.

Jarrah seedling emergence is greatest when leaf litter and understorey species are removed such as after fire (Stoneman and Dell 1994). Very few seedlings of either Marri or Jarrah were recorded from any of the quadrats. With respect to rainfall, December 1994 and January 1995 were both below average followed by an above average February and then two more well below average months (Table 3). Seed germination may have been stimulated by the February 1995 rain but failed to progress in the subsequent two dry months. Alternatively, low numbers of Jarrah and Marri seedlings may be due to seed removal by vertebrate and invertebrate fauna seed harvesting by birds, rodents and ants has significant effects on seedling emergence of Jarrah (Stoneman and Dell 1994).

Tree mortality was higher for Wandoo than for either Jarrah or Marri (Tables 1 and 2). Without a protective layer of thick rough bark, Wandoo trees appear to be more susceptible to high intensity fires. Burrows *et al.* (1990) reported death, severe bole damage and bark loss in Wandoo trees in a high intensity (about 2000 kW/m) section of a prescribed burn south-east of Perth (Burrows *et al.* 1990). Kimber (1971), however, found that Jarrah suffered no bole damage from fires intense enough to cause crown damage (McCormick 1971). Complete defoliation of Wandoos occurred in quadrats 4 and 5 which contained the majority of Wandoo trees in Bungendore Park. Furthermore, these quadrats were located on a steep west-north-west facing slope at the top of the scarp and fires are known to spread more rapidly up steep slopes (Hussey and Wallace 1993). In this region the fire was driven along and up the slope by winds from the south-west. High intensity fires are the most likely consequence of a long unburnt area is due to the fact that as time goes by (20–25 yrs), the fuel load contains less leaf litter and more bark, branches, boles and fruits (Western Australian Fire Review Panel 1994). Consequently, this area probably experienced the highest fire intensity in the park (estimated to be well above 4000 kW/m). In this study, as in that of Burrows (Burrows *et al.* 1990), Wandoo regeneration and seedling germination occurred in a clumped distribution, probably associated with ashbeds (forest soils which have been exposed to very high temperatures for a prolonged period during the combustion of heavy fuels such as logs and limbs). Wandoo regeneration away from ashbed was recorded by Burrows *et al.* (1990) to be poor in site-vegetation type M. Both tree mortality quadrats TM 4 and TM 5 were classified as vegetation site type M and several large fallen Wandoo trees smouldered for many days within one of these quadrats (TM 5) (Photo 7). Dense thickets of Wandoo saplings can now be found here.

When considering individual quadrats for Wandoo tree mortality, highest mortality occurred in that located in the highest fire intensity area (TM 5) (24 % dead on initial visit falling to 13 % after three years). Wandoo mortality in TM 4 was slightly less than that in TM 5 (falling from 13 % to just 5% after three years), probably because TM 4 is in a moderate fire intensity area and had been control burned just 5 years previous. Interestingly, TM 6 for which an unusually low Marri sapling mortality was recorded, also contained 32 Wandoo trees, none of which was recorded dead (Table 2).

Much of the regrowth of Wandoo was either by coppice shoots (including many of the larger trees with a dbh>20cm) or small numbers of seedlings. Only large, mature trees displayed epicormic shoot regrowth (Photo 8). Wandoo were slower to produce leaves from epicormic shoots than Jarrah or Marri, most appearing well after 6 months.

Wandoo seed regeneration is favoured by dry autumn fires and needs ashbeds for germination (CALM 1994) and so fewer than expected seedlings were recorded in this study, probably due to the timing of the fire. Ashbeds remain, however, for up to 2–3 years (Burrows 1983), so despite the timing of this fire, Wandoo seedlings continued to appear in subsequent years.

Allocasuarina trees are often badly damaged by fires but survive in poor condition such as with hollowed trunks or untidy and sparse canopy foliage (Baird 1983) (Photo 9). Three quadrats contained a total of 280 individuals of *Allocasuarina fraseriana*, only two trees failing to regenerate in a High/Moderate fire intensity quadrat unburnt for 16 years. Regrowth in this species was almost entirely via epicormic shoots along the trunk and in the crown (Photo 10). Both young and older trees resprouted vigorously.

Banksia grandis, especially older trees, appears more susceptible to fire than any other tree species in Bungendore Park. Moderate to high intensity fires (600–1500 kW/m) will kill younger plants (dbh <5 cm) to the ground (but these readily re-shoot from lignotuber) while older trees (dbh >12 cm) are killed outright (Burrows 1983). Shea *et al.* (1979) reported a *Banksia grandis* mortality of 20%, 20 months after a 4000 kW/m controlled burn near Dwellingup (whilst recording only 0.8% for Jarrah and 1.7 % for Marri in the same plot). 31%

Table 4. Quadrat burn details and site-vegetation type

Tree mortality quadrat No.	Fire intensity (H, M, L)	Years since last burn	Site vegetation type
TM1	½ H/M and ½ L/M	5	S (variant)
TM2	½ L and ½ H/M	16	S/P
TM3	L/M	16	P
TM4	M	5	M/G
TM5	½ H and ½ H/M	16	M/G
TM6	H/M	16	R
TM7	H/M	16	S
TM8	H/M	16	S/P
TM9	H/M	16	S/D
TM10	L	3	S (variant)

mortality was recorded from the seven quadrats containing *Banksia grandis* in Bungendore Park. Four of these quadrats (TM's 2, 7, 8 and 9) had very similar fire details (High/Moderate intensity and unburnt for 16 years – Table 4). In these quadrats, *Banksia grandis* mortality was high initially and remained high for subsequent visits. These quadrats also contained a greater number of older *Banksia* trees and the deaths of these appear to be largely responsible for the high mortality rates recorded here (Photo 11. showing old dead Banksias and healthy seedling Banksias in TM 8.). The regenerative capacity of *Banksia grandis* lignotubers appears to decrease with age and size of tree. Quadrats which showed a greater reduction in *Banksia grandis* mortality for subsequent visits were those in low fire intensity areas and which had been burned <5 years ago (TM's 1 and 10). In his study, Shea *et al.* (1979) also reported that seedling Banksias had re-established in many areas since the fire.

Banksias are highly susceptible to the Jarrah dieback fungus (*Phytophthora cinnamomi*) and the use of high intensity fires to reduce the *Banksia* population in a forest as a means of controlling the disease has been suggested. Intense wildfires have a sterilizing effect on the soil and greatly reduce the populations of soil microbiota (Australian House of Representatives 1984). Restrictions on vehicle movement and horse riding have kept the spread of dieback disease through Bungendore Park to a minimum and evidence of the disease is found mainly in and around previously disturbed areas such as disused gravel pits. As a result, and perhaps also from the effect of large numbers of *Acacia pulchella* which is known to suppress the activity of the dieback fungus (CALM 1994), the majority of the park remains relatively dieback-free. It would, however, take several high intensity fires to achieve the effect of controlling dieback through the reduction of the *Banksia grandis* population and no significant reduction in the density of *Banksia* understorey would be achieved from a single high intensity fire (Shea *et al.* 1979). Nevertheless, from the point of view of forest health, infrequent high intensity hot summer fires such as the 1994 wildfire in Bungendore are likely to be of long-term benefit due to some degree of soil cleansing and a flush of nitrogen-fixing legume species. Such fires are ecologically desirable (Burrows 1983) although Jarrah trees may suffer from hot fires which kill cambial tissue, sapwood and the outermost hardwood as this produces a scar that allows fungus to enter the tree which then allows termites to follow (Perry *et al.* 1985).

Neither of the two *Persoonia* species (*P. elliptica and P. longifolia*) was killed by the fire. Individuals of these species regardless of their location with respect to fire intensity or history all showed healthy epicormic regrowth in the upper trunk and crown.

SPECIES REAPPEARANCE

PART 1: OVERALL REAPPEARANCE

352 species are known to occur in Bungendore Park. Over the 7-year period of data collection, a total of 197 species were recorded to have re-appeared at some time during the study.

No single quadrat contained a significantly greater number of re-appeared species than other quadrats (Table 5), although the suite of species recorded from each plot varied depending on the vegetation type, fire intensity and fire history. The number of species re-appearing in each plot (average of 56 species per quadrat) was substantially lower than the total of 197 recorded for all plots over the 7-year study period, suggesting that to get a comprehensive list of reappearance species many sample quadrats in a wide variety of vegetation types is required.

Nearly half (48%) of all species

Table 5. Quadrat Species Reappearance, fire details and Vegetation Type.

	Species Reappearance Quadrat Number								
	1	2	3	4	5	6	7	8	9
Site vegetation type	P	G	G	R	S	T	S/P	D	S/P
Fire intensity	L/M	H	H	H/M	H/M	L	H/M	H/M	L
Years since last burn	16	5	16	16	16	1	16	16	3
Number of species recorded	54	65	58	66	49	33	63	58	64

recorded could be found in a single quadrat. Very few of the species recorded were found to be widely represented in the sample sites, only 11% being recorded from six or more of the quadrats and this figure dropping to just 6% recorded from seven or more quadrats. *Hibbertia hypericoides* was the only species recorded from all nine quadrats. Four species (*Eucalyptus marginata, Phyllanthus calycinus, Xanthorrhoea preissii* and *X. gracilis*) were located in eight quadrats. The next most widespread species were *Acacia pulchella, Chamaescilla corymbosa, Dryandra lindleyana, Hibbertia commutata, Lechenaultia biloba, Lomandra preissii* and the common weed *Oxalis pes-caprae* which were recorded from seven of the nine quadrats. There appears to be no relationship between the total number of species re-appearing (species diversity) and either vegetation type, fire intensity or time since last burn. These factors probably have a bigger influence on the type of species appearing after a fire and the densities with which these species re-appear.

Quadrat 6 contained the lowest number of species. This site was not burnt in the 1994 wildfire but rather was subject to a prescribed burn just one year before. Consequently, it was not sampled until the end of the study period when it would display a more consistent suite of species. This, however, was after the post-fire peak in species richness known to occur between 3 and 5 years (Burrows 2000 b.). Secondly, the quadrat was sampled in summer and many ephemeral species may not have been evident.

PART 2: REGENERATION STRATEGIES

Bungendore was a high intensity summer fire and the response mechanisms of different plant species varies depending on season, intensity and frequency. (Lamont 1985 and Hobbs 1995) (although van der Moezel suggest that these mechanisms may be adaptations produced in response to other environmental factors such as drought or insect attack) (van der Moezel *et al.* 1987). Previous studies of fire regeneration in the Jarrah forest have found that about 70 % of all understorey species on drier, upland sites resprout following fire, the remainder regenerating from seed stored in the soil or in woody fruits in the canopy (Burrows 1997). Higher numbers of seeder species are found in seasonally moist sites such as creek lines. Quadrats 2 and 4 contained the greatest percentage of seeders (Tables 6 and 7). One of these plots included exposed granite outcrops which retain moisture around their margins and the other was sited alongside a major drainage line in the park (Cooliabberra Creek) which flows in winter. *Acacia pulchella* and *Acacia alata* regenerated rapidly and profusely at these locations and high species densities were recorded for these two species (Photos 12, 13 and 14). Both these quadrats were located in High/ Moderate fire intensity areas, conducive to legume germination and seedling establishment (hot fires also increase seed production) (Skinner 1984). There is also a very large ant population in this area

Table 6. Broad Regeneration Strategies.

	All quadrats	Species Reappearance Quadrat Number 1	2	3	4	5	6	7	8	9
Regeneration Strategy	% of species using strategy									
Seeders	21.5	19	28	18	28	11	16	22	22	17
Sprouters	55	79	42	50	57	71	70	61	68	71
Geophtyes	22	28	28	28	13	17	9	16	11	10

Table 7. Specific Regeneration Strategies.

	All quadrats	Species Reappearance Quadrat Number 1	2	3	4	5	6	7	8	9
Regeneration Strategy	% of species using strategy									
2	19	19	23	18	28	11	16	18	22	17
4	5	8	5	5	8	6	6	7	4	7
5	41	61	32	33	39	51	42	38	48	54
6	4.5	5	0	5	4	6	13	11	6	5
7	2	5	5	7	6	8	9	5	4	5
8	2.5	0	5	0	0	0	0	4	0	0
9	2.5	0	0	0	0	0	0	0	4	0
10	1.5	0	2	2	0	0	3	0	0	0
11	22	28	28	28	13	17	9	16	11	10

Regeneration Strategy Key: (after Burrows 1994)

2 – killed by 100 % scorch, uses soil-stored seed
4 – survives 100 % scorch, soil suckers
5 – survives 100 % scorch, basal sprouts
6 – survives 100 % scorch, epicormic shoots
7 – survives 100 % scorch, large apical bud
8 – killed by 100 % scorch, uses seed (from soil or canopy)
9 – survives 100 % scorch, uses 4, 5, 6, 7, or 11
10 – uses spores (ferns)
11 – geopyhtes (surviving 100 % scorch, re-sprouting from underground storage organs).

which may have harvested a substantial underground reservoir of seed. Unlike woody trees and shrubs which survive for a long time after resprouting, however, obligate seed species such as some species of *Acacia* and other legumes which regenerate in large numbers after a hot summer fire tend to die within 7 –10 years.

(Burrows 1997). Both these species (*Acacia pulchella* and *A. alata*) showed signs of dying off after 6–7 years (Photos 15 and 16).

The response of leguminous species to fire is well documented. Shea *et al.* (1979) found that legume regeneration rarely followed 20 – 150 kW/m prescribed burns and more usually occurred after high intensity fires. He also noted that legume species had decreased in the forest as a result of prescribed burns. Burrows (1983) concluded that legumes needed dry soil (which allows better heat penetration) (Hussey and Wallace 1993), a large quantity of ground fuel and no subsequent drought, grazing or competition in order to regenerate successfully as these hard seeded species such as *Acacia* need hot fires to crack the seed coat. Many of these conditions were met by the 1994 fire in Bungendore Park and possibly helps to explain why the park has a large number of legumes and a low incidence of Jarrah dieback.

The benefits of legume regeneration to a forest are that they fix atmospheric nitrogen and so play an important role in forest fertility whilst encouraging the return of native mammal species (Shea *et al.* 1979), and many species such as *Acacia pulchella* produce fungus inhibiting micro-organisms which reduce the susceptibility of other dieback sensitive species to infection (Skinner 1984). Most legumes will, however, complete a useful lifecycle and achieve peak seed production within 6 years (Skinner 1984) and changes in species composition, density and diversity after fire are probably short lived (<10 years) as legumes die off. An occasional hot summer burn is, therefore, desirable in the Jarrah forest in order to maintain a large population of leguminous species (cool, controlled burns reduce legumes and favour Proteaceae) (McCormick 1971). It should be noted that Species Reappearance quadrat number 9 which is not located in a moist site, had a low fire intensity and was burnt just three years prior to the 1994 fire, displayed a vigorous regrowth of *Acacia lateriticola*, suggesting that the fire in this area was still sufficiently intense to achieve successful legume regeneration. (Photo 17). A density of 337 plants per 100 m^2 was recorded for this species in this quadrat in 1998 (compared to just 95 per 100 m^2 for *Hibbertia hypericoides*, another common species in this quadrat).

Of the many species using some form of re-sprouting as a method of survival against fire, the first to re-appear in Bungendore Park were *Macrozamia riedlei* and the two common *Xanthorrhoea* (*X. preissii* and *X. gracilis* although in some plots *X. gracilis* was 5–6 months behind *X. preissii*). Species of Xanthorrhoeaceae and Orchidaceae are also stimulated to flower after fire (Photo 18.). Within six months there were numerous woody perennials regenerating. Five genera in the Proteaceae (*Dryandra, Grevillea, Hakea, Banksia, Petrophile, Synaphea* and *Persoonia*) all had species regenerating commonly. Four species of *Hibbertia* (*H. hypericoides, H. commutata, H. huegelii* and *H.*

amplexicaulis) were widespread by this stage and *Bossiaea ornata*, *Daviesia decurrens*, *Hovea chorizemifolia*, *Kennedia coccinea* and *K. prostrata* represented the Papilionaceae family. *Phyllanthus calycinus*, *Trymalium ledifolium*, *Clematis pubescens*, *Isopogon sphaerocephalus*, *Lasiopetalum floribundum* and *Styphelia tenuiflora* were also common by six months. Of these species, all except *Synaphea petiolaris* persisted through to the final sampling 7 years after the fire (resprouters may survive drought and grazing better than obligate seeders as they have an intact food store root system –) (Hussey and Wallace 1993). Resprouters which were slow to re-appear included species of *Conostylis*, *Dampiera*, *Gompholobium*, *Astroloma*, *Leucopogon* and *Pimelea*, taking 2–3 years to return to the park.

PART 3: FIRE FREQUENCY, REGENERATION MECHANISMS AND FIRE MANAGEMENT STRATEGY

Delfs *et al.* (1987) suggested that resprouters have an advantage over seed regenerating species as they have a well established rootstock to mobilize nutrients. Resprouters are favoured by frequent low intensity fires but, if too frequent, rootstock reserves decrease and they don't reach flowering age (Burrows 1985), so their numbers in the forest would decrease (CALM 1994). Fires which are too frequent or too infrequent produce lowered species diversity (Burrows 2000 b.). They also encourage weed invasion (Fisher 1998., Baird 1984., and Moore and Graham 1985). Fires must not, therefore, be more frequent than the time taken for many plants to reach maturity and set seed and not just to reach flowering stage (Hussey and Wallace 1993). For example, *Dryandra sessilis* flowers after 3–4 years but does not set seed until 8 years after fire (Hussey and Wallace 1993). Up to ten years is needed between fires for some other species to germinate and set seed. Therefore, fires which are too frequent can cause changes to species composition (Australian House of Representatives 1984). Frequent fires can also be responsible for soil deterioration and consequent poor growth of annual and herbaceous geophytes (Baird 1977). The large numbers of geophyte species such as *Chamaescilla corymbosa*, *Burchardia umbellata*, Droseras, Stylidiums and species of *Thysanotus* recorded in this study, especially from quadrats 1,2 and 3 bears testament to the fact that this is not the case in Bungendore Park which has had very infrequent high intensity fires. Long periods of fire exclusion on the other hand can produce a permanent decline in species richness if time between fires is greater than the shelf life of the seed (Burrows 1997). McCaw (1988), reported a decrease in species richness and diversity in the Jarrah forest when the period between fires was > 6 years and a similar trend exists in the Karri forest of South-Western Australia (Western Australian Bushfires Board 1977). Best seed germination depends not on the frequency of the burn alone but on the right combination intensity and season

(Skinner 1984). Therefore, a combination of spring and autumn burns could be desirable (Skinner 1984). It is now generally accepted that a rotational burn cycle which includes different seasons (Burrows 2000 a., and Burrows 1983) is the most likely to maintain habitat and species diversity (Hussey and Wallace 1993 and Western Australian Bushfires Board 1977) and would keep forest fuel loads below 8 tonne/ha which is below wildfire fuel load levels (Burrows 2000 b.). This is supported by the 1984 report on bushfires in Australia (Australian House of Representatives 1984).

Bungendore Park displays a mosaic of fire history (Figure 1) due to the controlled burns which have been executed around its perimeter and the large central area which encompasses many different vegetation types. This area has not been burnt for at least 16 years which has probably helped contribute to the diversity of habitats and species within the park and helped maintain its healthy condition. Furthermore, the fact that the park contains some areas burnt with a low fire intensity will hopefully allow some species not adapted to high fire intensities to survive in these areas and re-colonize other areas later. It was suggested that in local urban reserves, small, unburnt areas be left as a species bank for the recolonization of burnt areas (Australian House of Representatives 1984). Every species behaves differently in response to fire – what is good for one is not good for another (Baird 1983) and so a rotational burn strategy is likely to benefit the majority of species in Bungendore Park.

PART 4: SPECIES DIVERSITY

By six months after the fire, just 30 % of all species recorded during the study period had been observed (Table 8). By the end of 1995, however, after the first post-fire winter, 55% of the total had been listed due to the appearance of many species of herbaceous geophytes such as *Burchardia*

Table 8. Overall Species Diversity.

	Time since 1994 fire				
	Early 1995 (< 6 months)	Late 1995 (6–12 months)	1996 (18–24 months)	3–5 yrs	6–7 yrs
Species (% of total known for park)	16	31	39	33	30
Species (% of total recorded for 7 years)	30	55	70	59	54

Table 9. Individual Quadrat Species Diversity.

Quadrat No.	Total Number of Species				
	Early 1995 (< 6 months)	Late 1995 (6–12 months)	1996 (18–24 months)	3–5 yrs	6–7 yrs
1	16	32	40	39	23
2	13	27	44	41	33
3	11	39	18	36	19
4	14	33	42	36	33
5	9	25	27	25	20
6	N/A	N/A	N/A	N/A	33
7	22	45	46	52	37
8	10	29	30	33	38
9	21	38	47	49	33

multiflora and *B. umbellata*, and many species of *Drosera*, *Stylidium* and orchids. Unlike most geophytes which use some form of underground perennating storage organ to re-sprout, Stylidiums regenerate from seed, explaining why they were slightly slower to re-appear (most not recorded until the second post-fire year) than the other geophyte species. Species diversity reached a peak of 70 %, 2 years after the fire (normally between 3 and 5 years) (Burrows 2000 b.), while orchid numbers were still high and with the appearance of perennial species that had been slower to regenerate.

Rainfall following the fire may have played a part in this rapid increase in species diversity. The 1994 fire was followed by no good rains for a period of 5 months. For example, by the end of the first sampling in March 1995, Bungendore Park had received only 11 mm. Understorey species have small seeds and so cannot survive on seed-stored food reserves. These species soon die off if fire is followed by dry summer (Burrows 1983). Two years of above average rainfall, however, then followed this initial dry spell (53 mm above average for 1995 and 191 mm above average for 1996). Species diversity in Bungendore Park declined after 2 years as short-lived and fire-stimulated species (herbs, some grasses and orchid species) died out. During this period, however, although diversity was declining, numbers of some individual species were increasing. For example, *Hibbertia hypericoides* was recorded from quadrat SR9 on every one of the sampling dates for this quadrat and yet its density went from 5 plants/100m^2 in March 1995 to 25 plants/100m^2 in August of the same year and by August 1998, density was 95 plants/100m^2. This was probably also the case for many other species. A re-sampling after 10–15 years would provide a good indication of the park's true species diversity.

ORCHID SURVEY

Before the fire, a total of 31 orchid

Table 10. Annual orchid species numbers, related to fire-stimulation.

Year	Total no. species	% Fire stimulated	Number of species flowering only after fire
1993	31	48	1
1995	47	49	4
1996	30	46	2
1998	27	37	0
2000	19	47	0

species were known to occur in the park (Table 10). Approximately half of these are fire-stimulated. One species (*Prasophyllum giganteum*) was recorded from the park before the fire and is known to flower only after a summer fire. This plant was, however, recorded in 1994 from an area of the park that had been control burned in 1993.

The 1994 wildfire resulted in an increased number of orchid species for Bungendore Park. Sixteen species, new to the Park, were recorded in 1995 (Table 11 and Appendix 1). Four of these flower only after fire (*Caladenia nana* ssp. *nana*, *Cyanicula ixioides* ssp. *candida*, *Microtis* aff. *alba* and *Prasophyllum hians*). The 1995 sampling also saw greatly increased abundance of many of the fire stimulated species (Photo 19). Of the 23 fire-stimulated species recorded for 1995, eight species (35%) had populations of >20 plants at their recording site whilst only 2 of the 24 species which are not fire-stimulated (8%), had populations in excess of 20 plants (15 of these 24 species – 63%, had populations of less than 10 plants). For example, the Purple Enamel Orchid (*Elythranthera brunonis*) flowers more profusely following a summer fire whilst the Pink Enamel (*Elythranthera emarginata*) is not stimulated by fire. In 1995, populations of purple enamels with >20 were common in the park but only one individual of the pink variety was seen. Many of the fire-stimulated species would probably have been present in the park before the fire but in smaller numbers.

By 1996, the total number of orchid species had dropped to pre-fire levels (30 species). Fewer fire-stimulated species were recorded (14 species compared to 23 in 1995), and many species from the 1993 list such as *Pyrorchis nigricans*, *Cyanicula gemmata*, *C. sericea*, *Diuris setacea* and *Elythranthera brunonis* either failed to return or re-appeared in much smaller numbers. Furthermore, 12 of the 16 new records which had appeared in 1995 (including two of the four "fire-only" species – *Cyanicula ixioides* ssp. *candida* and *Prasophyllum hians*) were not recorded in 1996 (Table 11).

Observations in 1998 and 2000 saw further decreases in overall orchid numbers although a few new records were picked up during this 5 year period – species which may have been present in the park before but not recorded.

Table 11. New records of orchid species (post-fire).

Year	Number of new records	No. species fire stimulated	No. species flowering only after fire	No. of 1995 species not recorded
1993	–	–	–	–
1995	16	8	4	–
1996	3	1	1	12
1998	4	1	0	15
2000	0	0	0	15

Only one of these new records (*Prasophyllum plumaeforme*) is enhanced to flower following a summer fire and none of these new recorded species requires fire to flower. *Microtis* aff. *alba* was the only one of the sixteen new records for 1995 to be seen in the last 5 years of the survey. By the end of the study, *Caladenia flava* ssp. *flava*, *Cyanicula sericea*, *Diuris brumalis*, *D. corymbosa*, *Pterostylis recurva*, *Thelymitra crinita* and *T. macrophylla* were the more common species seen in the park.

Orchids are stimulated to flower after fire due the response of orchid tubers to ethylene gas released from the fire (Dixon 1989). Researchers are still investigating the stimulatory response of fire on orchid species centering on investigations not only into this but also on the nutrients released by ash and changes in mychorrhizal soil fungi.

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Appendix 1. Seven Year Orchid Survey of Bungendore Park

Species	ORCHID SURVEY Common Name	Location	1993	1995 <10	1995 10–20	1995 >20	1995	1996	1998	2000
Caladenia flava ssp *flava*	Cowslip	widespread *	Y			X	Y	Y	Y	Y
Caladenia longicauda ssp *longicauda*	White Spider	SR9	Y	X			Y	Y	Y	
Caladenia macrostylis	Leaping Spider		Y	X			Y	Y		
Caladenia reptans ssp *reptans*	Dwarf Pink Fairy	SR9 *	Y	X			Y	Y	Y	Y
Caladenia uliginosa ssp *uliginosa*	Darting Spider	*	Y		X		Y	Y		
Cyanicula deformis	Blue Fairy	SR9 *	Y			X	Y	Y	Y	Y
Cyanicula gemmata	Blue China	widespread *	Y			X	Y	Y		
Cyanicula sericea	Silky Blue	widespread *	Y			X	Y		Y	Y
Diuris brumalis	Winter Donkey	*	Y	X			Y	Y	Y	Y
Diuris corymbosa	Common Donkey	SR2 *	Y	X			Y	Y	Y	Y
Diuris longifolia	Purple Pansy		Y	X			Y	Y		
Diuris magnifica	Pansy	North of pit 7	Y	X			Y			
Diuris setacea	Bristly Donkey	Just W of pit 10 *	Y			X	Y			
Elythranthera brunonis	Purple Enamel	widespread *	Y			X	Y	Y	Y	Y
Elythranthera emarginata	Pink Enamel	SR9	Y	1			Y	Y	Y	Y
Eriochilus dilatatus ssp *multiflorus*	Common Bunny	pit 5 *	Y		X		Y	Y	Y	Y
Leporella fimbriata	Hare	*	Y				Y	Y		
Monadenia bracteata	South African Orchid		Y		X		Y		Y	Y
Prasophyllum elatum	Tall Leek	SR2 *	Y	X			Y	Y		
Prasophyllum giganteum	Bronze Leek	SR9 only*	Y	X			Y	Y		
Prasophyllum parvifolium	Autumn Leek	SR8	Y	X			Y	Y	Y	
Pterostylis aff. *nana*	Snail	SR9	Y	X			Y	Y	Y	Y
Pterostylis barbata	Bird	pit 5 car park	Y	X			Y	Y	Y	
Pterostylis recurva	Jug	pit 5 car park	Y	X			Y	Y	Y	Y

Pterostylis vittata	Banded Greenhood	SR9	Y	X			Y	Y	Y	Y
Pyrorchis nigricans	Redbeaks	entrance + SR3 *	Y			X	Y			
Thelymitra antennifera	Lemon-scented Sun	Near SR3	Y	X			Y	Y	Y	
Thelymitra benthamaniana	Leopard	Pit 5 and near SR1	Y	X		X	Y			
Thelymitra crinita	Blue Lady		Y		X		Y	Y	Y	Y
Thelymitra macrophylla	Scented Sun		Y				Y		Y	Y
Thelymitra stellata	Star	Localities withheld	Y		X		Y		Y	Y
NEW *for* 1995										
Caladenia hirta ssp *hirta*	Sugar Candy	SR4 *		X			Y			
Caladenia longicauda ssp *clivicola*	Hill's White Spider	widespread *				X	Y		Y	Y
Caladenia marginata	White Fairy	SR9			X		Y			
Caladenia nana ssp *nana*	Little Pink Fan	betw pit 5 & SR3 only*		X			Y			
Cyanicula ixioides ssp *candida*	White China	south edge of pit 5 only*		1			Y			
Diuris filifolia	Cats Face	Top of pit 5			X		Y			
Diuris laxiflora	Bee	SR2				X	Y	Y		
Diuris micrantha	Dwarf Bee	SR2			X		Y			
Drakea livida	Warty Hammer	top of ridge above Howe St		X			Y			
Lyperanthus serratus	Rattle Beaks	Robin Ramble		X			Y			
Microtis aff. *alba*	Scented Mignonette	SR7								
only*		X			Y	Y				
Prasophyllum aff *elatum*	Crowded Leek	nr SR3 *		X			Y	Y		
Prasophyllum fimbria	Fringed Leek	SR2 usually*			X		Y			
Prasophyllum hians	Yawning Leek	Widespread only*			X		Y			
Prasophyllum ringens	Little Laughing Leek	SR3			X		Y	Y		
Thelymitra pauciflora	Slender Sun Orchid	SR8		X			Y			

Species	ORCHID SURVEY Common Name	Location	1993	1995 <10	 10–20	 >20	 1995	1996	1998	2000
NEW for 1996–1998										
Caladenia latifolia	Pink Fairies	Wattle Rd.						Y	Y	
Microtis media ssp *media*	Common Mignonette	SR2						Y	Y	Y
Prasophyllum plumaeforme	Dainty Leek	Near pit 5							Y	
Pterostylis aff. *sanguinea*	Crowded Banded Greenhood	SR9							Y	
Pterostylis crispula m.s.	Snail Orchid	Near pit 5							Y	
Spiculaea ciliata	Elbow	SR3							Y	Y
Thelymitra pauciflora	Slender Sun	SR3						Y		

* = fire-stimulated
only* /usually* = flower only/usually after fire
Y = recorded that year
X = number of individuals in 1995

REPRODUCTIVE OBSERVATIONS OF A THORNY DEVIL, *MOLOCH HORRIDUS*, IN A NATURAL SEMI-ARID ENVIRONMENT

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ABSTRACT

A female Thorny Devil (*Moloch horridus*) was observed digging a nest burrow approximately 50 km north of Kalgoorlie in December 2001. Seven neonates hatched, with one being found and measured nearby. The burrow dimensions were: 890 mm long, 110 mm wide and 80 mm high, with the nest burrow about 300 mm below the surface. The temperature in the burrow was 24.7 °C (1400 hrs) and 24.4 °C (overnight minimum) a couple of days after the neonates hatched. The hatchling was SVL 38 mm, tail 28 mm, and 2.4 g. These data are compared with other published information on egg laying and oviposit sites in Western Australia.

INTRODUCTION

Little field ecology and few reproductive data have been reported on the Thorny Devil, *Moloch horridus*. Withers (1993), Withers and Dickman (1995), and Withers and Bradshaw (1995) have studied water and energy balances, cutaneous water acquisition and the role of its diet in determining the water, energy and salt balance. Pianka and Pianka (1970) and Pianka *et al.* (1998) have studied the ecology and reproduction, and reproductive information has been reported by Pianka *et al.*(1996), Sporn (1955; 1958; 1965) and White (1947).

I had the opportunity whilst in the field to observe the digging of a nest burrow and on a return trip measure a hatchling *M. horridus* and the dimensions of the empty nest burrow.

RESULTS

A gravid *M. horridus* was observed digging a nest burrow on 12 December 2001 about 10 km west of Broad Arrow (30° 27' S: 121° 20' E) in the northern Goldfields of Western Australia. The burrow opening was approximately 110 mm wide and 80 mm high in a flattened horizontal 'D' shape. The burrow was located in very hard, red laterite clay substrate, with a shallow sandy surface containing a scattering of surface granite and quartz rocks. The nesting burrow opening was dug away from any vegetation and loose surface rocks.

Digging was achieved by several scrapes of one foot, either the front or back, and then the other foot on the same side. The process was then repeated on the other side. After digging for approximately 4–5 scrapes by each foot, she would rest for 20–30 seconds before commencing to dig again. The female *M. horridus* was caught, measured (Table 1) and released back into the opening of the nesting burrow immediately so she could continue digging. Eggs were clearly visible in the abdomen of the female dragon; however, the number could not be counted. At the time of capture the nest burrow was only about 150 mm deep so the Thorny Devil was easily visible. Within a minute of being released back into the burrow, the female Thorny Devil left the burrow and walked quickly to shelter under a nearby spinifex tussock (*Triodia* sp.). This female *Moloch* had been caught twice before on 9 and 11 January 2001.

On 13 and 14 December, the nest burrow was deeper and the *M. horridus* was no longer visible at the bottom of the burrow, so we were unsure if the female was present in the hole. The opening to the nest burrow was marked with rocks and sticks on 15 December so that it could be located on a subsequent visit.

The nesting burrow was checked again on 8 January 2002 when it was found that the burrow had been closed, so that the opening was flush with the surrounding substrate. There were no external markings present that would have drawn predator interest to the patch of soil where the opening of the burrow had been. The burrow was observed daily for the following 16 days but there was no change.

On 7 April 2002 the nesting burrow was again revisited. There was a small hole about 30 mm by 30mm at the point where the original burrow opening was dug. This was the escape hole for the hatchlings. The nest burrow was excavated to measure its dimensions. The contrasting soft disturbed soil and hard undisturbed adjacent soil enabled the burrow to be excavated. The length of the burrow was 890 mm and the end was approximately 300 mm below the surface. The burrow was predominately straight with only a shallow left bend half way down its length, to avoid a rock. There was no enlarged nest chamber at the end of the burrow and the width of the tunnel stayed constant for its entire length (approximately 100 mm). The burrow was only back filled for the first 100–150 mm. The egg cases where laying on the soil at the base of the burrow.

Seven empty eggshells were found in the bottom of the burrow. A thermometer was placed in what used to be the bottom of the burrow, the burrow refilled and left overnight. The burrow temperature was 24.7 °C at 1400 hrs (ambient temperature 35.9 °C) and had dropped to a minimum

Table 1. Size and mass of female and hatchling *Moloch horridus*

Date	SVL and tail length (mm)	Mass (g)
9/1/01	96, 75	56.1
11/1/01	96, 75	54.1
12/12/01 (digging)	100, 75	71.0
10/4/02 (hatchling)	38, 28	2.4

of 24.4 °C overnight compared to the ambient minimum of 12.7 °C (Table 2). On 10 April 2002, a hatchling (umbilical scar was still clearly visible and unhealed) *M. horridus* was pit-trapped less than 100 m away. It was measured and released at point of capture (Table 1).

DISCUSSION

The digging technique used by the female *M. horridus* north of Kalgoorlie was similar to that reported by Sporn (1955). Digging techniques were not described by Pianka *et al.* (1996) or White (1947). White (1947) did, however, mention that the *M. horridus* "scraped the sand back with its fore-feet like a cat" when sealing up the surface of the burrow. I did not observe backfilling and sealing of the nest burrow.

Pianka and Pianka (1970) reports clutch sizes of 3 to 10 with a mode of 8. Sporn (1955; 1965) reports clutches of 5 to 9 eggs (5 clutches). This observation of 7 eggs is within the ranges reported. The mean length of the seven dried eggs is 20.3 mm. Hudson (1977) reported the eggs shells to be at least 18 mm in length. Pianka *et al.* (1996) reported the relative clutch mass of three *M. horridus* from the Great Victoria Desert as 34.2, 41.7 and 40.9%.

Egg incubation time for reptiles varies according to ambient temperature (Thompson and Pianka 2001). Sporn (1965) reported incubation periods for captured *M horridus* hatched in Mandurah, WA, ranging from 90 to 132 days, with a mean of 115 days. Hudson (1977) reported that eggs took between 104 and 110 days to hatch and Pianka *et al.* (1996) reports incubation periods of 123–124 and 127 days for *M. horridus* that hatched in the Great Victoria Desert. The length of time between digging of the nest burrow and finding the hatchling *Moloch* was 113 days, which is comparable with those reported elsewhere, although I cannot be certain that the hatchling was from the nest burrow described.

These eggs were laid much later than those reported by Pianka *et al.* (1996) in the Great Victoria Desert – 19 September, 3 October and 12 November. It is possible that the *M. horridus* that I observed would have laid on 15 or 16 December. This is about one month later than those observed in the desert. Pianka *et al.* (1996) does, however, comment that the dates of egg laying in the Great Victoria Desert were earlier than his earlier reports (Pianka and Pianka 1970) thus lengthening the estimate of the duration of the egg-laying season for desert specimens. In captivity, Sporn (1965) recorded egg laying between October 16 and December 9. Sporn (1965) reported double clutching by *M. horridus* on 25 October and

29 December, and Philipp (1979) on 7 November and 11 January. Both of these observations were made in captivity. Philipp (1979) also reports that M. *horridus* was able to store sperm, as there was no male present to re-fertilise his female between the first and second egg laying. Observations in captivity may not represent what occurs in nature as the food availability and climate are varied.

I found no evidence of an enlarged chamber at the base of the burrow that was reported by others. White (1947) for example, reports a nesting chamber 178 mm in diameter and 101 mm high and Pianka *et al.* (1996; 1998) reports nesting chambers in three different burrows; two of which were measured (120 mm wide, 90 mm high and 150 mm long; and 120 mm wide, 80 mm high and 120 mm long). Sporn (1955; 1958; 1965) also reports nesting chambers for the M. *horridus* that he observed to lay eggs whilst held in captivity.

The temperatures observed in the nesting burrow north of Kalgoorlie (Table 2) are lower than those observed by Pianka *et al.* (1996). Pianka *et al.* (1996) reports temperatures of 31 and 30.8 °C in the burrow chamber, whereas, I found maximum burrow temperature to be 24.7 °C with a minimum of 24.4 °C overnight compared to the ambient overnight minimum of 12.7 °C. These data indicate the nesting burrow was able to sustain a fairly constant temperature even though the ambient temperature was variable (12.7 – 41.4 °C).

Table 2. Temperature of nesting burrow

Location	Temperature (°C)
Overnight burrow minimum	24.4
Ambient overnight minimum	12.7
Base of burrow at 1400 hr	24.7
Ambient air at 1400 hr	35.9
Ambient maximum	41.4

The burrow I report was considerably longer (890 mm) than those previously reported elsewhere, although the depth below the surface, internal height and width of the burrow north of Kalgoorlie, are similar to those reported by White (1947; length 430 mm), Sporn (1955; length 560 mm) and Pianka *et al.* (1996). It is unknown why the length was considerably longer in my observation, particularly as the highly compacted laterite is likely to be at least as difficult to dig in as the sandy substrates at Coorow, Mandurah and the Great Victoria Desert. The burrow was only backfilled for the first 150–200 mm; this is the same as Pianka *et al.* (1996) and Sporn (1955) reported. Pianka *et al.* (1996) reported that hatchling M. *horridus* had dug themselves a new escape hole about 300 mm from the original burrow opening. The seven hatchlings from the nesting burrow I observed had dug themselves out the original burrow entrance. Neither Sporn (1955; 1958; 1965) nor White (1947) reported where the hatchling escape hole was located.

Pianka *et al.* (1996) and Sporn (1958) reported no eggshells present in the burrow chambers for the nest burrows that were excavated in the Great Victoria Desert and for a single nest burrow in Mandurah. Pianka *et al.* (1996) concluded that the hatchlings might have consumed their own eggshells thus providing extra nutrients (calcium, etc) for early growth. Eggshells were present in the burrow that I excavated. Given the size of the eggshells (mean length 20.3 mm, 0.1g) its possible that the hatchling could eat its own eggshell which is approximately 5% of its body mass however, it seems improbable given that the diet of *M. horridus* is strictly ants (Pianka 1986).

In summary, *M. horridus* is an egg laying dragon lizard, that digs a nest burrow and lay eggs in late Spring and early Summer, but is reported as double clutching in captivity, and lays between 3 and 10 eggs per clutch that take between 90 and 132 days to hatch. Nest burrows are dug at an oblique angle in open areas and sealed so visual detection of the nest site is difficult. The hatchlings, which are perfect replicates of adults, dig their own escape hole and are independent from birth.

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A FAILED BREEDING ATTEMPT BY BANDED STILT IN THE EASTERN GOLDFIELDS AREA OF WESTERN AUSTRALIA

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SUMMARY

This paper is based on data gathered on a breeding attempt by Banded Stilt (*Cladorhynchus leucocephalus*) during two visits to Lake Goongarrie (by K.H. Coate on 2 April 1999 and R.E. Johnstone and P. Stone on 20 April 1999). Less than 25 nesting events of these birds have been recorded, the majority being from the semi arid areas of the eastern goldfields in Western Australia. The most recent report of Banded Stilt breeding in Western Australia was in 1995 (after 'Cyclone Bobby') when about 10,000 birds nested on Lake Ballard and 20,000 on Lake Barlee (Minton *et al.* 1995). Previous breeding reports in the Menzies area have come from Lakes Barlee (Burbidge and Fuller 1982), Ballard (Kolichis 1976), Marmion (Kolichis 1976) and possibly Goongarrie (Johnstone and Storr 1998). The incidence of runt eggs is discussed and possible reasons for the abandonment of the eggs.

LOCATION

Lake Goongarrie is a large ephemeral salt lake (about 81 square kilometres) situated about 80kms north of Kalgoorlie in Western Australia. The breeding colony was located on a low island (800m x 500m) at 29°55'07"S 121°12'04"E.

BACKGROUND

On 1 April 1999, K.H. Coate and his wife on their way to join a Western Australian Naturalists' Club's Easter excursion at Goongarrie Station, camped overnight on the western shore of Lake Goongarrie, which had a shallow covering of water. A strong east wind was blowing across the lake bringing distant sounds from a large concentration of Banded Stilt. Although no birds could be seen from the shoreline, it was decided to investigate their breeding status at first light the following morning. Expecting the birds to be in fairly close proximity, Coate departed the campsite with the understanding that he would return shortly afterwards.

After walking in an easterly direction for about 2 hours, through water of an average depth of 150–200 mm, (115mm on R.E. Johnstone's visit) he came upon an estimated 2,000–3,000 Banded Stilt. They were feeding over an area of about 500 square metres near the centre of the lake. Many pairs were copulating, which indicated a breeding colony was situated somewhere on the lake. On further investigation, a low island with a large breeding colony was discovered several kilometres to the south of this concentration of birds. He estimated there were about 3,000 birds there, although from photographs taken at the time, it would appear this was an under estimation. Along the gradually sloping shoreline and down to the water, were thousands of recently abandoned fresh eggs from a failed breeding attempt. Eggs were pushed together in piles or lying in water at the edge of the island, while others were covered or partially covered in sand. This indicated that weather conditions consistent with severe wind and wave action whipping up over the shallow lake body, was the cause of abandonment. Birds had regrouped and were vigorously re-nesting in low samphire shrubbery, higher up, directly behind the original site.

As the breeding of this species is a rare event in Western Australia, R.E. Johnstone and P. Stone visited the colony eighteen days later (20 April 1999) only to find it abandoned. A single flock of 1,000 birds was observed feeding near the centre of the lake.

Shortly after these visits Conservation and Land Management carried out an aerial survey and reported about 1,000 birds on Lake Goongarrie and about 1,000 birds on Lake Marmion north east of Lake Goongarrie. They found no breeding colonies on any of the Menzies lake systems, most of which had little water in them (pers. comm.).

WEATHER

Weather conditions contributing to the filling of Lake Goongarrie were received from the Bureau of Meteorology. Information was that it is not uncommon for a line of severe thunderstorms to bring heavy rain and strong wind to the Lake Goongarrie area, missing either Menzies and/or Kalgoorlie. Satellite imagery received from the 'Geo Stationery Meteorological Satellite GMS5', showed severe thunderstorms centred over Lake Goongarrie on the afternoons of 13, 14 and 15 March 1999. It would appear that during this time enough water was deposited in the normally dry lake to attract the Banded Stilts. The ability of Stilts to rapidly find suitable water in arid areas, following storms or after rain fronts have gone through, hundreds of kilometres away, is well recognised, but still a mystery.

There were two cyclones in the area in March 1999. 'Cyclone Elaine' between 17–20 March is not thought to be a factor, as it was more a rain bearing depression that went well to the south and west of Lake Goongarrie. The most likely cause

1. Buried and abandoned Banded Stilt eggs after severe wind and wave action decimated the breeding colony on an island in Lake Goongarrie. Photo: 2 April 1999, Kevin Coate.

2. Away from the abandoned eggs the Banded Stilts had regrouped and were vigorously re-nesting in low samphire shrubbery. Photo: 2 April 1999, Kevin Coate.

3. A clutch of freshly laid Banded Stilt eggs showing typical scrawls and blotches at Lake Goongarrie. Photo: 2 April 1999, Kevin Coate.

4. Banded Stilts nesting amongst samphire shrubbery away from the shoreline at Lake Goongarrie. Photo: 2 April 1999, Kevin Coate.

5. Bottom row four typical eggs of Banded Stilt and top rows a series of runt eggs collected on Lake Goongarrie on 20 April, 1999. Photo R.E. Johnstone.

for the decimation and abandonment of the first breeding colony, appears to have been severe weather conditions associated with 'Cyclone Vance' between 18–23 March. The gold mining town of Menzies, about 40kms NNW of Lake Goongarrie, recorded 83.4mm of rain between 22–24 March. Menzies does not have a weather station to record wind, however, wind gusts of up to 34 knots were recorded at Kalgoorlie on 23 March 1999.

Before Johnstone *et al.* visited the area, there were isolated thunderstorms on 11 April at Ora Banda about 37km to the southwest, and Menzies (where 18mm of rain was recorded). On 12 April, Menzies had another storm, from which a lesser amount of rain fell.

NEST DATA

Johnstone and Stone found most eggs from the first breeding attempt were rotten on the beach area. Protected nests above the strand zone contained eggs ranging from fresh to 0.3 incubation. Nests with eggs from the more recent breeding attempt ranged from fresh to 0.2 or 0.3 incubation. Most nests were small scrapes 13–16cm wide, 3–4cm deep and placed 20–25cm apart (sometimes up to 1 m in outer areas). Some nests were large deep scrapes 20cm wide and 4cm deep, built up and lined with fine pieces of quartz and pieces of samphire. The entire main nesting area (including first and second attempts) measured 70m long and 14m wide. Nests were counted in three 5m plots in different parts of the colony, and contained 350 nests, 320 nests and 330–350 (partly in strand zone). Overall this gave an estimate of 14,500 nests.

Egg weights ranged from 34.5 to 48g (mean 18 eggs 40.75g). Egg size, 132 eggs from 32 clutches ranged from 48.0–60.4 x 36.7–41.5 mm. A series of eggs including some runt eggs were collected from the colony. The smallest runt measured 19.9 x 14.7 mm.

About 500m to the east of the main site (not there on Coate's visit) was another small abandoned colony above the beach in open samphire. It was in an area 35m long by 7m wide and contained 30 fresh scrapes, 67 nests with 1 egg, 43 nests with 2 eggs and 22 nests with 3 eggs. A number of eggs were checked – all fresh. Twenty metres further east was a third abandoned colony (not there on Coate's visit) that contained 10 fresh scrapes and 6 nests with one egg.

DISCUSSION

Despite the appearance of very favourable breeding conditions with egg laying and incubation under way, all three colonies were abandoned at the same time.

On Coate's visit there was no sign of predation, but Johnstone found crows had recently predated 2 clutches of eggs. There was an abundance of food. On both visits the lake contained large numbers of brine shrimp (*Artemia salina*).

Although infrequently filled, the

ephemeral lakes system out from Menzies are ideal for Banded Stilt when conditions are favourable. However, flooding is unpredictable and water can dry up quickly under the harsh conditions that prevail.

There has been a number of instances of previous breeding colonies being abandoned in the area. The first record was in 1929 when T. Smith of Kalgoorlie found thousands of young Rottnest Snipe (Banded Stilt) dead in a strip of country about 30 miles wide some distance from Menzies (Jenkins 1975). Police sergeant A. Middleton of Menzies reported chicks walking through the town in 1963 (Jenkins 1975). In September 1980 A.A. Burbidge and P.J. Fuller found a recently abandoned colony on islands in Lake Barlee (Burbidge and Fuller 1982). They estimated there to be about 179,000 nests in the area, with about 255,000 addled eggs and dead chicks scattered around the colony.

In September 1986, K.H. Coate *et al.* came upon hundreds of recently killed immature Banded Stilt along the road north of Menzies. These birds, not yet able to fly had walked south from Lake Ballard when the water dried up. In one measured stretch of 5km, 234 dead birds were counted, almost all having been killed by motor vehicles. A few small clusters of 2 or 3 birds were seen alive near small pools of water in roadside drains. On arrival at Menzies it was learned that an estimated several thousand birds had walked through the town 3 days earlier. It seemed possible that some instinct was directing them south from Lake Ballard (25km north of Menzies). When driving past Lake Goongarrie (40km to the south of Menzies), there appeared to be some water in the lake.

There are also some historical reports of Banded Stilt abandoning breeding sites just prior to egg laying: e.g. in early January 1967, P. Stone (pers. comm.) found 3,000 birds on Lake Kondinin, which had been filled by rain in July 1966. About 90–100 pairs of Banded Stilt completed nest scrapes on sandy spits and islands, but by the end of January (when "Cyclone Elsie" passed well to the north of this area, but dropped rain inland) only 300 birds remained on the lake and no eggs were laid despite the water levels remaining very high. P. Stone also recorded small colonies abandoned on Lake Grace in 1960 and 1965 (pers. comm.).

Although the reason for the abandonment of eggs by the Banded Stilt in April 1999 is unclear, there are several possibilities. (1) Storms in the area during 11–12 April. (2) They may have sensed the shallow coverage of water in Lake Goongarrie would not last; hence moved to a more favourable site away from the Menzies lake systems.

During March 1999 cyclones 'Elaine' and 'Vance' dumped huge amounts of water in lake systems to the south and west of the Menzies lake systems, completely filling many of them. For example, on 31 March Coate visited another large ephemeral lake – Lake Deborah East, about

180km SSW from Lake Goongarrie, and found it to be brimming full with water.

ACKNOWLEDGEMENTS

We would like to thank Kevin Smith and Brad Santos of the Severe Weather Section, Bureau of Meteorology, for researching weather patterns over Lake Goongarrie during March and April 1999; and Yvonne Coate who assisted with the preparation of this paper. K.H. Coate would also like to thank Yvonne Coate for her efforts in alerting members of the Western Australian Naturalists' Club camped 20 kms away at Goongarrie station homestead, to the possibility of a search when he failed to return from the lake after 6 hours. We also thank Phil Stone for providing data on Banded Stilt at Lake Kondinin.

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Red-necked Phalaropes regularly appearing on Rottnest – Over the last few years Red-necked Phalaropes (*Phalaropus lobatus*) have been regularly seen on Rottnest Island. Red-necked Phalaropes are an unusual migratory wader to the south-west of Western Australia. They were first recorded on Rottnest in August 1979 by Roy Wheeler (*Western Australian Bird Notes*, No 13, 1980) which was probably the first record for the south-west of WA (Ron Johnstone, pers. comm., 1994).

The first Red-necked Phalarope I saw was on 30 July 1994, possibly the earliest winter sighting of the species in the south-west of WA. It was with eighteen Banded Stilts at the western end of Pearse Lakes (near where the old salt works were located) on Rottnest. The phalarope kept ducking its head into the water and at the same time its tail popped up. At one stage it swam close to the shore and stood while splashing itself for about a minute. It flew briefly after its washing session and then resumed swimming around and feeding busily. It swam more quickly than the stilts. It appeared to be less than half the size of a stilt and could easily be overlooked. The following day the phalarope could not be seen at that site. Further sightings of a Red-necked Phalarope were made on other Rottnest lakes as well as at Little Parakeet Bay on Rottnest in the spring and summer of 1994/95 as reported on the Royal Australasian Ornithologists Union (now Birds Australia) telephone hotline.

The Readers' Digest, 1986, *Complete Book of Australian Birds* reports that only a few trickle on to Australia each year, arriving ... in September and leaving by April. The first was not recorded until 1962, near Melbourne. Saunders and de Rebeira, 1993, *Birds of Rottnest* also report that "Another rare visitor that is being recorded more frequently in south-western Australia is the Red-necked Phalarope. The latest sighting to date on Rottnest Island was in late August 1992, when a single bird was present on Government House Lake."

Hayman, Marchant and Prater, 1987, *Shorebirds an Identification to the Waders of the World* report "Some females leave breeding grounds (far north Asia, Europe and North America) in late June. Vagrants have occurred in inland South America, near Cape Town (regular in recent years), Sri Lanka, Australia and New Zealand." The Readers' Digest explains that "Conventional sexual roles are reversed in Phalaropes. The female is larger and more brightly coloured than the male in breeding plumage. She conducts displays and initiates courtship and establishes the breeding territory. The male builds the nest – in a tussock of marsh grasses, lined with plant matter – and incubates and rears the young on his own."

My next sighting was of three Red-necked Phalaropes, a female in breeding plumage and two birds in juvenile or eclipse plumage, on 9 October 1995 on

Government House Lake, Rottnest. The birds were regularly seen during that week of school holidays and were the highlight of the Rottnest Voluntary Guides' daily bird walks. Often they were close together and within ten metres of the causeway making spectacular viewing. My daughter Shannon (12) and her cousins Miranda Ajduk (12) and Matthew Ryder (11) also spotted the phalaropes. Rottnest Voluntary Guides regularly saw those three phalaropes on Government House Lake and Pearse Lakes that spring and summer. Red-necked Phalaropes have been reported on Rottnest since then with the reports of a single bird in spring 1999 (Athene Baugh, pers. comm., 1999) and I saw another in January 2001 on Government House Lake.

I wonder whether Red-necked Phalaropes also visit the Swan and Canning Rivers where they would be very difficult to spot.

– PETER COYLE, 4 Luke Place, Ascot, WA 6104

Competition between a Rainbow Lorikeet and a Twenty-eight Parrot for a nesting hollow – There is currently a great deal of controversy surrounding the ecological impacts of introduced Rainbow Lorikeets (*Trichoglossus haemotodus moluccanus*) on Western Australian avifauna. Competition for nesting hollows between this species, first reported at Wembley in 1968 (Storr, 1973, *Western Australian Naturalist* 12: p116), and less aggressive endemic parrot species has been cited as being potentially detrimental to native parrot populations. This note describes an observed confrontation between a nesting Rainbow Lorikeet and a Twenty-eight Parrot (*Barnardius zonarius semitorquatus*), in the grounds of The University of Western Australia. At approximately midday on Monday 22 July 2002 I observed a Twenty-eight parrot attempt to enter a nesting hollow in a Marri (*Corymbia calophylla*) already occupied by a nesting Rainbow Lorikeet. The nesting hollow was located on a main branch approximately 12m from the ground. The Twenty-eight Parrot was seen to land on the branch next to the hollow and inspect the general area prior to landing at the hollow's opening. It was immediately repelled from the opening by a vocalising Rainbow Lorikeet emerging from the hollow. The Rainbow Lorikeet did not pursue the fleeing Twenty-eight Parrot, but returned to its nest. This observation supports previously cited evidence and personal accounts of Rainbow Lorikeets displacing native Twenty-eight Parrots from nesting sites in the Perth metropolitan area.

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CLUB NEWS

Programme

General Meetings and Branch Meetings are held at various venues in Nedlands, Kalamunda, Rockingham and North Beach.
The Retired and Leisured Group meets on alternate Wednesdays at 10a.m.
Excursions and field days are planned from time to time and will be advertised in the Club's monthly newsletter "The Naturalist News".

THE WESTERN AUSTRALIAN NATURALIST

(Journal of the W.A. Naturalists' Club)

Editor

MR JOHN DELL

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