



THE WESTERN AUSTRALIAN NATURALIST

Vol. 22 No. 1
June 28 1998

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Print Post Approved
PP 6358 23/00015
ISSN 0726 9609

Western Australian Naturalists' Club

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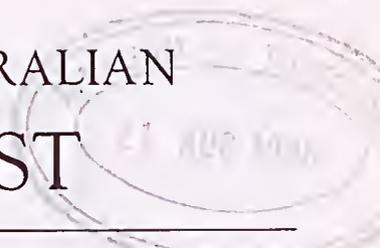
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THE WESTERN AUSTRALIAN NATURALIST



Vol. 22

28th June 1998

No. 1

VERTEBRATE FAUNA OF THE NIFTY MINE SITE, GREAT SANDY DESERT, WITH COMMENTS ON THE IMPACTS OF MINING AND REHABILITATION

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ABSTRACT

Vertebrate populations were surveyed in the vicinity of the Nifty Copper Mine in the Great Sandy Desert from 1994–1997. A total of 56 reptile, 5 frog, 24 mammal and 91 bird species were recorded, including several species of conservation significance such as the Bilby, Mulgara, Northern Marsupial Mole, Ghost Bat and Grey Falcon. Frogs, particularly *Notaden nicholli*, were very abundant and did not exhibit higher levels of skeletal abnormalities in the vicinity of the mine compared to remote sites. Fauna recolonisation of rehabilitating waste dumps was rapid, particularly for *Mus musculus*, *Smithopsis youngsoni*, *Varanus brevicauda* and *Ctenotus quattuordecimlineatus*. Several waterfowl species and Zebra Finches, Magpie-larks, White-backed Swallows, Fairy Martins, Diamond Doves and Budgerigars benefited from permanent water associated with the mine. Control of feral animal populations and improved fire management are highlighted as being important for maintaining the exceptional biodiversity of the Nifty area.

INTRODUCTION

Nifty Copper Operations (NCO) (121°35'E and 21°40'S) is an open cut copper mine with acid heap-leach pads and electrowinning

processing plant approximately 70km west of Telfer in Western Australia. (Fig. 1). The Nifty mine is situated amongst dunefields near the south-western margin of



Figure 1. Location of Nifty

the Great Sandy Desert. The sand-dunes are generally oriented from south-east to north-west and reach heights of 18m above the adjacent sandy or clay swales. The principal vegetation in the swales is *Triodia basedowii* which is replaced by *Plectrachne schinzii* on dunes and deep sand. Several

Eucalyptus, *Acacia* and *Grevillea* species form a sparse overstory in some areas and *Melaleuca*, *Thryptomene maissoneuvei*, *Calytrix carinata*, *Acacia ancistrocarpa* and *A. translucens* form localised dense shrub cover (Hart, Simpson and Associates 1992). Drainage is largely endoreic, with water

collecting in low-lying regions vegetated largely by *Melalueca glomerata* and *Eucalyptus coolabah*.

The Nifty mine is located in one of the hottest regions of Australia with daily maximum shade temperatures consistently exceeding 40°C and occasionally reaching 50°C at the mine meteorological station during the summer months. The average annual rainfall of 315mm, originates primarily from cyclonic rain depressions occurring from December to March. The rainfall is extremely variable with single rainfall events sometimes exceeding the annual average.

The mine is managed on a fly in/fly out basis with the entire workforce of approximately 100 housed in camp accommodation. No pets are allowed and feral cats and foxes are discouraged by diligent environmental hygiene and daily burial of rubbish in the mine waste-rock dumps. With the exception of the open pit, leach pads and processing plant which together occupy approximately 70ha, these overburden and waste-rock dumps are the principal environmental disturbance on site. Waste-rock dumps are modelled to blend with and resemble local landforms and the walls are battered off to a slope of 20°. Revegetation of these dumps proceeds rapidly following spreading of topsoil. *Triodia basedowii* is the principal early coloniser and is gradually replaced by a succession of *Acacias*, *Grevilleas* and other shrubs. Areas rehabilitated in November 1993 already had a vegetation cover and species diversity exceeding

that of neighbouring control sites by June 1995 (Nifty Copper Operations 1995).

A series of fauna surveys were conducted at Nifty in order to: identify any rare or regionally significant vertebrates or habitats; determine any impacts of the development on local species; and assess the response of the vertebrate fauna populations to waste-rock dump rehabilitation (Read 1994, Read and Moseby 1995, Read and Niejalke 1996).

METHODS

Small terrestrial reptiles, amphibians and mammals were surveyed at nine monitoring sites in the vicinity of NCO in April 1994, October 1995, and March and November 1996. The habitat type and landuse of the trap sites are presented in Table 1. Four pitfall and a minimum of 10 small Elliott traps were set at each site for 5 consecutive nights on each survey. Twenty litre buckets spaced at 8m intervals and linked by flymesh drift fence served as pit traps. Large Elliott traps were set at most sites and at opportunistic locations to survey for medium-sized mammals during the October 1995 survey. Active searches for tracks, scats or burrows were conducted at all sites. Spotlight searching was carried out by vehicle on established tracks throughout the region for 1.5 to 3 hours on at least three nights each survey and by foot at sites where signs of Bilbies were evident. Four sites, with four pits and ten small Elliott traps, on rehabilitating waste dumps were

Table 1. Location, habitat type and land use of the Nifty vertebrate monitoring sites

Site	Easting	Northing	Habitat	Landuse
1	336624	7601768	<i>E. coolabah</i> & <i>T. basedowii</i> run-on swale with termite mounds	control
2	350402	7604285	<i>E. coolabah</i> & <i>T. basedowii</i> run-on swale with termite mounds	mining; adjacent to rehabilitated camp site
3A	350779	7605286	<i>E. chippendalei</i> & <i>P. schinzii</i> dune crest	mining; 200 m west of waste rock dump
3B	350876	7605489	<i>Melaleuca</i> spp. and <i>T. basedowii</i> swale	mining; 200 m west of waste rock dump
4A	358624	7601786	<i>E. chippendalei</i> & <i>P. schinzii</i> dune crest	control
4B	358474	7601968	<i>T. basedowii</i> swale, patch-burnt in 1989	control
5	362957	7600080	<i>P. schinzii</i> & <i>T. basedowii</i> sand plain	control
6R	367415	7600232	<i>T. basedowii</i> clay palaeodrainage channel	control
6T	367497	7600119	<i>T. basedowii</i> clay palaeodrainage channel with termite mounds	control
R1	351487	7604923	rehabilitation commenced April 1995	mining; rehabilitating waste-rock dump
R2	351601	7604739	rehabilitation commenced 1994	mining; rehabilitating waste-rock dump
R3	351684	7604787	rehabilitation commenced 1994	mining; rehabilitating waste-rock dump
R4	352171	7604517	rehabilitation commenced May 1995	mining; rehabilitating waste-rock dump

surveyed contemporaneously with the aforementioned sites on the latter two surveys.

In addition to pitfall trap capture, frogs were collected opportunistically at night following rain and carefully checked for departures from bilateral symmetry which could indicate skeletal abnormalities. Frogs were returned to their capture location at the conclusion of each sampling session to avoid re-sampling the same individuals.

Three mist-nets were set to catch bats around the sewer ponds and adjacent sand dunes on the nights of 11 and 12 October, 1995 and an Anabat ultrasonic bat detector was operated at two sites for three nights on the two later field trips. Identification of several bat species through sonographs alone was tentative due to the geographic and individual variability in calls of some species (T. Reardon pers. comm.).

Quantitative bird counts were conducted at six sites for one hour during a morning and afternoon on each of the last three surveys. Opportunistic sightings or collections of species by mine staff since the 1994 survey were verified and added to the data base. A trapping session in March 1997, conducted by CALM personnel, used some of the established monitoring sites and established additional sites. Data from this survey have been included as opportunistic records, to maintain the consistency of the systematically collected site specific data. Voucher specimens of all species not previously verified, with the

exception of endangered taxa, were lodged with the Western Australian Museum.

Field work was conducted under CALM licence nos. SF001227, SF001666, SF002001 and SF002002.

RESULTS

Reptiles

A total of 57 reptile species have been recorded from the Nifty region (Table 2). In addition, a ridge-tailed monitor differing from adult *Varanus acanthurus* by its small size and simple dots rather than ocelli on the dorsal surface was collected, which probably represents an undescribed species (K. Aplin pers. comm.). The whip snake collected is similar to *Demansia rufescens* except that it has a nuchal bar and hence probably represents one of the undescribed species in this genus (L. Smith pers. comm.). One Flat-shelled Turtle (*Chelodina steindachneri*) was collected from a road near the minesite and lodged with Western Australian Museum. Since this species is dependent on aquatic habitats it is most likely that this record represents an individual which was transported to the site, rather than an individual straying from the Oakover River, approximately 40km away. However, *C. steindachneri* is remarkably resistant to desiccation and individuals are often found in isolated waterholes which dry for up to 12 months (Cann 1978). Therefore, there is a slight chance that the individual recorded from Nifty was a naturally nomadic individual.

Table 2. Reptiles, amphibians and mammals recorded on NCO fauna surveys until June 1997

Species	Sites													Total	
	1	2	3A	3B	4A	4B	5	6R	6T	R1	R2	R3	R4		OPP
REPTILES															
Geckos															
<i>Diplodactylus conspicillatus</i>						3	2	2	1					4	12
<i>D. jeanae</i>														1	1
<i>D. stenodactylus</i>	1		2	1	4			3		1	4	1		36	53
<i>Gehyra pilbara</i>		1	1						5						7
<i>G. purpurascens</i>		?		?										9	9
<i>Gehyra cf. punctata</i>														1	1
<i>Heteronotia binoei</i>	1	1	3		1			4					1		10
<i>Nephrurus laevis</i>					1					2				10	14
<i>N. levis</i>	+			1								2		15	18
<i>Rhynchoedura ornata</i>		1		1										9	11
<i>Strophurus ciliaris aberrans</i>														2	2
Legless Lizards															
<i>Delma borea*</i>														1	1
<i>Delma haroldi</i>	1														2
<i>Lialis burtonis</i>														2	2
<i>Pygopus nigriceps</i>		1								1				10	13
Dragons															
<i>Ctenophorus caudicinctus</i>															5
<i>C. clayi</i>															1
<i>C. isolepis</i>	5	5	5	1		3	7	3	4	6	1	1		8	49
<i>C. nuchalis</i>				1										8	9
<i>Diporiphora winneckeii</i>			4	1	5	1		1						18	31
<i>Gemmatophora longirostris</i>		+			1									4	5
<i>Moloch horridus</i>				+										2	2
Skins															

<i>Ctenotus ariadne</i>	3	1	1	4	2	2	1	1	2	1	1	17
<i>C. brooksi</i>	2	4	2	2			1					9
<i>C. calurus</i>	1	1	1	2								9
<i>C. colletti</i>	1	5	3	5	4	1	1	1				21
<i>C. grandisgrandis</i>	1	4	4	7	3	2						28
<i>C. helena</i>	2				1							5
<i>C. leae</i>		2		1								3
<i>C. nasutus*</i>												1
<i>C. pantherinus ocellifer</i>	3	1	2	2	3	7	5	1	2	2	10	38
<i>C. piankai</i>	1	5	3	1	2	4	2		1	1	2	21
<i>C. quattuordecimlineatus</i>		3	1	5	1		4	2				21
<i>Egernia striata</i>												1
<i>Eremiascincus fasciolatus</i>	10	17	6	7	10	5	4	4	2	1	3	37
<i>Lerista bipes</i>		5	5	2								73
<i>L. ips</i>			3									7
<i>L. xanthura</i>	2	4	1	5	3	1	1	1	2	2		3
<i>Menetia greyii</i>												22
<i>Notoscincus ornatus</i>												3
<i>Tiliqua multifasciata</i>												1
Goannas												
<i>Varanus acanthurus</i>	1	1	1	1	2	2	3	2	2	1		4
<i>V. breviceauda</i>	1	2	1	1	1	3	1	1	2	1		13
<i>V. eremius</i>												16
<i>V. giganteus</i>												1
<i>V. gilleni*</i>												1
<i>V. gouldii</i>	1	1	1	1	1	1			7	12		1
<i>Varanus</i> sp.												1
Blind Snakes												
<i>Ramphotyphlops grypus</i>												6
<i>R. endoterus</i>												11
<i>Ramphotyphlops</i> sp.												2

Table 2 (cont.)

Species	Sites											Total			
	1	2	3A	3B	4A	4B	5	6R	6T	R1	R2		R3	R4	OPP
Pythons															
<i>Aspidites ramsayi</i>														2	2
<i>A. melanocephalus</i>														1	1
<i>Liasis stimsoni</i>														2	2
Elapid snakes															
<i>Demansia sp. aff. rufescens</i>				1			2							1	4
<i>Pseudonaja nuchalis</i>											1			3	3
<i>P. modesta</i>														2	3
<i>Pseudechis australis</i>														1	1
<i>Simoselops anomalus</i>					1									1	1
Tortoises															
<i>Chelodina steindachneri</i>														1	1
FROGS															
<i>Cyclorana maini</i>	1													30	32
<i>Litoria rubella</i>														12	12
<i>Neobatrachus aquilonius</i>	1	1												15	29
<i>Notaden nicholli</i>	42	13	27	15	7	7	9	67	14	14	14	8	12	343	578
<i>Uperoleia sp. aff. russelli</i>	3	2	5					18			1			20	49
MAMMALS															
Dasyurids															
<i>Dasykaluta rosamondae*</i>				1										8	9
<i>Dasyercus sp.</i>				0			3							1	4
<i>Ningau'i ridet</i>			3	1	4	1	3					1		3	9
<i>Pseudantechinus macdonnellensis</i>	1							2						3	8
<i>Planigale maculata</i>	2				1			2	1					1	6
<i>Sminthopsis youngsoni</i>		2	1		2	5	1	1	2	1	1	1	6	12	12

Reptile species richness was highest at the swale site 3B, whereas capture rates were highest at the sand dune sites 3A and 4A where subterranean species of *Lerista* and *Eremiascincus fasciolatus* were abundant (Table 1). *Lerista bipes* was the most common reptile captured and did not appear to favour a specific habitat type although it was not recorded at the recently burnt 4B site in the 1994 survey. *Ctenophorus isolepis* and *Eremiascincus fasciolatus* were also common and widespread, with the latter species more common on the dunes. Several species, namely *Ctenotus leae*, *C. brooksii*, *Lerista ips*, *L. xanthura*, *Notoscincus ornatus*, *Simoselaps anomalus* and *Ramphotyphlops endoterus* were predominantly recorded at dune sites. By contrast, *Diplodactylus conspicillatus*, *Ctenotus grandis* and *C. piankai* were largely restricted to swale habitats. *Gehyra pilbara* and *Varanus acanthurus* were usually recorded at sites with termite mounds whilst *Nephrurus* spp., *Ctenous quattuordecimlineatus* and *Varanus brevicauda* were trapped most frequently on rehabilitation sites.

Mammals

Twenty-one native and three introduced species of mammal have been recorded in the Nifty region (Table 2). This figure may increase further if more detailed analyses of bat sonographs can distinguish between different *Nyctophilus* species. In addition, kangaroo tracks have been recorded at several sites which

could be attributed to Red Kangaroos (*Macropus rufus*) in open country or Euros (*M. robustus*) near rocky outcrops or ranges. The diversity of carnivorous marsupials is particularly striking with six sympatric genera of dasyurids recorded. The most conservation significant species recorded, the Bilby (*Macrotis lagotis*), Mulgara (*Dasycercus* sp.) and Northern Marsupial Mole (*Notoryctes caurinus*), are all rare and threatened nationally (Maxwell *et al.* 1996). The mole is a recently described species, known only from 6 localities in the Gibson and Great Sandy Deserts, and the Mulgara may represent an undescribed species (Maxwell *et al.* 1996). The Ghost Bat is also considered to be vulnerable (Richards and Hall 1996).

Pseudomys hermannsburgensis, the most common mammal in the Nifty region was widespread through all habitats surveyed, whereas the other common rodent, the Spinifex Hopping Mouse (*Notomys alexis*) favoured dune sites. Capture rates for *Notomys alexis* may not accurately reflect true population density as *Notomys* are rarely caught in shallow pitfalls and Elliott trap captures may depend on food availability. The Wongai Ningai (*Ningai ridei*) was recorded most frequently at *Plectrachne* dominated sites, which are favoured by this species elsewhere (McKenzie and Youngson 1983). By contrast, another common small dasyurid, the Lesser Hairy-footed Dunnart (*Sminthopsis youngsoni*), was more common on the swales. Both the Fat-tailed Antechinus

(*Pseudantechinus macdonnellensis*) and the Common Planigale (*Planigale maculata*) were observed entering holes in termite mounds which are likely to be important habitat components, especially for *P. macdonnellensis* (McKenzie and Youngson 1983).

Although their tracks and droppings were recorded at most sites, camels were rarely seen and their impact on the local environment was apparently minimal since little evidence of browsing or overgrazing was noticed. Cat and fox densities were generally low. Despite 5–10 hours spotlighting on each trip the only feral predator observed was a cat 20 km from Nifty on the Woodie Woodie road. However, cat, fox and dingo tracks were recorded at several monitoring sites (Table 2) and frequency of recording signs of foxes and cats increased during the survey period. Signs of foxes and cats were also recorded respectively from 7 and 4 of 15 predator transects in the Nifty region in November 1996 (Paltridge 1997). These observations concur with those of Algar and Sinagra (1997) that feral predator numbers had increased following recent heavy rains. The remains of Bilby, Desert Banded Snake, Spinifex Hopping Mouse, House Mouse, goanna and dragon have been recorded from cat stomach contents or faeces collected from Nifty whereas local foxes have been recorded preying upon Spinifex Hopping Mouse, Blue-tongue Lizard and invertebrates (Paltridge 1997, Algar and Sinagra 1995,1997)

Bilby tracks, scratchings, scats and

holes were most common in run-on areas in swales, predominantly vegetated with *Triodia* and *Melaleuca* (Read and Moseby 1995, Read and Niejalke 1996, Paltridge 1997). This concurs with the findings of a regional survey which concluded that Bilbies were more common in alluvial regions and drainage lines rather than sand plains and dunes (McKenzie and Youngson 1983), probably due to increased moisture and nutrient levels (Southgate 1990). Low sandy mounds around *Melaleuca* shrubs were apparently favoured burrow sites although several Bilby burrows were situated at the base of dunes or between *Triodia* hummocks.

Mulgara burrow systems were located most consistently at site 4B in a *Triodia basedowii* swale which was burnt in 1989. An active warren located 30m from a sand-dune and approximately 150m from an older patch of unburnt spinifex in October 1995 was apparently replaced with another 140m away in March 1996 then usurped again by a warren between these two in November 1996. Warrens had one to three main entrances (60mm diameter) to the burrow system with associated spoil heaps, one to six smaller entrances (50mm diameter) and one or two pop-holes, all within a 5m diameter. The *Triodia* formed tight clumps averaging 30cm in diameter at about 50% cover. These findings are consistent with some previous studies on Mulgara habitat which suggest a habitat preference for recently burnt spinifex of 20–80% cover (L. Baker, pers. comm.),

although Masters (1993) found that Mulgaras were more common on old spinifex, compared to recently burnt areas.

Three marsupial moles have been recorded at Nifty since 1994; one as a roadkill, one disturbed during drilling operations, and one drowned in floodwaters from the Cyclone Kirsty rains in March 1996. All three were probably the recently described Northern Marsupial Mole (*N. caurinus*), although only one specimen was lodged with the Western Australian Museum. *Notoryctes caurinus* is believed to be parapatric with *N. typhlops*. Despite extensive searches for its distinctive tracks no further signs of this elusive fossorial mammal have been located near the Nifty mine.

Amphibians

Five species of frog inhabit the Nifty region despite the absence of permanent water bodies. *Notaden nichollsi* is clearly the most abundant and widespread frog species in the region (Table 2), as it is in the eastern Simpson Desert (Predavec and Dickman 1993), and is one of the most common vertebrates at Nifty. Distinct age cohorts could not be detected from the SVL measurements of *N. nichollsi*, which ranged from 6 to 48 mm (Read and Niejalke 1996). There may be some form of commensualism between *N. nichollsi* and the undescribed species of *Uperoleia* which has affinities to *Uperoleia* aff. *russelli*, since these taxa, or closely related forms, are regularly excavated from the same burrows by Aboriginal women in the

Tanami Desert (R. Paltridge pers comm.). *Neobatrachus aquilonius* and *Cyclorana maini* were mainly restricted to larger swamps. With the exception of a single specimen from a deep pond near site 1, *Litoria rubella* was restricted to the permanent water at Nifty camp and sewer ponds.

Birds

Ninety-one species of birds have been recorded from the area (Table 3). Zebra Finches were clearly the most abundant and widespread bird during the surveys and numbers peaked near the mine (Table 3), probably due to the permanent supply of water there. Galahs were also very abundant and concentrated around waterpoints and a favoured roost amongst Coolibahs at site 2. Other consistently widespread and abundant birds included Singing Honeyeaters, Grey-headed Honeyeaters, Pied Honeyeaters, Yellow-throated Miners, Budgerigars, Diamond Doves, Red-browed Pardalotes, White-winged Fairy-wrens, Variegated Fairy-wrens and Black-faced Woodswallows. Crimson Chats were abundant in most surveys but were rare in October 1995. Black and Brown Honeyeaters were common in the October and November surveys, whilst White-fronted Honeyeaters were only abundant in the March 1996 survey. The diversity of raptors at Nifty is notable with 12 species recorded, yet the Nankeen Kestrel was the only regularly recorded species.

Both Grey and Peregrine Falcons are rare and possibly threatened

through much of their ranges and Wedge-tailed Eagles and Rufous-crowned Emu-wrens are regionally uncommon (Start and Fuller 1983). The Bush Stone-curlew and Australian Bustard have declined historically and are recognised as being of national conservation significance (Garnett 1992)

Mining Impacts

House mice (*Mus musculus*) were common on the rehabilitating waste dumps despite being rare at other sites. Apparently *M. musculus* did not outcompete *P. hermannsburgensis* which was as common on the rehabilitation sites as control sites. *Mus musculus* predation has been linked with reductions in small skink numbers elsewhere (Newman 1994), and may have been responsible for the slow colonisation of rehabilitation sites by skinks. Several other species such as *Sminthopsis youngsoni*, *Varanus brevicauda* and *Ctenotus quattuordecimlineatus* were also trapped more frequently at rehabilitated sites and hence may be favoured by the conditions there. Gould's Goannas were regularly recorded in the Nifty camp and three *Ctenophorus nuchalis* were observed in close proximity to the mine, while none were found in undisturbed habitats in the region. Bradshaw (1981) also recorded a population of *C. nuchalis* at Shark Bay which was restricted to a disturbed, man-made environment and replaced by congeners in undisturbed habitats.

A suite of species including Magpie-larks, White-backed Swallows, Fairy Martins, Zebra

Finches, Diamond Doves and Budgerigars were more common near mine and camp waterbodies than at control sites (Table 3) and hence have probably benefited from the project-related water supplies. Richard's Pipits benefited from the open spaces on the waste-rock dumps. By contrast, Horsfield's Bronze Cuckoo and songlarks were recorded in low numbers at control sites but not near the mine. Low population sizes preclude verification of whether these species avoided disturbed regions or whether their distribution was a stochastic artefact of low densities.

Twenty-six waterfowl species have now been recorded at Nifty. Waterfowl activity was centred upon the artificial Lake Nifty, the Nifty camp sewer ponds and the desalination plant water ponds. Grey Teal have bred on Lake Nifty (Read & Moseby 1995). Migratory waders, presumably moving across Australia *en route* from the south-east Australian coastline to the Broome region, and large flocks of granivorous finches, parrots and pigeons, also utilise water bodies in the Nifty region. A total of 30 bird deaths associated with utilisation of the toxic pregnant liquor ponds were recorded from November 1994 until March 1997. Clean water bodies are valuable in minimising the likelihood of serious avifauna problems associated with birds drinking or alighting upon toxic water bodies (pers. obs.).

Of the 574 *N. nichollsi* inspected following 265mm of rainfall associated from Cyclone Kirsty in

Table 3. Bird records from Nifty Copper Operations until December 1996. Names and name sequence follows Christidis and Boles (1994).

	1	2	3	4	5	Mine	Total	No. of sites
Emu (<i>Dromaius novaehollandiae</i>)	+						0	3
Black Swan (<i>Cygnus atratus</i>)							0	1
Australian Wood Duck (<i>Chenonetta jubata</i>)							0	1
Pacific Black Duck (<i>Anas superciliosa</i>)						+	0	1
Grey Teal (<i>A. gracilis</i>)		4				6	10	4
Pink-eared Duck (<i>Malacorhynchus membranaceus</i>)						2	2	1
Hardhead (<i>Aythya australis</i>)						+	0	1
Hoary-headed Grebe (<i>Polycephalus poliocephalus</i>)						6	6	3
Australasian Grebe (<i>Tachybaptus novaehollandiae</i>)		1				5	6	3
Little Black Cormorant (<i>Phalacrocorax sulcirostris</i>)							0	1
Australian Pelican (<i>Pelecanus conspicillatus</i>)							0	1
White-faced Heron (<i>Ardea novaehollandiae</i>)						+	0	5
White-necked Heron (<i>A. pacifica</i>)							0	1
Black-breasted Buzzard (<i>Hamirostra melanosternon</i>)							0	1
Black Kite (<i>Milvus migrans</i>)				1			1	1
Whistling Kite (<i>Haliastur sphenurus</i>)		+					0	1
Spotted Harrier (<i>Circus assimilis</i>)			1			+	1	6
Brown Goshawk (<i>Accipiter fasciatus</i>)		1					1	1
Wedge-tailed Eagle (<i>Aquila audax</i>)						+	0	1
Little Eagle (<i>Hieraaetus morphnoides</i>)	1			+			1	3
Brown Falcon (<i>Falco berigora</i>)			1	1		1	3	6
Australian Hobby (<i>F. longipennis</i>)					3		3	4
Grey Falcon (<i>F. hypoleucos</i>)							0	1
Peregrine Falcon (<i>F. peregrinus</i>)	1						1	1
Nankeen Kestrel (<i>F. cenchroides</i>)	2			1	2	5	10	12
Baillon's Crane (<i>Porzana pusilla</i>)							0	1
Spotted Crane (<i>P. fluminea</i>)						+	0	1
Black-tailed Native-hen (<i>Gallinula ventralis</i>)						+	0	2

Table 3 (cont.)

	1	2	3	4	5	Mine	Total	No. of sites
White-winged Fairy-wren (<i>M. leucopterus</i>)	10		48	7	37	15	117	14
Rufous-crowned Emu-wren (<i>Stipiturus ruficeps</i>)	3				3	+	6	3
Red-browed Pardalote (<i>Pardalotus rubricatus</i>)	5	2	8	4			21	14
Spiny-checked Honeyeater (<i>Acanthagenys rufogularis</i>)	18	5	3	1		1	39	15
Yellow-throated Miner (<i>Manorina flavigula</i>)	11	5	29	25	9	14	93	19
Singing Honeyeater (<i>Lichenostomus virescens</i>)	62	71	8		5	2	148	15
Grey-headed Honeyeater (<i>L. keartlandi</i>)	20	5	8			+	33	8
Brown Honeyeater (<i>Lichmera indistincta</i>)	10	1	4	3	1	1	10	6
White-fronted Honeyeater (<i>Phylidonyris albifrons</i>)	3	18	9		17	11	46	6
Black Honeyeater (<i>Certhionix niger</i>)	3	27	16	43	9	3	70	11
Crimson Chat (<i>Ephthianura tricolor</i>)						3	101	15
Magpie-lark (<i>Grallina cyanoleuca</i>)						3	3	5
Willie Wagtail (<i>Rhipidura leucophrys</i>)			1			+	1	4
Spangled Drongo (<i>Dicrurus hottentottus</i>)							0	1
Black-faced Cuckoo-shrike (<i>Coracina novaehollandiae</i>)	5	2	+			+	7	9
White-winged Triller (<i>Lalage sueurii</i>)	3						3	3
Masked Woodswallow (<i>Artamus personatus</i>)			2		2	+	4	4
Black-faced Woodswallow (<i>A. cinereus</i>)	5	16	5	8	7	12	53	15
Little Crow (<i>Corvus bennetti</i>)		1					1	2
Torresian Crow (<i>C. ortu</i>)		1	1			1	3	3
Richard's Pipit (<i>Anthus novaeseelandiae</i>)						9	9	6
Zebra Finch (<i>Poephila guttata</i>)	22	63	124	32	132	228	601	20
Painted Firetail (<i>Emblema picta</i>)	1		4	13	14	6	38	5
White-backed Swallow (<i>Cheramoeca leucosternum</i>)	1	2	14			13	30	9
Fairy Martin (<i>Cecropis ariel</i>)		2	6			+	8	5
Spinifexbird (<i>Eremiornis carteri</i>)	1		1				2	3
Rufous Songlark (<i>Cinclorhampus mathewsi</i>)		+					0	1
Brown Songlark (<i>C. cruralis</i>)				+			0	1

March 1996, 29 (5.1%) abnormalities were detected. Sample sizes for the other frog species were not sufficient to calculate meaningful abnormality frequencies although these preliminary data suggest similar rates amongst other species (Read and Niejalke 1996). None of the 48 *N. nichollsi* collected from the rehabilitation sites or pools in the immediate vicinity of the mine exhibited any visible skeletal abnormalities. Most (21) of the abnormalities recorded were shortening, hooking or bifurcation of the distal elements of a single digit and recurring abnormalities on the right foot or left hand may indicate a genetic aberration, rather than a deformity caused by environmental insults.

DISCUSSION

The Nifty area supports a reptile assemblage which rivals the world's most diverse described reptile assemblages (Pianka 1986), along with a diverse assemblage of mammals and birds which include several rare and threatened species. The persistence of such a diverse fauna assemblage is probably at least partly attributable to the paucity of exotic mammals, particularly rabbits, and the absence of pastoral influences in the region.

The decline and extinction of many Australian medium-sized mammals has also been partially attributed to changes in the burning regimes of desert regions (Morton 1990). Traditional owners used patch burning techniques to

flush game and promote new vegetation growth. These practises resulted in a mosaic of vegetation patches of varying sizes and ages. Such a mosaic increased diversity of plants and animal assemblages and enabled some animals to move and take advantage of resources as they became successional available within a burnt area (Masters 1993; 1996, James 1994). However, since Aboriginal displacement, many spinifex deserts have reverted largely to more uniform regions of similar age and successional stage which are not suitable for several species and prone to large scale, destructive bushfires. The vegetation cover at Nifty exceeds 35% cover in many localities, which is denser than optimum Bilby habitat (Paltridge 1997) and fire also promotes growth of important Bilby food plants (Southgate 1990). Fire management, based upon traditional patch burning, in conjunction with CALM scientists is being implemented to increase the productivity of the spinifex and improve the local habitats for threatened mammal species, particularly Mulgaras and Bilbies.

Further survey work should reveal an even richer herpetofauna and avifauna than reported here. Two small skinks, *Morethia ruficauda* and *Lerista vermicularis* which have been recorded nearby at Telfer (Hart, Simpson and Associates 1991) also potentially inhabit the Nifty region. The fossorial lizard guild at Nifty is particularly interesting. Sympatric trapping of *Lerista ips*, *L. bipes* and *L. xanthura* along with

Eremiascincus fasciolatus at site 3D provides an opportunity to test the thesis of Henle (1989) that fossorial guilds of reptiles are only stable if all species are morphologically and ecologically well separated.

Grey Falcons are a rare and threatened species nationally (Garnett 1992) and were not recorded on a series of bird surveys of the Great Sandy Desert (Start and Fuller 1983). Hence the Nifty record of an injured individual which was sent to Perth for rehabilitation is particularly significant. The Wedge-tailed Eagle record is locally significant since this species has become rare in the region, presumably due to the decline in medium-sized prey species (Storr 1981). The persistence of Wedge-tailed Eagles in the region may therefore be dependent on the maintenance of the Bilby and populations of other medium-sized mammals.

Frog abnormality rates recorded from remote control sites in the Nifty region were higher than that recorded from undisturbed sites elsewhere in the Australian arid zone (Tyler 1989, Read & Tyler 1990, Read & Tyler 1994) but lower than from an undisturbed locality in Western Australia (Roberts 1985). Since higher levels were detected at remote sites than sites in the immediate vicinity of mining operations, these data suggest that the mining operation has not had a deleterious impact on local frog communities. The 1996 survey therefore provides a useful baseline for studies measuring the extent and degree

of any future impacts of NCO on the local frog populations.

In conclusion, the Nifty region supports a diverse faunal community including several taxa of conservation and scientific interest. Potential deleterious impacts of the mine and processing plant, including land disturbance and contamination, mortality of avifauna attracted to toxic ponds and increases in feral animals attracted to food and shelter resources, appear to be well managed to date, with negligible pervasive impacts on the regional environment. Continued advances in rehabilitation techniques, persistent dump maintenance, feral animal control programmes and deterrence of waterfowl from toxic waterbodies should ensure that impacts to the local wildlife is minimal through the life of the mine. Indeed, collection of monitoring and research data on plant and animal responses to mining, rehabilitation and seasonal conditions, along with a proactive controlled patch-burning policy, could enhance both the scientific knowledge and ecosystem functioning of this remote and poorly studied region.

ACKNOWLEDGEMENTS

This survey would not have been possible without the assistance of several talented and dedicated personnel. Mark Robertson (NCO) assisted with field work, compilation of historic data and most importantly, collection of additional data between surveys. Katherine Moseby, Darren

Niejalke and Rachel Paltridge assisted with field work, interpretation of results and report preparation. Peter Kendrick (CALM) and John Angus conducted an additional trapping session which added considerably to the dataset. Terry Reardon (SA Museum) identified bat sonographs and Laurie Smith, Ken Aplin and Norah Cooper from the WA Museum identified or verified collected specimens. John Dell provided useful comment on a draft of this document.

This work was supported by WMC Resources Ltd. with special thanks to Sean Kildare for establishing the monitoring program and to Olympic Dam Corporation, Mark Robertson and Shelley Innes for continued assistance, Nifty Copper Operation and WMC Corporate Relations for financial and logistical assistance. CALM granted permission to conduct the surveys and provided additional information on feral predators and fire management.

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DISCOVERY OF THE RED FLOWERING GUM *CORYMBIA FICIFOLIA* IN THE STIRLING RANGE

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The biogeography and genetics of *Corymbia ficifolia* (F.Muell) K.D. Hill & L.A.S. Johnson. (Myrtaceae) previously *Eucalyptus* has recently been described by Wardell-Johnson & Coates (1996). The main distribution of this species occurs in a small area between Walpole and Denmark in southern Western Australian. With an average rainfall of between 1200 and 1400 mm, this is the wettest part of the State and these authors suggested that *C. ficifolia* is a relic of a past wetter climatic regime.

Both the main population and a small outlying population at Boulder Hill, 110 km to the east, are restricted to humic podzol soils (Wardell-Johnson & Coates 1996). *Corymbia ficifolia* is known to hybridize with the closely related *C. calophylla* where there is a transition in soil types, with *C. calophylla* typically occurring on heavier soils. Within the area of *C. ficifolia*'s main distribution and at Boulder Hill, hybrids occur on shallow sands over clay (Wardell-Johnson & Coates 1996).

A previously unknown population of *C. ficifolia* (K.L. Brown 54) was recently discovered at the base of the northern slopes of

Isongerup Peak in the Stirling Range National Park. The population consists of 16 individuals of *C. ficifolia* and at least two hybrids between *C. calophylla* and *C. ficifolia* (T.R. Lally & K.L. Brown 1377). The plants are 2–3m high resprouts from the 1991 fires. This season (early 1997) appears to be the first year of flowering since the fires as no fruits could be found. Both *C. ficifolia* and the hybrids grow on light brown sandy clays over quartzite on a ridge leading up from the base of the peak. Associated species include *E. marginata*, *Beaufortia decussata*, *Agonis parviceps* and *Mesomelaena* sp.

The common white flowering form of *Corymbia calophylla* (T.R. Lally & K.L. Brown 1378) and what appeared to be a pink flowering form (T.R. Lally & K.L. Brown 1380) were also found growing within close proximity, on the same land form and soil type. An individual of *C. ficifolia* resprouting from a trunk 1–2m in diameter was found 500 metres to the east of the main group and a group of the what is presumed to be the pink flowering hybrids were observed to the northeast at the base of the Second Arrow

(approximately 1 km away) indicating that there may be more plants of *C. ficifolia* in the area.

Given that *C. ficifolia* is thought to be a relic from a past wetter climate, it is not surprising that this species occurs in the Stirling Range, 100 km north of its main distribution. The local climate around the ranges is cooler and wetter than surrounding areas due to the orographic effects of the high peaks. Indeed 143 plant species are known to reach their inland limit in the Stirling Range due to the cooler wetter climate while 87 species are known to be endemic, most of these being closely related to species from the wetter regions of the south west (Keighery and Beard 1993, Keighery 1993). Interestingly the population of *C. ficifolia* in the Stirling range occurs on quite different soils from the other two populations indicating that climatic rather than edaphic factors are possibly driving its

distribution (cf. Wardell-Johnson & Coates 1996).

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BIRDS OF THE GARDNER AND DENISON RANGES, AND LAKE WILLSON AREA SOUTH-EAST KIMBERLEY, WESTERN AUSTRALIA

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SUMMARY

This paper is based mainly on data gathered during visits to the Gardner and Denison Ranges in June-July 1975, August-September 1993, April 1994, July 1995, May 1997, September-October 1997 and May 1998. A total of 155 species of bird were recorded during these visits many of which are an important extension of known range. Additional data have also been collated from the literature and other sources. Conservation recommendations are made.

INTRODUCTION

The Gardner Range (19°15'S, 128°52'E) (Figure 1) lies near the Western Australian-Northern Territory border, about 190 km SE of Halls Creek in close proximity to the Tanami Desert. The Denison Range (19°17'S, 128°18'E) is to the west of the Gardner Range and about 10 km E of Sturt Creek homestead. Lake Willson (19°22'S, 128°16'E) is situated about 10 km S

of the Denison Range and about 25 km SE of Sturt Creek homestead.

The first exploration of the area was carried out in 1900 by A. A. Davidson for the Central Australian Exploring Syndicate Ltd, which was formed to explore and prospect an area of 8,000 square miles in the central portion of the Northern Territory (Davidson 1905). R. T. Maurice visited the area during his exploration in 1902 from Fowler Bay in South Australia to Cambridge Gulf in the Kimberley and noted parrots, cockatoos, quail and fresh Emu tracks near Slatey Creek (Maurice 1904). The Gardner Range was named after F. L. Gardner, Chairman of the syndicate and was misspelt for many years, appearing on some maps as "Gardiners Rangers". The Denison Range was named in 1955 after Denison Downs Station (the original name of Sturt Creek Station), by P. Nelligan following his surveys of the area. Lake Willson was named during the

GARDNER AND DENISON RANGES



1966 army field check, after Sapper B. H. Willson, a member of the survey team.

The Gardner and Denison Ranges are composed mostly of Proterozoic sandstones surrounded by flat to gently undulating sandplain. The sandplains are dissected by drainage channels and scattered rocky outcrops and hills. The Gardner Range rises to a maximum of 690 m above sea level whereas the Denison Range rises no more than 429 m at its highest point. Although semi-arid there is a considerable amount of surface water at springs, soaks and rockholes along Slatey and Lewis Creeks. Good permanent water can be obtained from Mt Brophy Spring at the northern end of the Gardner Range and at Talbot and Maurice Springs in the Denison Range. Lake Willson seldom dries completely and according to station people in the vicinity, can flood out for 1–2 km from the shoreline in a good season.

Nothing was known of the avifauna of the area before June–July 1975 when naturalist W. H. Butler visited the region collecting specimens for the Western Australian Museum (Butler 1977). Sixty-seven species of bird were recorded during this survey. No further work was carried out until we began visiting the area in 1993. Lodge visited Mt Brophy Spring and Lake Willson areas from 18–22 August and 4–9 September 1993 and compiled data on breeding species. Lodge again visited Mt Brophy Spring from 10–16 April 1994. From the 3–11 July 1995

Lodge and Coate visited all the sites and compiled extensive bird notes. They returned again from 14–19 July 1997 visiting most areas including Maurice Spring and Bradshaw's Well in the Bramall Hills. More recently Johnstone and Lodge visited most sites from 29 September to 4 October 1997 and K.H. Coate visited all sites including Granny Soak from 4–11 May 1998. Additional information has also been extracted from the G. M. Storr-R. E. Johnstone, Western Australian bird data base.

For the purpose of this paper we recognise five major habitat types and study sites (see Figure 1); they are briefly described below.

Site 1: Mt Brophy Spring (19°06'39"S, 128°49'08")

Situated in close proximity to Brophy Creek at the northern end of the Gardner Range and about 13 kms from the old and now disused Tanami Track. The spring is surrounded by *Eucalyptus camaldulensis*, dense stands of *Acacia neurocarpa* and *Melaleuca nervosa crosslandiana* trees. Away from the spring is an open woodland with Snappy Gum (*Eucalyptus brevifolia*), bloodwood (*Corymbia* sp), *Acacia coriacea sericophylla*, *Melaleuca nervosa crosslandiana* and hummock grass (*Triodia* sp.). On rocky sandstone slopes leading toward Mt Brophy, the vegetation consists of scattered *Corymbia pachycarpa* to 4 m. high, a small mallee (*Eucalyptus odontocarpa*), various *Acacia* sp. (including *Acacia orthocarpa*) *Grevillea wickhamii*, *Grevillea refracta* and hummock grass (*Triodia* sp.). In

the gullies are a mixture of *Acacia neurocarpa*, *Acacia colei* var. *colei*, *Melaleuca nervosa crosslandiana*, *Corymbia pachycarpa pachycarpa* and *Eucalyptus aspera*.

In 1995 after good seasons, many species of small mammal were seen. Active mounds of Pebble-mound Mice (*Pseudomys* sp.), previously unknown to be in the area, were found (19°07'120"S, 128°50'02"E) over rocky hills.

Site 2: *Slatey Creek within the Gardner Range (19°15'43"S, 128°52'58"E)*

This study area consists of a semi permanent waterhole lined with *Eucalyptus camaldulensis*, *Melaleuca nervosa crosslandiana*, and *Acacia neurocarpa*, which is surrounded by steep rocky hills covered in hummock grass (*Triodia* sp.) with a few sparse Snappy Gum (*Eucalyptus brevifolia*). Permanent water can be obtained from a large rockhole near the site of a former mineral exploration camp. Along the creek where the valley broadens out, are a number of pockets, where vegetation is quite dense with *Melaleuca nervosa crosslandiana*, a number of *Acacia* spp., *Eucalyptus aspera* and *Gastrolobium grandiflorum*. In July 1995, there was abundant water in pools and rockholes along the creek. Through the ranges in the vicinity are several rough and eroded drilling tracks.

Site 3: *Lewis Creek Floodout (19°18'40"S, 128°24'19"E and 19°16'45"S, 128°24'05"E)*.

Created when the creek floods out over a large sandplain. Stands of good sized mature *Eucalyptus victrix* trees with plenty of

hollows are scattered over both lakes. A sometimes dense cover of perennial Spiny Mudgrass (*Pseudoraphis spinescens*) with occasional small patches of *Nymphoides indica* float on the surface. In shallow water around the lake's edge a fresh water algae (*Chara* sp.) is abundant. On 9 July 1995 and 16 May 1997 the overall depth of water was no more than about 1 metre. Prior to May 1997 it appeared from water marks on trees that the water level had remained at about 2 metres for some time. From the age and position of old Eurasian Coot (*Fulica atra*) nests, we estimated water level to have peaked toward the end of March in 1997.

On both visits cattle (*Bos taurus*) were wandering in and around the floodout area.

Site 4: *Lake Willson (19°22'31"S, 128°16'54"E)*

A dense grassland of *Eragrostis desertorum* growing to a height of about 50 cm surrounds the lake and extends out into *Melaleuca glomerata* woodlands. On the northern and eastern fringes of the lake are extensive stands of *Melaleuca glomerata*, ranging from small to about 7 m. *Abutilon otocarpum* and *Sesbania cannabina* are plentiful in the grassland. Around the southern side *Halosarcia indica leiostachya* is common. Away from the lake, in depressions flooded when the lake overfills, are thickets of multi-stemmed *Melaleuca* (*Melaleuca lasiandra* and *Melaleuca glomerata*), growing to a height of about 3 metres. A small white barked *Eucalyptus* sp. is also

sometimes associated with these depressions.

Lodge's visits to Lake Willson in 1993 and 1994 followed good seasons. The lake far exceeded its normal boundaries, attracting spectacular numbers of waterfowl. Large harvester termite mounds (*Nasutitermes* sp.) that had collapsed well away from the usual lake edge, provided nesting platforms for Black-winged Stilt (*Himantopus himantopus*), Masked Lapwing (*Vanellus miles*) and Black Swan (*Cygnus atratus*). When Lodge and Coate visited in 1995, the water had receded back from the vegetation. After a visit in October 1996, the manager of Sturt Creek Station, Mervyn Wortley, found Lake Willson to be almost dry. Exceptionally heavy rainfall in 1997 had however, refilled the lake to a slightly higher level than the 1995 visit.

Many thousands of Little Red Flying-fox (*Pteropus scapulatus*) were colonising a dense area of partly submerged *Melaleuca glomerata*, during Lodge's visit in August 1993. On all visits Dingoes (*Canis lupus dingo*), feral Horses (*Equus caballus*) and Donkeys (*Equus asinus*) were recorded and in May 1998 a single Camel (*Camelus dromedarius*).

Site 5: Talbot Spring and areas to the south and south-east, following the Denison Range (19°14'20"S, 128°17'20"E).

Talbot Spring is located in a small gorge, the entrance of which is fenced off to prevent cattle wandering in and damaging the water supply. *Eucalyptus aspera* and Rock Fig (*Ficus platypoda*) grow near the source of the spring. Palms (*Livistona* sp.) at one time were the dominant plant species in the gorge, but were used locally for construction of stockyards and buildings and no longer occur there. Maurice Spring at the southern end of the Denison Range has many similarities to Talbot Spring, and at one time according to anecdotal evidence from local people, was also heavily vegetated with the palm (*Livistona* sp.). Until 1977 both Talbot and Maurice Springs were shown on maps as Palm Spring.

Within the gorge is some ancient Aboriginal rock art. Outside the entrance to the gorge, two small dams have been built across the spring fed creek, and are surrounded by densely growing young *Eucalyptus camaldulensis*, *Acacia neurocarpa* and *Acacia colei* var. *colei*.

CLIMATE

Temperature

Sturt Creek Station does not keep temperature records. The nearest station is Halls Creek, more than 150 kms to the north-west of the study area. These have been included only as a guide.

Mean Maximum Temperatures

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Mean Max.	36.9	35.8	35.6	33.8	29.9	27.3	27.1	29.9	33.8	37.1	38.4	38.2	33.6
Highest	44.0	43.3	42.2	39.4	36.9	33.8	34.1	36.6	39.5	43.8	45.0	44.9	45.0
Lowest	22.3	23.3	21.3	19.7	13.4	12.4	11.4	14.6	18.4	23.1	19.4	23.6	11.4

Rainfall

The area is semi arid desert and has an average rainfall of 372 mm. The nearest rainfall station to the Gardner and Denison Ranges is Sturt Creek Station, and while statistics from there are helpful, they can only be used as a guide. Anecdotal data suggest that tropical storms occurring in the Gardner Range have at times filled Lewis and Slatey Creeks while no rain was recorded at Sturt Creek Station.

Monthly Rainfall Records 1974–1997

The following data is based on rainfall records for Sturt Creek Station from the Bureau of Meteorology over a 23 year period (to end 1997).

YEAR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1974–75	0.4	100.4	121.0	122.6	0.0	0.0	0.0	3.6	89.8	21.6	50.0	50.6	560.0
1975–76	125.6	80.2	18.8	3.0	0.0	7.2	7.2	0.4	22.6	109.8	50.6	121.6	547.2
1976–77	N/R	326.4	37.4	N/R	N/R	0.0	0.0	0.0	3.4	14.6	7.2	17.0	406.0
1977–78	273.0	58.4	8.0	0.4	58.6	N/R	N/R	0.0	N/R	3.0	16.0	101.8	519.2
1978–79	129.6	24.8	101.8	0.4	64.8	91.0	76.8	4.0	3.0	0.0	0.0	23.0	519.2
1979–80	45.2	138.0	16.2	30.8	0.0	2.0	0.0	0.0	2.6	0.0	13.4	35.8	284.0
1980–81	170.2	250.4	18.8	0.0	0.0	0.0	0.0	0.0	0.0	36.2	0.0	54.4	530.0
1981–82	197.0	355.0	281.3	0.0	0.0	0.0	0.0	0.0	5.0	4.0	46.0	81.6	970.9
1982–83	9.0	56.0	169.0	140.0	0.0	0.0	0.0	0.0	0.0	17.0	34.0	36.2	461.2
1983–84	232.0	N/R	299.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	556.0
1984–85	37.0	37.0	21.0	42.0	0.0	0.0	0.0	0.0	50.5	0.0	18.0	8.6	214.1
1985–86	251.6	64.5	31.1	6.0	0.0	23.0	0.0	0.0	0.0	7.0	22.5	28.0	433.7
1986–87	92.8	73.8	8.0	0.0	0.0	52.0	N/R	N/R	N/R	N/R	N/R	N/R	226.6
1987–88	37.5	35.0	49.1	1.0	4.5	0.0	0.0	0.0	0.0	0.0	50.6	88.8	276.0
1988–89	9.2	20.2	219.9	0.0	0.0	0.0	0.0	0.0	2.5	0.5	86.8	106.3	445.4
1989–90	4.2	37.1	19.0	14.4	N/R	0.0	0.0	0.0	0.0	0.0	0.0	6.2	80.9
1990–91	485.1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	0.0	N/R	N/R
1991–92	52.2	43.8	9.0	4.8	40.0	N/R	N/R	N/R	N/R	N/R	34.0	41.2	225.0
1992–93	149.6	629.8	12.4	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	803.8
1993–94	N/R	N/R	N/R	N/R	N/R	N/R	N/R	0.0	N/R	0.0	N/R	142.6	142.6

1994-95	94.1	288.4	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	15.5	N/3	398.0
1995-96	N/R	42.4	109.0	58.8	6.0	N/R	N/R	N/R	N/R	8.0	50.2	60.6	335.0
1996-97	176.2	222.6	0.0	N/R	N/R	N/R	N/R	N/R	N/R	24.0	0.0	214.2	637.0

N/R = indicates that no records were sent to the Bureau of Meteorology for that month.

Summary of Total Monthly Precipitation using available data between 1899 and 1997

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Average	102.0	102.8	53.7	18.2	10.7	8.0	6.1	1.9	3.6	10.1	22.3	59.6	371.8
Highest	485.1	629.8	338.8	224.0	140.0	103.1	76.8	42.5	89.8	109.8	150.9	292.4	920.5
Lowest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.7

Summary of Rain Days using available data between 1899 and 1997

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Average	6.7	6.6	3.8	1.1	1.2	0.6	0.5	0.2	0.4	1.1	2.5	4.7	28.5
Highest	24	20	15	8	10	5	9	3	6	7	10	15	66
Lowest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10

ANNOTATED SPECIES LIST

CASUARIIDAE

Emu *Dromaius novaehollandiae*

Moderately common, usually in ones and twos. Favouring sandy areas at Brophy Spring, Lewis Creek floodout and around Lake Willson. Adult with chick 1 m high at Lewis Creek floodout on 4 October 1997 and 7 adults and 4 juveniles at Lake Willson in May 1998.

PHASIANIDAE

Brown Quail *Coturnix ypsilophora australis*

Moderately common to common throughout the region in ones, twos and small groups (up to 6). Adults with small young at Brophy Spring and Lake Willson in September 1993 and a recently used nest with broken eggs at

Lewis Creek floodout on 4 October 1997.

ANATIDAE

Magpie Goose

Anseranas semipalmata

Ten in dense cover of *Halosarcia indica* at the southern end of Lake Willson on 14 May 1997. Probably only a rare visitor to Lake Willson (and nearby Lake Gregory) when filled.

Plumed Whistling Duck

Dendrocygna eytoni

Common. About 500 including groups of juveniles at the Lewis Creek floodout in May 1997 and small flocks (up to 10) in October 1997; 30 in small groups around Lake Willson in May 1997 and flocks of 60 and 200 near mouth of Slaty Creek (Lake Willson) in October 1997.

Wandering Whistling Duck
Dendrocygna arcuata

Common. About 200 including some juveniles at Lewis Creek floodout in May 1997 and flocks of 7-60 recorded at Lake Willson in 1997.

Black Swan *Cygnus atratus*

Common in pairs and small groups (up to 22) and less frequently larger groups (up to 200). Recorded at the Lewis Creek floodout and Lake Willson. Small numbers breeding in April, May and June.

Australian Wood Duck
Chenonetta jubata

Scarce. Small flocks (up to 20) recorded on Lewis Creek floodout and Lake Willson in July 1995, May and October 1997 and May 1998.

Grey Teal *Anas gracilis*

Very common at Lake Willson and Lewis Creek floodout in small flocks (up to 40) and larger aggregations (up to 1000) in August 1993, April 1994, July 1995 and May 1997. Much less frequent (largest group 40) at these sites in October 1997. Also small groups at pools on Brophy Creek. At Lake Willson favoured the shoreline and drainage creeks. Adult with 8 small ducklings at Lake Willson in August 1993 and nest with eggs in hollow of eucalypt in Lewis Creek Floodout May 1997.

Pacific Black Duck
Anas superciliosa

Moderately common in pairs and flocks (up to 200). Recorded at Lake Willson, Lewis Creek

floodout and pools on Brophy Creek.

Pink-eared Duck *Malacorhynchus membranaceus*

Very common at Lake Willson (thousands breeding) in August 1993, September 1993 and April 1994; common, about 500 on the lake in May 1997 and less frequent in small flocks (up to 50) in October 1997. Also moderately common in small flocks (up to 20) at the Lewis Creek floodout in May 1997. Many nests at Lake Willson were built on old disused Eurasian Coot (*Fulica atra*) nests in forks of *Melaleuca glomerata* trees about a metre above the water and several were in tree hollows.

Hardhead *Aythya australis*

Moderately common to common at Lake Willson and Lewis Creek floodout. Mainly in small flocks (up to 40). Most frequent at Lake Willson in May 1997 with about 2000 in small loose groups scattered around the lake. Adult with 7 small ducklings at Lewis Creek floodout in May 1997.

PODICIPEDIDAE

Australasian Grebe *Tachybaptus novaehollandiae*

Common at Lake Willson usually in small groups (up to 18), occasionally large groups (up to 200) on all visits; 13 at Lewis Creek floodout in May 1997 and 2 on Brophy Creek in May 1997.

Hoary-headed Grebe *Poliiocephalus poliocephalus*

Scarce. Four at Lake Willson on 14 May and one on 4 October 1997.

Great Crested Grebe *Podiceps cristatus australis*

Scarce to moderately common, only recorded at Lake Willson. Several adults and two nests, one with 3 eggs, in April 1994; a flock of 25 circled at the lake several times before landing and dispersing in July 1995; 3 on the lake in May 1997 and 69 in May 1998.

ANHINGIDAE

Darter *Anhinga melanogaster novaehollandiae*

Common at Lake Willson during flood years, August 1993 and April 1994 and at Lewis Creek floodout in May 1997; less frequent during other visits. Also recorded at pools on Slaty Creek. Breeding (at all stages) at Lake Willson in April 1994; at several locations there were hundreds of nests; especially on the west side in thick stands of *Melaleuca glomerata* and occasionally in company of Little Black Cormorants. Breeding also at Lewis Creek floodout in May 1997.

PHALACROCORACIDAE

Great Cormorant *Phalacrocorax carbo novaehollandiae*

Scarce. Small numbers at Lake Willson in April 1994. Two nests both with 5 eggs found in a solitary *Melaleuca glomerata* tree in deep water near a large colony of Little Black Cormorant *Phalacrocorax sulcirostris*.

Pied Cormorant *Phalacrocorax varius*

Scarce, only recorded at Lake Willson. About 50 on 16 April 1994 and 12 including one sitting on a nest and several about to nest on 14 May 1997.

Little Black Cormorant *Phalacrocorax sulcirostris*

Common to very common at flooded Lake Willson in 1993, 1994, 1995 and May 1997; a flock of 20 at Talbot Spring on 13 July 1995; 50–60 nests (with almost mature young) at Lewis Creek floodout in May 1997; and 4 at same place on 3 October 1997). Thousands breeding at Lake Willson in *Melaleuca glomerata* and dead *Acacia neurocarpa* trees in August 1993 (most nests empty, some with large young); April 1994 (breeding at all stages); and May 1997 about 150 nests ranging from eggs to half grown young.

Little Pied Cormorant *Phalacrocorax melanoleucos*

Common to very common at flooded Lake Willson in August 1993 and April 1994; moderately common at Lake Willson and Lewis Creek floodout in July 1995 and May 1997; one at pool on Brophy Creek on 18 May 1997; 13 at Lewis Creek floodout on 3 October 1997, and 3 at Lake Willson on 4 October 1997. Breeding in thousands at Lake Willson in August 1993 (most nests empty, some with large young), at all stages in April 1994; and 20–30 nests, 4 with small young at Lewis Creek floodout in May 1997.

PELECANIDAE

Australian Pelican *Pelecanus conspicillatus*

Moderately common (up to 45) at Lake Willson in August, September 1993, April 1994 and May 1998, less frequent on other visits; also 8 at Lewis Creek floodout in July 1995.

ARDEIDAE

White-necked Heron *Ardea pacifica*

Moderately common. Mainly ones and twos occasionally small groups (up to 15). Recorded at Brophy Springs, pools on Slatey Creek, Lewis Creek floodout and Lake Willson. Breeding in small numbers at Lewis Creek floodout in May (nests with large young) and October 1997 (nests with eggs and hatchlings).

White-faced Heron *Ardea novaehollandiae*

Moderately common in ones, twos and small groups (up to 30). Recorded at Brophy Spring, Lewis Creek floodout and Lake Willson. Nest with 2 eggs at Brophy Spring on 7 September 1993.

Great Egret *Ardea alba*

Moderately common at Lake Willson (70 in May 1997) and Lewis Creek floodout (25 in May 1997) in wet years, less frequent (mainly ones and twos) in October 1997. Nest with 3 eggs and one with small young at Lake Willson in April 1994.

Intermediate Egret *Ardea intermedia*

Common at Lewis Creek

floodout; 4 in July 1995, 30 in May 1997 and 100 in October 1997; also 6 at Lake Willson in October 1997.

Little Egret *Ardea garzetta nigripes*
Uncommon. Only recorded at Lewis Creek floodout. Six in July 1995, 4 in May 1997 and 2 in October 1997.

Cattle Egret *Ardea ibis*

Uncommon. A flock of 25 at Lewis Creek floodout in May 1997, 10 or 12 in October 1997 and 3 at Lake Willson in May 1998.

Rufous Night Heron *Nycticorax caledonicus hilli*

Uncommon to common. Ones and twos at Brophy Spring, at pools on Slatey Creek, at Lewis Creek floodout and Lake Willson. One eating a fresh water crab *Holthuisana* sp. in a recently dried up pool, in the middle of the day, in July 1995. Breeding in April 1994 at Lake Willson (nests with eggs and chicks) in *Melaleuca glomerata* on west side of lake.

THRESKIORNITHIDAE

Glossy Ibis *Plegadis falcinellus*

Moderately common at Lewis Creek floodout and Lake Willson. Usually in small groups (up to 12) but occasionally in larger flocks (up to 165). Breeding in May 1997 at the Lewis Creek floodout, 34 nests (4 freshly made nests, 1 with 3 eggs, 17 with small young and others with half grown to fully fledged young).

Australian White Ibis *Threskiornis aethiopicus moluccus*

Scarce. Two at Lewis Creek

floodout in May 1997.

Straw-necked Ibis *Threskiornis spinicollis*

Moderately common at Lewis Creek floodout and Lake Willson. Mainly small flocks (up to 80). Recorded in May, July and October.

Royal Spoonbill *Platalea regia*

Scarce. Small groups (up to 4) at Lewis Creek floodout and Lake Willson in October 1997. Breeding in October at Lewis Creek floodout; 1 nest with 2 heavily incubated eggs and another with 3 feathered young.

Yellow-billed Spoonbill *Platalea flavipes*

Scarce. Only recorded at Lewis Creek floodout. Mainly ones and twos. Breeding in May (1 nest with half grown young another with almost fledged young) and October (3 nests, 1 with 2 feathered chicks).

CICONIIDAE

Black-necked Stork
Ephippiorhynchus asiaticus

Scarce. Ones and twos at Lewis Creek floodout in July 1995, October 1997 and Lake Willson in May 1998. A nest with fresh twigs in top of eucalypt appeared to have been used recently.

ACCIPITRIDAE

Black-shouldered Kite *Elanus caeruleus axillaris*

Scarce. Single birds in open country along Slatey Creek.

Square-tailed Kite *Hamirostra isura*

Scarce. One over Brophy Creek on 18 May 1997 and one at Granny Soak in May 1998.

Black-breasted Buzzard
Hamirostra melanosternon

Moderately common; in ones and twos throughout the region. Pair at nest in a dead tree at Brophy Creek on 16 August 1995; nest with 2 eggs at Brophy Creek on 30 September 1997; and nest with one egg (chipping) and a downy hatchling on Slatey Creek on 3 October 1997. Old nests also observed at Granny's Soak and south end of Denison Range. Pair at Slatey Creek had been feeding almost exclusively on skinks *Tiliqua multifasciata*.

Black Kite *Milvus migrans affinis*

Uncommon. Mainly ones, twos and small groups (up to 4). Attracted to campsites, fires and roadkills. One flushed from a disused nest platform, with remains of a freshly killed juvenile Eurasian Coot *Fulica atra* at Lewis Creek floodout in May 1997.

Whistling Kite *Haliastur sphenurus*

Uncommon to moderately common throughout the region. Mainly ones and twos. Most frequent at Lewis Creek floodout and Lake Willson during flood years e.g. July 1995 and May 1997, less frequent during other visits. Breeding (egg laying) in April and August-September; 4 nests at Lake Willson were in large *Acacia neurocarpa* and *Melaleuca glomerata* trees standing in 2 m of

water; 9 nests all with young at Lewis Creek floodout in May 1997; and a nest with 2 eggs at Lewis Creek floodout on 3 October 1997.

Brown Goshawk *Accipiter fasciatus*

Uncommon. Mainly ones and twos and favouring well wooded areas. Most records in May and July especially 5 at Maurice Spring in the Denison Range were probably migrants of *A. f. fasciatus* from southern Australia. A nest with 3 eggs in bloodwood at Brophy Creek on 30 September 1997 belonged to the northern subspecies *A. f. didimus*.

Collared Sparrowhawk *Accipiter cirrocephalus*

Uncommon in ones and twos. Recorded at Brophy Spring, along Brophy and Slatey Creeks and at Lake Willson, nest with 4 eggs in *Melaleuca nervosa* at Brophy Spring on 7 July 1993 and nest with 2 eggs and 2 hatchlings in a river gum on Slatey Creek on 2 October 1997.

Little Eagle *Aquila morphnoides*

Scarce; ones and twos. Only recorded at Brophy Spring and Talbot Spring. One disturbed eating a freshly killed Little Black Cormorant (*Phalacrocorax melanoleucos*) on the ground near dam at Talbot Spring in July 1995.

Wedge-tailed Eagle *Aquila audax*

Moderately common. Ones and twos throughout the region. One at a nest in a coolibah at Lewis Creek floodout on 3 October 1997.

Spotted Harrier *Circus assimilis*

Uncommon. Ones and twos at

Brophy Creek and on open spinifex flats edge of Slatey Creek. Nest with 3 eggs, 16 m up on a horizontal limb of a river gum *Eucalyptus camaldulensis* at Brophy Spring on 7 September 1993.

Swamp Harrier *Circus approximans*

Moderately common around the rookeries at Lake Willson in April 1994. This species is a non-breeding visitor to the Kimberley (February-July).

FALCONIDAE

Brown Falcon *Falco berigora*

Moderately common in ones and twos throughout the region. Observed in all habitats. Both dark and pale phase birds seen. Nest with 3 partly eaten eggs at Lewis Creek floodout on 3 October 1997.

Australian Kestrel *Falco cenchroides*

Moderately common. Mainly ones and twos. Favouring the vicinity of watercourses with river gums. Nest with 4 eggs at entrance to a large hollow in the trunk of a *Eucalyptus camaldulensis* on Brophy Creek on 8 September 1993; and nest with 4 eggs (chipping) in hollow of *Eucalyptus camaldulensis* on Slatey Creek on 3 October 1997.

Australian Hobby *Falco longipennis*

Moderately common in ones, twos and threes. Favouring river gums along watercourses, the Lewis Creek floodout and Lake Willson.

Peregrine Falcon *Falco peregrinus*
One at Granny Soak in May 1998.

Black Falcon *Falco subniger*
Two probably a pair (one slightly larger than other) at Lewis Creek floodout on 3 October 1997 and one in May 1998.

GRUIDAE

Brolga *Grus rubicunda*
Moderately common in small flocks (up to 22). Most plentiful at Lake Willson (58 in October 1997 and 60 in May 1998) and Lewis Creek floodout, less frequent along watercourses. Feeding on bulbs of the sedge (*Cyperus bulbosus*) at Brophy Creek and Talbot Spring in July 1995. Many old nests around the Lewis Creek floodout in September 1993.

RALLIDAE

Baillon's Crake *Porzana pusilla*
Scarce to moderately common transient and visitor to Lewis Creek floodout and Lake Willson when filled. In May 1997 about 20 were scattered over both lakes at Lewis Creek floodout, taking refuge in dense patches of floating spiny mudgrass (*Pseudoraphis spinescens*). Old nest found at Lewis Creek floodout in May 1997.

Australian Spotted Crake *Porzana fluminea*
One flushed from spiny mudgrass at Lewis Creek floodout on 16 May 1997. There are very few records of this species for the Kimberley.

Purple Swamphen *Porphyrio porphyrio melanotus*
Moderately common at Lewis Creek floodout in small groups (up to 12) also one loose group of 50. Recorded in July 1995 and May and October 1997. Nest with 4 eggs and several old nests found in May 1997.

Black-tailed Native Hen *Gallinula ventralis*
About five thousand around the Lewis Creek floodout in September 1993; appears to be only transient or a visitor to this wetland when filled.

Eurasian Coot *Fulica atra australis*
Common to very common at Lake Willson and Lewis Creek floodout. Thousands around Lake Willson in August-September 1993 and April 1994, less frequent (100s) during other visits. Large numbers breeding at Lake Willson in August-September 1993 (nests with 1-9 eggs); April 1994 (eggs and newly hatched young); and at Lewis Creek floodout (many half grown downy chicks) on 16 May 1997. Some nests at Lake Willson were built on top of nests of Australasian Grebe.

OTIDIDAE

Australian Bustard *Otis australis*
Moderately common in ones, twos and threes. Recorded throughout the area in July 1995, May and October 1997 and at Lake Willson in May 1998. One flushed from an egg laid on bare sandy ground in low spinifex with

scattered *Acacia* near Brophy Spring on 30 September 1997.

TURNICIDAE

Red-chested Button-quail *Turnix pyrrhothorax*

Moderately common at Lake Willson in September 1993 and one flushed from marshy area at Brophy Spring on 4 May 1995. Call a distinctive 'g-oom' repeated several times.

Little Button-quail *Turnix velox*

Common throughout the area in July 1995, less frequent during other visits. Mainly ones, twos and small groups (up to 4). Favouring spinifex flats with *Acacia* and *Grevillea*.

SCOLOPACIDAE

Black-tailed Godwit *Limosa limosa melanuroides*

A single bird feeding in shallow water at edge of Lake Willson on 4 October 1997. Visitor (July-February) to Kimberley from northern hemisphere.

Marsh Sandpiper *Tringa stagnatilis*

Three at Lake Willson on 10 July 1995 and single birds and one group of 4 at same place on 4 October 1997. Visitor (July, September, October and April) to Kimberley from northern hemisphere.

Wood Sandpiper *Tringa glareola*

One at Lewis Creek floodout on 3 October 1977. Visitor (August-May) to Kimberley from northern hemisphere.

Common Sandpiper *Tringa hypoleucos*

Single birds at Lake Willson on 4 October 1997. Visitor (mainly July-April) to Kimberley from northern hemisphere.

Red-necked Stint *Calidris ruficollis*

Thirteen at Lake Willson in May 1998. A rare passage migrant with few inland records.

Long-toed Stint *Calidris subminuta*

Two at the edge of Lake Willson on 4 October 1997. A rare passage migrant to this region with few Kimberley records.

Sharp-tailed Sandpiper *Calidris acuminata*

Two and a flock of 10 at edge of Lake Willson on 4 October 1997. A rare passage migrant to this region with few Kimberley records.

Curlew Sandpiper *Calidris ferruginea*

Two and a flock of 6 at edge of Lake Willson on 4 October 1997. Rare visitor to Kimberley from northern hemisphere.

BURHINIDAE

Bush Stone-curlew *Burhinus grallarius*

Single birds around Brophy Springs in October 1997. Mainly on open stony flats with spinifex.

RECURVIROSTRIDAE

Black-winged Stilt *Himantopus himantopus leucocephalus*

Common at Lake Willson in August 1993 and July 1995 (when lake filled); about 30 in May 1997; and 10 in October 1997. Breeding in August 1993; a loose colony with nests on top of collapsed termite mounds on the floodout away from the lake; many fresh nest scrapes, 2 nests with 2 eggs and 1 nest with 1 egg.

Red-necked Avocet *Recurvirostra novaehollandiae*

One at Lake Willson in May 1998.

CHARADRIIDAE

Masked Lapwing *Vanellus miles miles*

Common at Lake Willson and Lewis Creek floodout. Mainly ones, twos and small groups. Breeding at Lake Willson on 23 August 1993 (1 nest with 1 egg and one with 3 eggs); 5 September 1993 (nest with 4 eggs); 11 April 1994 (nest with 4 eggs); and 4 October 1997 (nest with 4 eggs). Nests were placed on small islands created by collapsed termite mounds on the floodout away from the lake and on bare ground left by receding water.

Red-capped Plover *Charadrius ruficapillus*

Common at Lake Willson in small groups (up to 4) and larger flocks (up to 40). Mainly bare edge of lake and grassy flats. Nests with 2 eggs on 21 August 1993; 4 September 1993; and 4 October 1997.

Black-fronted Dotterel *Charadrius melanops*

Common at Lake Willson and

moderately common around pools on Brophy Creek. Nest with 3 eggs on top of an old Brolga's nest at Lake Willson on 4 September 1993; nests with 2 eggs on bare ground edge of lake on 10 September 1994 and 4 October 1997; and nest with 2 eggs in washed gravel in Brophy Creek on 9 September 1993.

Oriental Plover *Charadrius veredus*

Common in small groups (up to 10) around edge of Lake Willson on 4 October 1997. visitor (September-February) to Kimberley from northern hemisphere.

Red-kneed Dotterel *Erythrogonus cinctus*

Common in small groups (up to 14) at Lake Willson and Lewis Creek floodout. Recorded in July 1995 and May and October 1997.

GLAREOLIDAE

Australian Pratincole *Stiltia isabella*

Common in twos and small groups (up to 15) at Lake Willson in September 1993 and October 1997. Favouring the damp grassy edge of lake. Nest with 1 egg and one with 2 eggs on 4 September 1993.

LARIDAE

Gull-billed Tern *Sterna nilotica macrotarsa*

About 6 at Lake Willson on 10 July 1995.



Figure 1. Gardner Ranges (K. Coate)

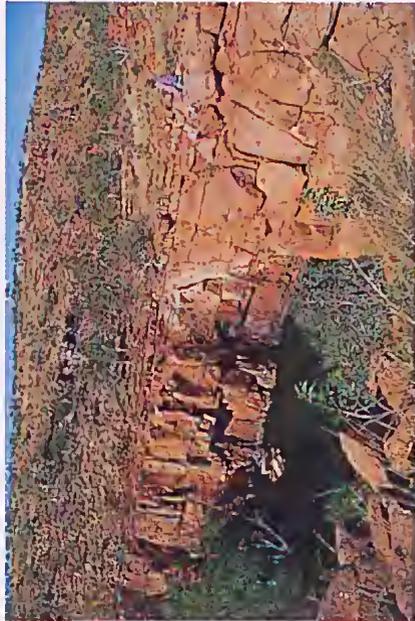


Figure 2. Large permanent rockhole within the Gardner Range (K. Coate)



Figure 5. Lewis Creek Floodout (K. Coate)



Figure 6. Lewis Creek Floodout showing spiny mudgrass and *Eucalyptus vitrix* trees, with Denison Range in background (K. Coate)



Figure 3. Mt Brophy Spring (K. Coate)



Figure 7. Lake Willson 1995 (K. Coate)



Figure 4. Granny Soak (K. Coate)

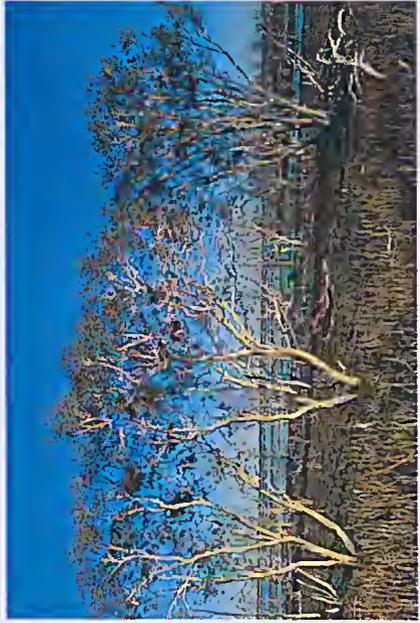


Figure 8. Lake Willson 1995, showing disused nests of Little Black Cormorant in *Melaleuca glomerata* trees (K. Coate)

Caspian Tern *Sterna caspia*

Seven at Lake Willson on 14 May 1997 and 4 in May 1998.

Whiskered Tern *Sterna hybrida javanica*

Uncommon. Small flocks (up to 6) at Lake Willson on 10 July 1995 and 4 October 1997.

COLUMBIDAE

Common Bronzewing
Phaps chalcoptera

Uncommon to moderately common, in ones, twos and threes. Favouring thickets of *Melaleuca*, *Eucalyptus* and *Acacia* along creeks and around Lake Willson. Nest with 2 eggs in eucalypt over a creek near Bradshaw's Well on 2 October 1997.

Flock Pigeon *Phaps histrionica*

Small flocks (up to 25) recorded by W.H. Butler in June 1975.

Crested Pigeon *Ocyphaps lophotes*

Uncommon, mainly in ones and twos except for one group of 15 at Granny's Soak. Mainly about watercourses. Nest with 2 small young 2 m above water in thick *Melaleuca* at Lake Willson on 13 April 1994.

Spinifex Pigeon *Geophaps plumifera*

Common, mostly in pairs but also in small flocks (up to 10). Favouring rocky slopes of ranges; also descending to small pools in creeks. Several nests with eggs or newly hatched young on rocky hills at Brophy Spring in July 1995.

Diamond Dove *Geopelia cuneata*

Very common around Lake Willson in October 1997 but generally uncommon in ones, twos and small groups (up to 4). Most habitats including ranges, thickets and scrub along creeks and around wetlands and open spinifex flats. A nest with 2 eggs in *Grevillea refracta* at Brophy Spring on 4 July 1995.

Peaceful Dove *Geopelia striata placida*

Common throughout the area in July 1995, less frequent during other visits and confined largely to watercourses. These records represent the southern limit for this species in east Kimberley.

Bar-shouldered Dove *Geopelia humeralis*

Several at the Lewis Creek floodout on 9 July 1995. The southernmost records for south-east Kimberley (previously only recorded south to the lower Mary, Black Elvire and Negri Rivers).

PSITTACIDAE

Galah *Cacatua roseicapilla roseicapilla*

Uncommon to moderately common in pairs and small groups. Mainly in vicinity of watercourses. Much more frequent in neighbouring pastoral country.

Little Corella *Cacatua sanguinea sanguinea*

Common in flocks (up to 100). Mainly about watercourses, also ghost gum *Corymbia bella* and coolibah flats.

Major Mitchell's Cockatoo
Cacatua leadbeateri

Uncommon. Ones, twos and threes around Mt Brophy Springs, Brophy Creek, Lewis Creek floodout, Maurice Spring and base of Denison Range. Observed feeding on the green seed pods of *Acacia colei* on Brophy Creek in October 1997.

Cockatiel *Nymphicus hollandicus*

Common throughout the region in July 1995 scarce during other visits.

Australian Ringneck *Platycercus zonarius zonarius*

Moderately common. Mainly in pairs and favouring watercourses with tall river gums *Eucalyptus camaldulensis*. The northern limit of this species in Western Australia.

Budgerigar *Melopsittacus undulatus*

Very common throughout the area in July 1995, and occasional small flocks seen in May 1997. Breeding in large numbers at Lewis Creek floodout in July 1995.

Night Parrot *Pezoporus occidentalis*

On 5 July 1996 at Mt Brophy Springs K. Coate and G. Lodge found 4 immaculately clipped tunnels leading into small cavities in the top of three spinifex tussocks, which were possibly made by Night Parrots. They were all within 3 m of each other. Three tunnels faced east with entrance 4–6 cm in diameter and extended for about 21 cm from near the top of the spinifex clump at an angle of 45

degrees. The cavity at the base of the tunnel was several centimetres above the ground. The fourth tunnel faced west and was much shorter. The spinifex had been bitten off at a 45° angle consistent with parrot clippings.

CUCULIDAE

Pallid Cuckoo *Cuculus pallidus*

Moderately common at Lake Willson in July 1995 and May 1997, and at Lewis Creek floodout in October 1997; elsewhere uncommon. Breeding at Lewis Creek floodout in October 1997, parasitising White-breasted Woodswallow. This is the first breeding record for this species in the Kimberley, most birds being non-breeding visitors and passage migrants from the south.

Horsfield's Bronze Cuckoo
Chrysococcyx basalis

Moderately common throughout the area. Recorded in most habitats including creekside vegetation, *Melaleuca* thickets around wetlands and open *Acacia* – spinifex.

Channel-billed Cuckoo *Scythrops novaehollandiae*

One record, a fledgling, light brown with darker barrings on back, found in a nest of Little Crow *Corvus bennetti* at Lake Willson on 10 April 1994. The southernmost breeding record for south-east Kimberley. This species is an uncommon visitor and passage migrant to the Kimberley during October-March.

STRIGIDAE

Boobook Owl

Ninox novaeseelandiae boobook

Moderately common. Recorded at Brophy Spring, along Brophy Creek, Mongrel Creek and at Lewis Creek floodout. Mainly in creekside vegetation especially river gums and coolibahs. Breeding in hollows of river gums on 7 September 1993 (nest with 2 eggs); and 30 September 1997 (2 nests with 3 eggs and one with 2 eggs).

TYTONIDAE

Barn Owl *Tyto alba*

Uncommon. Recorded at Brophy Spring and Lewis Creek floodout during most visits e.g. 4 flushed from hollows of *Eucalyptus* at Lewis Creek on 9 July 1995 and 2 on 3 October 1997, also one at Granny Soak in May 1998. Nest with 4 eggs in hollow of large *Eucalyptus camaldulensis* at Brophy Spring on 18 August 1993 and a pair with fully fledged young in same hollow on 3 July 1995.

PODARGIDAE

Tawny Frogmouth *Podargus strigoides phalaenoides*

Scarce. Recorded at Palm Spring (Maurice Spring) by Butler in June 1975 and 2 adults and 2 feathered chicks at nest in eucalypt near Brophy Spring on 1 October 1997.

CAPRIMULGIDAE

Spotted Nightjar *Eurostopodus argus*

Moderately common. Mainly rocky slopes of ranges also around water holes and Lake Willson.

AEGOTHELIDAE

Australian Owlet Nightjar

Aegotheles cristatus leucogaster

Moderately common throughout the area in July 1995, less frequent during other visits. Nest with 2 eggs in hollow of *Eucalyptus camaldulensis* edge of Brophy Creek on 8 September 1993.

HALCYONIDAE

Red-backed Kingfisher

Todiramphus pyrrhopygia

Moderately common. Mainly ones and twos and favouring vicinity of watercourses. Nest with 5 eggs in a 28 cm long tunnel dug into the vertical bank of Brophy Creek on 8 September 1993.

Sacred Kingfisher *Todiramphus sanctus sanctus*

Moderately common in September-October 1997. Mainly single birds along watercourses (Brophy Creek, Bradshaw's Well and Lewis Creek floodout). Most are probably passage migrants that begin moving south in October.

MEROPIDAE

Rainbow Bee-eater *Merops ornatus*

Moderately common to very common. Mainly a winter visitor and passage migrant (moving north in February-May and south in October-November). Recorded in June-July 1975, September 1993,

July 1995 and May and October 1997. Favouring open sandy areas along watercourses and edges of Lewis Creek floodout and Lake Willson. Breeding in October 1997, nest burrows with eggs at Brophy Creek, Lewis Creek floodout and Lake Willson.

MALURIDAE

Variegated Fairy-wren *Malurus lamberti assimilis*

Scarce to moderately common throughout the area, in pairs and small parties (up to 5). Mainly sandplain vegetation with *Acacia*, *Grevillea*, *Triodia* and *Melaleuca* thickets. Nest with 3 eggs at base of bush edge of Lake Willson on 22 August 1993 and nest with 2 young in dead *Acacia* at Brophy Spring on 30 September 1997.

White-winged Fairy-wren
Malurus leucopterus leuconotus

Moderately common throughout the area, in pairs and small parties (up to 5). Mainly sandplain vegetation with *Acacia*, *Grevillea* and *Triodia*, also spinifex flats with scattered *Hakea* and open grassy flats.

Rufous-crowned Emu-wren
Stipiturus ruficeps ruficeps

Moderately common in pairs and small parties (up to 10). Recorded along Brophy Creek around Mt Brophy Spring, Slatey Creek, Bramall Hills and southern end of Denison Range. Mainly dense *Triodia* with scattered *Acacia* and *Grevillea* on sandy or stony substrates. The first records for the Kimberley, previously only known north to Well 48 Canning

Stock Route (Storr 1981) and reported between Stafford Bore and Well 51 by K. Coate on 3 July 1993.

PARDALOTIDAE

Red-browed Pardalote *Pardalotus rubricatus*

Locally common but generally uncommon; in ones and twos. Mainly along watercourses. Nest with 2 eggs on 18 May 1997 and fresh nest burrow on 30 September 1997.

ACANTHIZIDAE

Weebill *Smicrornis brevirostris*

Moderately common throughout the area, in small flocks. Mainly eucalypts along watercourses. Nest with 2 eggs 1 m up in drooping leaves of *Eucalyptus brevifolia* on 7 July 1995.

MELIPHAGIDAE

Brown Honeyeater *Lichmera indistincta indistincta*

Common throughout the area. All wooded habitats, but locally aggregating at flowering trees and shrubs, especially *Melaleuca*, *Grevillea* and *Eucalyptus*.

Black Honeyeater *Certhionyx niger*
Common in June 1975 and May 1997, uncommon or scarce during other visits. Mainly attracted to flowering *Eucalyptus pachyphylla* and *Grevillea wickhamii*.

Pied Honeyeater *Certhionyx variegatus*

Common throughout the area in

June 1995; several near Mt Brophy Spring in July 1995; several throughout area in September-October 1997, and one at Mt Brophy Spring in May 1998. Mainly attracted to flowering *Grevillea*.

Singing Honeyeater *Meliphaga virescens*

Moderately common throughout the area. Recorded in all habitats with flowering trees and shrubs.

Grey-headed Honeyeater *Meliphaga keartlandi*

Common in sandplain vegetation with flowering *Grevillea wickhamii* around Mt Brophy Spring, also in gullies in ranges with flowering *Eucalyptus*.

Grey-fronted Honeyeater *Meliphaga plumula*

Common throughout the area. Mainly creekside vegetation with thickets of *Melaleuca nervosa*. Also attracted to flowering *Grevillea wickhamii*, *Eucalyptus camaldulensis* and *E. brevifolia*. Several nests with young in *Melaleuca nervosa* at Brophy Creek in August-September 1993. Two nests (1 with 2 large young, the other with 1 egg and a broken egg on ground below), in *Melaleuca nervosa*, also nest with 2 young in *Eucalyptus* and another with 2 eggs in *Grevillea wickhamii* at Brophy Creek; and two nests with 2 eggs and several with small young in *Eucalyptus camaldulensis* and *E. brevifolia* on Slatey Creek in July 1995. Many fledged young were observed along Slatey Creek in July 1995.

White-plumed Honeyeater *Meliphaga penicillata*

Locally common e.g. at Mt Brophy Spring, Brophy Creek, Granny Soak, Talbot Spring, Maurice Spring and around Lake Willson less frequent elsewhere. Mainly river gums on watercourses also ghost gum flats and *Melaleuca* thickets including *M. glomerata* around Lake Willson.

Breeding recorded at Lake Willson; nest with 2 small young in drooping leaves of small *Eucalyptus* on 21 August 1993, nest with 2 eggs also in drooping leaves of *Eucalyptus* and another with 2 young in leaves of *Melaleuca glomerata* on 11 April 1994. Many fledged young noted at Lake Willson in May 1997.

Black-chinned Honeyeater *Melithreptus gularis laetior*

Uncommon. Recorded at Mt Brophy Spring, Granny Soak, East Palm Spring (=Maurice Spring), Lewis Creek floodout and near Lake Willson. Near Lake Willson mainly attracted to flowering *Eucalyptus pachyphylla*, *Eucalyptus odontocarpa* and *Grevillea wickhamii*.

Little Friarbird *Philemon citreogularis citreogularis*

Scarce. Only recorded near Mt Brophy Spring and Granny Soak. Mainly attracted to flowering *Melaleuca nervosa*. These are the southernmost records for south-east Kimberley.

White-fronted Honeyeater *Phylidonyris albifrons*

Common throughout the area in June 1975; otherwise scarce.

Several 3 km north of Lake Willson on 14 May 1997; and several in flowering *Grevillea wickhamii* near Mt Brophy Spring on 30 September 1997.

Rufous-throated Honeyeater
Conopophila rufogularis

Locally common e.g. at Mt Brophy Spring, Bradshaw's Well, and around Lake Willson, but generally uncommon. Mainly attracted to flowering *Melaleuca nervosa*, *Eucalyptus camaldulensis* and *Grevillea wickhami*. These represent the southernmost records for the Kimberley.

Yellow-throated Miner *Manorina flavigula*

Moderately common throughout the area. Mainly small flocks (up to 15). Favouring eucalypt woodland along watercourses. Two nests (one with young the other 2 eggs) in hanging branches of *Eucalyptus victrix* at Lewis Creek floodout on 16 May 1997, and nest with young in ghost gum at Granny Soak on 1 October 1997.

Spiny-cheeked Honeyeater
Acanthagenys rufogularis

Locally moderately common e.g. around Mt Brophy Spring, head of Slatey Creek and south end of Denison Range, but generally scarce. Attracted to flowering *Melaleuca* and *Eucalyptus*. These represent the northernmost records for Western Australia.

Orange Chat *Epthianura aurifrons*
Eleven at Lake Willson in May 1998. The northernmost record for Western Australia.

Crimson Chat *Epthianura tricolor*
Common around Lake Willson in September 1993 and at Lake Willson, Talbot Spring and Granny Soak in May 1998; also two near Mt Brophy Spring on 3 July 1995. Two nests (one with 3 eggs the other 3 large young) in flooded *Triodia* at Lake Willson on 4 September 1993.

EOPSALTRIIDAE

Red-capped Robin
Petroica goodenovii

Two in well vegetated area about 2 km north of Mt Brophy Spring on 18 May 1997 and single males observed at Denison Range and Granny Soak in May 1998. A non-breeding winter visitor to southern Kimberley (May-August).

POMATOSTOMIDAE

Grey-crowned Babbler
Pomatostomus temporalis rubeculus

Moderately common, throughout the area. Mainly vegetation along watercourses. The Denison and Gardner Ranges and Lake Willson are the southern limit of the Kimberley population. Nest with 2 young at Lake Willson on 18 May 1997.

PACHYCEPHALIDAE

Crested Bellbird *Oreoica gutturalis*
Moderately common in ones and twos around Mt Brophy Spring, Granny Soak and in Gardner Range.

Rufous Whistler *Pachycephala rufiventris rufiventris*

Scarce. Recorded around Mt Brophy Spring, Granny Soak and Talbot Spring.

Grey Shrike-thrush *Colluricincla harmonica rufiventris*

Scarce. Recorded around Mt Brophy Spring, Granny Soak and in Gardner Range. One was collected by Butler in a thicket of flowering *Grevillea* near Granny Soak.

DICRURIDAE

Grey Fantail *Rhipidura fuliginosa*

Three at Lewis Creek floodout in May 1998. Probably migrants from south-eastern Australia.

Willie Wagtail *Rhipidura leucophrys leucophrys*

Common throughout the area. Mainly in ones and twos and favouring watercourses and edge of Lake Willson. Nest with 3 small young in *Eucalyptus* in dried up backwater of Lake Willson on 4 September 1993.

Magpie Lark *Grallina cyanoleuca*

Moderately common resident throughout the area, in ones and twos, and also a moderately common dry season visitor in small flocks (up to 8). Mainly open areas around water. Two nests with 4 eggs at Lake Willson on 21 August 1993, one with 3 eggs at same place on 4 September 1993, and one with 2 addled eggs and 1 chick at Lewis Creek floodout on 3 October 1997.

CAMPEPHAGIDAE

Black-faced Cuckoo Shrike

Coracina novaehollandiae novaehollandiae

Uncommon to moderately common, usually in ones and twos but occasionally in small flocks. In all wooded habitats. Nest with 3 eggs in bloodwood at Mt Brophy Spring on 10 October 1997. Six feeding on fruits of *Ficus* on cliff face at Bradshaw's Well on 2 October 1997.

Ground Cuckoo Shrike

Pteropodocys maximus

Uncommon in ones, twos, threes and small flocks (up to 6). Recorded at Granny Soak, Lewis Creek floodout and Maurice Spring (East Palm Spring) at south end of Denison Range.

White-winged Triller *Lalage tricolor*

Uncommon to moderately common in ones, twos and small parties, (most frequent in May 1997). Recorded throughout the area in most wooded habitats.

ARTAMIDAE

White-breasted Woodswallow

Artamus leucorhynchus

Locally common e.g. at Lewis Creek floodout and Lake Willson, elsewhere scarce. Nest with small young in old Magpie Lark nest 3 m up in small eucalypt at Lake Willson on 21 August 1993; nest with 4 eggs and 1 egg of Pallid Cuckoo in hollow spout of *Eucalyptus victrix* at Lewis Creek floodout on 3 October 1997; and

nest with 4 pin-feathered young in spout of dead tree at Lake Willson on 4 October 1997.

Masked Woodswallow *Artamus personatus*

Common nomad. Most flocks around Gardner Range and sandplain country around Mt Brophy Spring. Attracted to flowering trees especially *Grevillea wickhamii*.

White-browed Woodswallow
Artamus superciliosus

Scarce; 7-8 in with flocks of Masked Woodswallows at Mt Brophy Spring on 4 July 1995 and 18 May 1997. Feeding on blossom of *Grevillea wickhamii*.

Black-faced Woodswallow
Artamus cinereus melanops

Common throughout the area. All wooded habitats. Nest with 3 young in small *Melaleuca glomerata* and another with 3 eggs in small *Eucalyptus* at Lake Willson on 21 August 1993, and nest with 3 eggs in small bloodwood near Mt Brophy Spring on 30 September 1997.

Little Woodswallow *Artamus minor*

Common to moderately common in Gardner and Denison Range, Bramall Hills and around Lewis Creek floodout. Usually in pairs or small parties (up to 16).

CRACTICIDAE

Pied Butcherbird
Cracticus nigrogularis

Moderately common throughout the area. Mainly open eucalypt

woodland also *Acacia* and *Grevillea* on plains. Nest with 2 pin-feathered young in *Melaleuca* at Granny Soak on 1 October 1997 and another with young in eucalypt on rocky hill, Denison Range, on 4 October 1997.

Australian Magpie *Cracticus tibicen tibicen*

Two at Mongrel Creek crossing (19°10'S, 128°56'E) in river gums on 2 October 1997.

CORVIDAE

Torresian Crow *Corvus orru ceciliae*
Locally moderately common e.g. at Mt Brophy Spring and around Lake Willson but generally scarce or uncommon. Usually in ones and twos occasionally small groups (up to 6). More frequent in adjacent pastoral country. Mainly river gums along watercourses. Nest with young in tall river gum at Mt Brophy Spring on 1 October 1997.

Little Crow *Corvus bennetti*
Moderately common around Lake Willson in small flocks (up to 20), scarce or absent elsewhere. Nest with a young Channel-billed Cuckoo at Lake Willson on 10 April 1994.

ALAUDIDAE

Singing Bushlark *Mirafra javanica*
Uncommon. Mainly ones, twos and threes. Recorded on open spinifex flats around Mt Brophy Spring; and on grassy flats on Slatey Creek and around Lake Willson.

MOTACILLIDAE

Richard's Pipit

Anthus novaeseelandiae australis

Uncommon to moderately common throughout the area. Spinifex flats with scattered *Acacia* and *Grevillea*, open stony flats on ranges and around wetlands.

PASSERIDAE

Zebra Finch *Taeniopygia guttata castanotis*

Moderately common to common throughout the area. Pairs and small flocks (up to 20). Breeding recorded in June and July including many nests under old cormorant nests in *Melaleuca glomerata* at Lake Willson in July 1995.

Painted Finch *Emblema pictum*

Common around Mt Brophy Spring and on rocky slopes and gullies of the Gardner Range in May 1995; and in Gardner Range and Talbot Spring area in May 1998; but generally uncommon and patchily distributed with only small numbers recorded at Granny Soak and Denison Range in June 1975 and at Bradshaw's Well in October 1997. Two nests with young built in clumps of *Triodia* near Mt Brophy Spring on 4 May 1995. A female eating decomposed bone of an old camel skeleton in Gardner Range in May 1998.

Pictorella Mannikin *Heteromunia pectoralis*

Scarce. Two at Lake Willson on 14 May 1997 and 2 near Slatey Creek

just north of Bramall Hills on 17 May 1997. These are the southernmost records for south-east Kimberley.

DICAEIDAE

Mistletoebird *Dicaeum hirundinaceum hirundinaceum*

Uncommon throughout the area. All wooded habitats including *Melaleuca* thickets.

HIRUNDINIDAE

Tree Martin *Hirundo nigricans nigricans*

Common non-breeding winter visitor (only recorded in May-June), around wetlands.

Fairy Martin *Hirundo ariel*

Common around Lake Willson but generally uncommon to moderately common in small flocks. Two clusters of nests built on trunk and branches of small *Melaleuca lasiandra* 500 m from water, in dried out area edge of Lake Willson on 4 September 1993; about 10 nests at Bradshaw's Well on 2 October 1997; and old nests at Talbot Spring (Palm Spring), Denison Range in June 1975.

SYLVIIDAE

Little Grassbird
Megalurus gramineus

Status uncertain; probably only a rare non-breeding visitor. Several observed and calling in a dense stand of *Melaleuca glomerata* in 4 m of water at Lake Willson on 15 April 1994. This species has only

recently become established in north-east Kimberley.

Spinifex-bird *Eremiornis carteri*

Uncommon throughout the area. Spinifex on stony slopes and sandy flats.

Rufous Songlark *Cincloramphus mathewsi*

Locally common (at Lake Willson in May 1997) but generally scarce or uncommon. Mainly around wetlands and along watercourses.

Golden-headed Cisticola *Cisticola exilis exilis*

Two in dense cane grass (*Sorghum* sp.) 10 km north of Mt Brophy Spring on 3 and 5 July 1995. Previously only recorded south in east Kimberley to Ord River Station.

DISCUSSION

A total of 155 species (103 non-passerine and 52 passerine) were recorded from the area covered in this paper. The number can be compared with the 121 species recorded in the Edgar Ranges in south-west Kimberley (Johnstone *et al.* 1981). The richness of the avifauna is mainly due to the diversity of habitats, especially the wetlands of the Lewis Creek floodout and Lake Willson. Without the wetland species the total (about 110) is more comparable with that of the Edgar Ranges. A considerable amount of work has been done in the area and we feel that most of the resident species have been recorded. More work however during different seasons would

no doubt add other visiting waders and waterfowl to the list.

Most of our visits to the area were after good seasons with above average rainfall. It would appear, judging from rainfall records from Sturt Creek, that the flooding of Slatey and Lewis Creeks into Lake Willson is not that uncommon. During these periodic floodings the Lewis Creek floodout and Lake Willson become an important breeding and refuge area for many waterbirds including Grey Teal *Anas gracilis*, Pink-eared Duck *Malacorhynchus membranaceus*, Hardhead *Aythya australis*, Little Black Cormorant *Phalacrocorax sulcirostris*, Little Pied Cormorant *Phalacrocorax melanoleucos*, Black-tailed Native Hen *Gallinula ventralis* and Eurasian Coot *Fulica atra*. Some species of waterfowl including the Magpie Goose *Anseranas semipalmata*, Plumed Whistling Duck *Dendrocygna eytoni* and Wandering Whistling Duck *Dendrocygna arcuata* are no doubt visitors from the Ord region to the north, and the Australian Wood Duck *Chenonetta jubata* and Great Crested Grebe *Podiceps cristatus* visitors from southern Australia.

The Gardner and Denison Ranges are on the boundary between two major zoogeographic subregions, the Torresian in the north and the Eyrean in the south. The Ord River drainage lies close the north, and the dunes of the Great Sandy and Tanami Deserts lie to the south. Although situated just within the Kimberley Division, the Torresian element in the avifauna is small and comprises

only 7 species none of which are resident in the Pilbara: Magpie Goose *Anseranas semipalmata*, Red-breasted Button-quail *Turnix pyrrhоторax*, Flock Pigeon *Phaps histrionica*, Channel-billed Cuckoo *Scythrops novaehollandiae*, Little Fiarbird *Philemon citreogularis*, Rufous-throated Honeyeater *Conopophila rufogularis* and Pictorella Mannikin *Heteromunia pectoralis*.

The Great Sandy Desert is a major barrier between the Kimberley and the Pilbara regions, and many species have a broken distribution with a population in the Kimberley and one in the Pilbara or southern Western Australia. Species whose Kimberley population is at its southern limit in the Gardner and Denison Ranges and Lake Willson area include: Brown Quail *Coturnix ypsilophora*, Black-necked Stork *Ephippiorhynchus asiaticus*, Peaceful Dove *Geopelia striata*, Bar-shouldered Dove *Geopelia humeralis*, Little Corella *Cacatua sanguinea*, Australian Owllet Nightjar *Aegotheles cristatus*, Little Grassbird *Megalurus gramineus*, Golden-headed Cisticola *Cisticola exilis* and also the Kimberley subspecies of the Brown Goshawk *Accipiter fasciatus didimus*. Some arid country species whose range is continuous across the deserts are at or near their northern limit in south-east Kimberley in the Gardner and Denison Ranges: these include Major Mitchell's Cockatoo *Cacatua leadbeateri*, Australian Ringneck *Platycercus zonarius*, Rufous-crowned Emu-wren *Stipiturus ruficeps*, Spinifex-bird *Eremiornis carteri*, White-fronted Honeyeater *Phylidonyris*

albifrons, Spiny-cheeked Honey-eater *Acanthagenys rufogularis*, White-plumed Honeyeater *Meliphaga penicillata* and Orange Chat *Ephianura aurifrons*.

The area contains many flowering trees and shrubs and often a good ground cover of spinifex and soft grasses. It contains a fairly low number of sedentary bird species such as the Common Bronzewing *Phaps chalcoptera*, Variegated Fairy-wren *Malurus lamberti*, Red-browed Pardalote *Pardalotus rubricatus* and Brown Honeyeater *Lichmera indistincta*. A larger category comprises nomads, breeding and non-breeding visitors and nectivorous birds following the flowering trees and shrubs.

Non-breeding winter visitors to the area from southern Australia include the Brown Goshawk *Accipiter fasciatus fasciatus*, Red-capped Robin *Petroica goodenovii* and the Tree Martin *Hirundo nigricans*. The Rainbow Bee-eater *Merops ornatus* is a breeding visitor.

This survey has shown that the Gardner and Denison Ranges and the Lake Willson area is of outstanding conservation importance and also contains areas of spectacular scenery. We would firmly recommend that a reserve be established in the region taking in the two range systems and the Slatey Creek, Lewis Creek drainage including Lake Willson.

ACKNOWLEDGEMENTS

We thank Mervyn Wortly, the manager of Sturt Creek Station, and Les Verdon of Gordon

Downs for their local knowledge and assistance, and Kevin F. Kenneally and Daphne J. Edinger, Science Publications Unit, Department of Conservation and Land Management for botanical identifications. We would also like to thank Mr and Mrs W.H. Butler whose grant to the Western Australian Museum defrayed the costs of R.E. Johnstone's fieldwork in 1997 and Landscape Expeditions for making it possible for K.H. Coate's visit in 1998. We are also grateful to Yvonne Coate, who assisted with the preparation of the article.

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DRINKING TIMES OF KANGAROOS, SHEEP, GOATS AND EMUS IN A PASTORAL AREA

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A recent study of the efficacy of Finlayson troughs was conducted on Middalya Station, W.A. (23°54'S, 114°46'E). They are electrical devices which were designed to restrict the access of Red Kangaroos (*Macropus rufus*) and Euros (*Macropus robustus*) to water troughs (King *et al.* 1997) in an attempt to control their grazing. During those trials it became obvious that it was necessary to know the drinking patterns of Red Kangaroos, Euros and Sheep (*Ovis aries*).

Finlayson troughs consist of a trough surrounded by an electrified wire 5–10 cm above the ground at a distance of 1.1 m from the trough (Norbury 1992). While Sheep approaching the trough can easily step over the wire and drink, Red Kangaroos and Euros cannot because of the length of their hind feet and tail and they receive a shock. Preliminary

studies conducted on single electrified Finlayson troughs in late 1992 and early 1993 showed that these devices denied many Red Kangaroos and Euros access to water. However, the Finlayson troughs also resulted in an unacceptably high number of Sheep receiving shocks and being repelled from water sources when they were continuously activated (King *et al.* 1997).

Russell (1969) stated that Euros were rarely seen moving during the day. Davies (1972) presented data showing that even under relatively cool conditions Red Kangaroos and Euros drank between 1600 and 0800 hours, and Dawson *et al.* (1975) found that Red Kangaroos and Euros graze and drink mainly between dusk and dawn, while Sheep drink in the morning and evening during hot weather. Henzell and McCloud (1984)

reported that Goats (*Capra hircus*) appeared to visit watering points almost exclusively during daylight hours, but their observations were only made from 50 minutes after dawn to a short time after sunset.

On the basis of those findings, timers which inactivated the power to the Finlayson troughs during daylight hours were installed in an attempt to reduce shocks to Sheep while still restricting Red Kangaroos and Euros from drinking during the night. The timers activated the devices between 1900 and 0500 hours. Observations were made to determine whether the activation times were appropriate, and to determine the reactions of Red Kangaroos, Euros and Sheep to the Finlayson troughs (King *et al.* 1997).

Finlayson troughs were installed on 21 water points on 100,000 ha of Middalya Station. The study area consists of plains, dunes and ridges which are mainly vegetated with spinifex (*Triodia spp.*) and scattered shrubs (*Acacia*, *Eremophila*, *Maireana* and *Atriplex*) while *Eucalyptus microtheca* and *E. camaldouensis* occur on alluvial plains and floodplains (Payne, Curry and Spencer 1987). Summers are hot to very hot and winters are mild. Maximum temperatures during this study ranged from 32°C to 45°C. Annual rainfall (222 mm) is variable and mainly falls between January and July. No rainfall occurred during any observation period in this study.

The Finlayson trough near Mulbia Dam was activated on 22 November 1993. Red Kangaroos

and Euros, and Sheep which attempted to drink at that water point were observed using 8 x 55 binoculars from a vehicle parked approximately 50m from the water point. It was not always possible to identify the species of kangaroo being observed, so the observations of Red Kangaroos and Euros were combined. Red Kangaroos were much more abundant among those animals which could be identified to species. Other large species of mammals, birds and reptiles which drank at the trough were also recorded.

Continuous observations for periods of 60–68 hours (beginning between 1715 and 1815) were made at Mulbia Dam on four occasions, starting on 27 October (before activation), and after activation on 22 November 1993, 10 January and 7 February 1994. Additional observations (between 1800 and 0600) were made for a total of 54 hours over nine other nights in November and for 33 hours over three nights (between 1800 and 0600) in December, 1993.

The times at which Red Kangaroos, Euros, Sheep, Goats and Emus (*Dromaius novaehollandiae*) were recorded drinking are shown in Figure 1a, 1b, 1c and 1d. Red Kangaroos and Euros drank only between 1600 and 0900 hours. In October, before the Finlayson trough was activated, all kangaroos drank between 1800 and 0600 hours. Small numbers drank before 2000 or after 0600, and the peak time for kangaroos attempting to drink on cool nights (daytime maximum temperatures between

32–34°C) was between 2100 and 2400 hours, while on hot nights (daytime maximum temperatures between 41–45°C) large numbers of kangaroos continued to attempt to drink between 2100 and 0300 hours (Figure 1a). Lower numbers of kangaroos approached the trough on cool nights than on hot nights, but many were prevented from drinking after the trough was activated.

Sheep drank throughout the entire day, but the peak drinking times were from 0500 to 0900 and from 1800 to 2100 and the number which drank during hot (18.6 per hour) and cooler days (20.4 per hour) was similar (Figure 1b). Goats mostly drank between 0700–1600, with peak drinking times between 0700–1000 and 1300–1600. Very small numbers of Goats drank between 1600–0700 (Figure 1c). Emus were observed drinking (68 individuals, group size from 1–13) throughout the daylight hours, with peak times around 1200 (Figure 1d). All Sheep, Goats and Emus which attempted to drink after activation of the trough were successful and their drinking times did not appear to be affected.

The only other species recorded as drinking were four Foxes (*Vulpes vulpes*), three Goannas (*Varanus gouldii* or *V. panoptes*), one Australian Bustard (*Ardeotis australis*), one Bush Stone Curlew (*Burhinus magnirostris*) and one corvid (*Corvus sp.*).

Our data substantiate the earlier findings of Davies (1972), that few Euros drank between 0800–1600, and by Dawson *et al.* (1975) who

suggested that Red Kangaroos and Euros drink between dusk and dawn. No Red Kangaroos or Euros drank between 0900 and 1600 during our periods of observation (Figure 1a).

The statements by Dawson *et al.* (1975) that Sheep move to and from watering points in daylight and drank in the morning and the evening during hot weather described their general drinking pattern. This study found, however, that small numbers of Sheep drank throughout the day with peak drinking times in the morning and evening (Figure 1b).

Finlayson troughs were fitted with timers which deactivated them during the peak drinking times for Sheep. The number of electrical shocks received by Sheep was substantially reduced. The shocks they received were mainly to their feet and did not deter them from approaching the water points. Activation of the Finlayson troughs only between 1900 and 0500 hours initially reduced the access of Red Kangaroos and Euros to the watering points by up to 80% when other water sources were available. However, once all other water points became inaccessible to them, Red Kangaroos and Euros found ways to circumvent the electrical devices and by February 1994 68% of those attempting to drink were successful. These methods included altering their gait (both increasing and decreasing their speed) when approaching the trough, ap-proaching the trough sideways instead of head-on, or lifting their tail or positioning

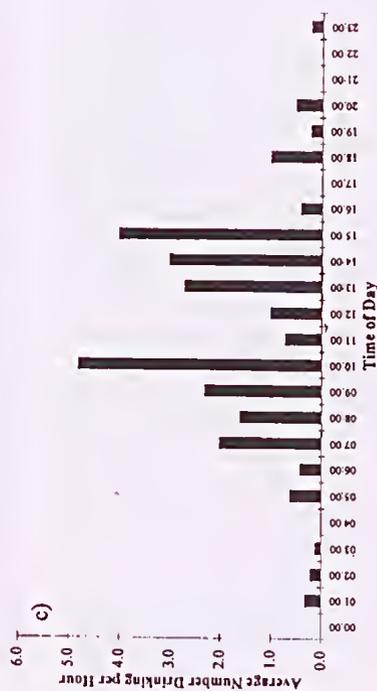
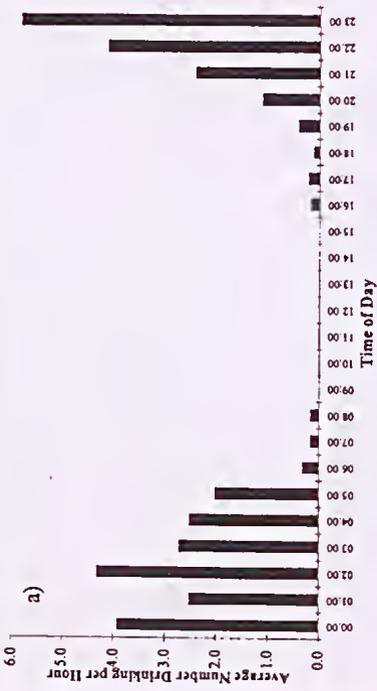


Figure 1. The Drinking Behaviour of a) Kangaroos, b) Sheep, c) Feral Goats and d) Emus at a trough on Middalya Station from October 1993 to February 1994.

their feet or tail to avoid contact with the wire when drinking (King *et al.* 1997).

Henzell and McCloud (1984) stated that feral Goats appeared to visit watering points almost exclusively during daylight. Their data show similar peak drinking periods to those found in this study. However, some Goats in our study did drink during the hours of darkness (Figure 1c).

Davies (1972) found that under cool conditions (minimum of 0°C, maximum of 30°C) Emus tended to drink in the middle of the day. Our observations (Figure 1d) show that a similar pattern occurred between late October and February when daily maximum temperatures were often over 40°C. Under both cool and hot conditions, drinking extended into the early evening.

Knowledge of the differences in drinking times of Red Kangaroos and Euros and those of Sheep allowed for selectivity in the use of Finlayson troughs to prevent access of Red Kangaroos and Euros to the water without adversely affecting Sheep, Goats or Emus. However, other behavioural traits of Red Kangaroos and Euros such as their strong affinities to their home range and their ability to learn ways of overcoming methods aimed at depriving them of access to water sources resulted in these devices being unsuitable for that purpose when used over large areas (King *et al.* 1997).

ACKNOWLEDGEMENTS

We are grateful to Darryl

Blackshaw, Doug Hearman, Kevin Mavric, Stuart Wheeler, David Blood, Kevin Shackleton and John Stretch for their patience while making observations, and to Mick and Winsome Hearman who allowed us to conduct the study on Middalya Station. The study was funded by the Australian Wool Research and Promotion Organisation and the Meat Research Corporation.

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THE WEEDS OF GARDEN ISLAND - AN ANNOTATED LIST

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ABSTRACT

Currently 122 species of weed have been recorded from Garden Island, the site of the first European settlement on the West Coast of Western Australia in 1829. The most serious weed of Garden Island is Arum lily. Another potentially serious weed is Bridal Creeper. There are 30 widespread weeds (*Homeria* and *Trachyandra* could be serious) on the island. Nine weeds restricted to beaches and another 6 confined to rocky headlands, including the serious weeds; *Lycium* and *Lavatera*. Eleven weeds recorded for the island appear to have become extinct and 6 weeds are just persisting. There are 4 very localised weeds, one *Agonis flexuosa* (Peppermint) needs to be removed urgently. There are 10 weeds localised to developed areas. New weed records are mainly from the developed areas and beaches and require monitoring.

INTRODUCTION

Recently there have been published a series of studies on the native vegetation, flora (McArthur, 1990 and Keighery *et al.*, 1997) and fauna (Brooker *et al.*, 1995 and Brooker *et al.*, 1995) of Garden Island.

These studies have demonstrated that Garden Island contains a number of very significant plant communities, especially those woodlands and forests dominated by *Callitris preissii* or *Melaleuca lanceolata*. Elsewhere, on the mainland and Rottnest Island occurrences of these communities

have been largely cleared and the remaining remnants severely impacted by weeds, feral animals, fire, and other disturbances, thus they are in need of extensive rehabilitation. Garden Island is the key area for the continuance of these now rare communities and should be kept as free of weeds of these communities as possible.

Apart from one very serious invasive weed, the Arum Lily, about which a workshop was recently held (Scott and Wykes, 1997), little is known about the abundance, distribution and

effects of weeds on Garden Island. This paper documents major changes that have occurred in the weed flora over the last 14 years. It also details the current state of knowledge of the other introduced and naturalised plants of Garden Island and uses comparable mainland sites and data to estimate threats of these weeds.

METHODS

To compile a list of the weeds of Garden Island all known published and unpublished sources and opportunistic collections were consulted, with the records updated to current taxonomy. Quadrats established as part of the floristic survey of the Swan Coastal Plain (Gibson *et al.*, 1994) were used to assess weed spread. A separate ground survey of the weeds of Garden Island and Woodmans Point was undertaken in 1992. Weeds were rated on their actual potential impact on the natural communities of Garden Island by reference to Woodmans Point, Rottnest Island (Keighery, 1986) and the Perth area as detailed in Dixon and Keighery (1995).

GENERAL NOTES ON THE WEED FLORA OF GARDEN ISLAND

The weed flora of Garden Island is listed in Appendix 1. Currently a total of 122 taxa of introduced plants have been recorded from the Island.

This weed flora is not static and

since the last published listing (Marchant and Abbott, 1982) there have been additions, deletions and other changes, for example, our surveys in 1992 revealed 22 new records of introduced plants for the Island.

A) CHANGES

Four factors affecting the weed flora of the Island have changed greatly since the last major survey in 1979 (Marchant and Abbot, 1981).

1) Cessation of uncontrolled introductions occurring around the Settlement and northern shacks.

Most of the species grown in these areas listed in previous reports have either:

(a) Apparently died out—This includes the records for the following 6 planted garden species: *Auricularia heterophylla* (Norfolk Island Pine), *Punica granatum* (Pomegranate), *Craetagus* sp. (Hawthorn), *Hedra helix* (Ivy), *Ixora* sp. and *Vitis vinifera* (Grape).

(b) Have persisted, or spread only marginally by vegetative means—This includes the records for the following 15 species: *Agave americana* (Century Plant), *Allium ampeloprasum* (Wild Leek), *Eucalyptus gomphocephala* (Tuart), *Euphorbia dendroidea* (Tree Spurge), *Ficus carica* (Fig), *Ipomoea indica* (Blue Morning Glory), *Iris germanica* (German Iris), *Leucojeum aestivum* (Snowflake), *Melia azederach* (Cape Lilac), *Narcissus tazetta* (Jonquil), *Nerium oleander* (Oleander), *Ornithogalum arabicum* (Arabs Eye), *Schinus terbinthifolius* (Japanese Pepper)

and *Vinca major* (*Vinca*). One species, *Anredra cordifolia* (Potato Vine) is apparently still spreading via bulbils in the leaf axils.

2) Capping of the old bores where numerous weeds grew and flourished.

This has apparently resulted in the demise of 5 previously recorded species listed: *Cymbalaria muralis* (Ivy Leaved Toadflax), *Nasturtium officinale* (Water Cress), *Musa sapientum* (Plaintain Banana), ?*Arundo donax* (Bamboo) and *Typha orientalis* (Bullrush).

3) Increases in the number of weeds present on the beaches of Garden Island— During my brief studies on the island I have located 7 new weeds on the beaches and headlands of Garden Island: *Mesembryanthemum crystallinum* (Ice Plant), *Arctotheca calendula* x *populifolia*, *Conyza parva* (Fleabane), *Euphorbia paralias* (Sea Spurge), *Thinopyrum distichus* (Sea wheat) and *Lycium ferocissimum* (Box Thorn). This increase reflects both the increased usage of these areas, by recreational boaters and searching of rocky headlands by the author. Several of these weeds were recorded from the new beach being developed at Broun Bay at the base of the causeway.

Sea Spurge is currently spreading along the north-western beaches of Garden Island, and will become a major component of the strand flora. This population probably arrived on a boat or in gear which had seeds present on it. The size of the population suggests that this species has been resident for some time (Keighery and Dodd, 1997).

The single plant of Sea Wheat probably came from Woodmans Point, where the species is abundant on the fore dunes. If other plants arrive and establish it will also become a major component of the strand flora.

4) The presence of irrigated lawns and frequent vehicular traffic to the mainland is giving a new suite of weeds at the Stirling Base. A notable example of this is *Juncus acutus* (Spiny Rush) which has invaded irrigated ovals from a nearby drainage basin (GIEAC, 1996). Some of these weeds could build up populations here and then spread into adjacent bushland areas.

One potential weed in this category is *Hibbertia cueniformis* (Cutleaved Hibbertia) which Wykes (pers. comm., 1997) has noted that planted material is self-seeding around the base. Elliot and Jones (1990) have previously noted this occurring in this species and feel it has the potential to be an environmental weed in coastal areas of Australia, especially since it occurs naturally in coastal areas from south of Rockingham to Esperance. It also has seed spread by birds and it could potentially spread throughout the island.

Examples of plants in the base area which are known bushland weeds in the Perth Area are: *Brassica tournefortii* (Prickly Turnip), *Conyza albida* (Tall Fleabane), *Pseudognaphalium luteoalbum* (Jersey Cudweed), *Senecio vulgaris* (Common Fireweed), *Minuartia mediterranea* (Sand Wort). The following species are unlikely to invade bushland on

Table I. Unburnt Callitris/Melaleuca/Acacia sites.

Key						
GI,3,4	Woodland quadrats on Garden Island, Swan Coastal Plain Survey (SCP).					
GB	Burnt Melaleuca quadrat on Garden Island					
WP	Unburnt quadrat at Woodmans Point, SCP Survey					
TD	Unburnt Callitris quadrat at Trigg Dunes, SCP Survey					
	GI	G3	G4	GB	WP	TD
<i>Callitris preissii</i>	*	*			*	*
<i>Acacia rostellifera</i>			*		*	*
<i>Acanthocarpus preissii</i>	*	*	*	*		*
<i>Acrotriche cordata</i>						*
<i>Agrostis preissii</i>		*				
* <i>Aira cupiana</i>	*		*	*		*
* <i>Anagallis arvensis</i>	*		*			
<i>Apium anuum</i>		*	*			
* <i>Briza maxima</i>						*
<i>Calandrinia calyptrata</i>					*	*
* <i>Catapodium rigidum</i>		*				*
* <i>Cerastium glomeratum</i>	*	*				
<i>Clematis microphylla</i>	*	*	*	*		*
<i>Comesperma integerrimum</i>		*		*		
<i>Conostylis candicans</i>					*	
<i>Crassula colorata</i>			*			
* <i>Crassula glomerata</i>	*			*		*
* <i>Daucus glochidiatus</i>						*
<i>Eremophila glabra</i>	*			*		
* <i>Erhrata longiflora</i>					*	
<i>Eucalyptus gomphocephala</i>					*	
* <i>Euphorbia pepus</i>					*	
* <i>Galium murale</i>	*	*	*	*	*	*
<i>Hardenbergia comptoniana</i>		*			*	
* <i>Lagurus ovatus</i>	*					*
<i>Lasiopetalum oppositifolium</i>			*			
<i>Lepidium puberulum</i>		*				
<i>Leucopogon australis</i>			*			*
<i>Melaleuca acerosa</i>					*	
<i>Melaleuca lanceolata</i>	*	*	*	*		
<i>Myosotis australis</i>		*				
* <i>Myrsiphyllum asparagoides</i>		*		*		
<i>Oxalis perrenenans</i>	*					
<i>Parietaria debilis</i>	*	*		*		
<i>Phyllanthus calycinus</i>	*	*		*		
<i>Poa poiformis</i>				*		
<i>Poranthera microphylla</i>	*	*				
<i>Rhagodia baccata</i>	*		*		*	*
<i>Santalum acuminatum</i>					*	
<i>Spyridium globulosum</i>	*		*	*	*	*
<i>Senecio lautus</i>						*

Table 1 (cont.)

	G1	G3	G4	GB	WP	TD
* <i>Sonchus oleraceus</i>	*				*	*
* <i>Solanum nigrum</i>	*					*
<i>Solanum symonii</i>	*			*		
<i>Stipa flavescens</i>	*	*				
<i>Thomasia cognata</i>				*		
<i>Thysanotus patersonii</i>	*					
* <i>Trachyandra divaricata</i>	*		*	*	*	
<i>Trachymene caerulea</i>	*	*		*		
<i>Trachymene pilosa</i>	*	*	*	*		
* <i>Vulpia myuros</i>		*				
* <i>Zantedescia aethiopica</i>	*		*			
Total	25	21	16	20	18	16
No. Weeds	9	3	7	5	6	6
% Weeds	36	14	44	25	33	37

Garden Island: *Conium maculatum* (Hemlock), *Cotula bipinnata* (Fern Cotula) and *Digitaria sanguinalis* (Crab Grass) and will probably remain in the base area.

B) DISTRIBUTION, ABUNDANCE AND THREAT OF WEEDS RECORDED

1) Weeds on Garden Island and communities on the adjacent mainland.

There is little information available on the distribution, abundance or threat potential (ability of the species to both invade and multiply in native plant communities) of most of the weeds recorded for Garden Island. Most weed lists simply record the presence of a species, rather than detailing their spread, abundance or threat potential. Except for a few major weeds this is the case for Garden Island. To

help estimate the potential of weed species in these communities a series of monitoring quadrats were established on the island and in similar communities at Woodmans Point on the mainland.

Species diversity of unburnt woodlands and shrublands (data from Gibson *et al.*, 1994) ranges from 16–25 species per 100m² (Table 1). The percentage of weeds in these sites ranges between 14 and 37%. These weeds are nearly all small annuals, except for the tuberous herb *Trachyandra divaricata*. Normally in such areas there are moss covered or bare areas free of shrubs or herbs. These micro-sites are the location of many of the unusual herbs found on Garden Island (eg: *Myostis australis*, *Cynoglossum australe* and *Lepidium puberulum*) and not on the adjacent mainland. These bare areas also lower fuel loads in these

Table 2. Weeds and Fire – Woodman's Point, 1992.

Key
a, b, c, d, e 100m² quadrats
a Forcdune in recreation area
b Swale in recreation area
c, d, e Woodman's Point Conservation Area
R Regeneration mode after fire: S=from seed; R= from rootstocks, bulbs or rhizomes.
GI Weed recorded from Garden Island.
D Dead

	a	b	c	d	e	R	GI
<i>Callitris preissii</i>	*	*	*	*	*	S	
<i>Acacia cyclops</i>	*	*		*	*	R	
<i>Acacia cochlearis</i>		*	*		*	S	
<i>Solanum symonii</i>		*	*			S	
<i>Melaleuca acerosa</i>		*		*	*	R	
<i>Melaleuca huegelii</i>		*				S	
* <i>Leptospermum laevigatum</i>	*	*				S	
* <i>Nicotiana glauca</i>	*				*	S	*
<i>Spyridium globulosum</i>	*	*	*	*	*	S	
<i>Hardenbergia comptoniana</i>	*					R	
<i>Scaevola crassifolia</i>	*	*	*	*	*	R	
<i>Anthocercis littorea</i>	*	*	*	*	*	S	
<i>Olearia axillaris</i>	*					S	
<i>Leucopogon parviflorus</i>	*					R	
<i>Acanthocarpus preissii</i>	*					R	
<i>Clematis microphylla</i>	*					R	
<i>Hardenbergia comptoniana</i>	*	*		*		R	
<i>Rhagodia baccata</i>	*			*	*	R	
<i>Comesperma integerrimum</i>	*				*	R	
<i>Schoenus grandiflora</i>			*	*		S	
* <i>Trachyandra divaricata</i>	*	*	*	*	*	R	*
<i>Threlkeldia diffusa</i>		*				R	
* <i>Myrsiphyllum asparagoides</i>	*	D	D	D		R	*
* <i>Pelargonium capitatum</i>	*			*		R/S	
* <i>Anagallis arvensis</i>			*	*		S	*
* <i>Avena barbata</i>		*				S	*
<i>Carpobrotus virescens</i>		*	*		*	S	
* <i>Carpobrotus edulis</i>		*				S	
* <i>Arenaria serpyllifolia</i>				*		S	
* <i>Brassica tournefortii</i>					*	S	*
* <i>Conyza albida</i>	*					S	*
* <i>Dishisma arenaria</i>			*			S	*
* <i>Erhrata longiflora</i>		*	*	*	*	S	*
* <i>Galium murale</i>				*		S	*
* <i>Galium aparine</i>				*		S	
* <i>Lactuca serriola</i>	*					S	
* <i>Bromus diandrus</i>	*		*			S	*

Table 2 (cont.)

	a	b	c	d	e	R	GI
* <i>Lagurus ovatus</i>	*	*	*	*		S	*
* <i>Lolium rigidum</i>		*				S	*
* <i>Sonchus oleraceus</i>	*		*		*	S	*
* <i>Solanum nigrum</i>				*		S	*
* <i>Euphorbia terracina</i>			*			S	
<i>Crassula colorata</i>				*	*	S	
* <i>Crassula glomerata</i>	*		*	*	*	S	*
* <i>Dittrichia graveolens</i>	*		*			S	*
* <i>Phytolacca octandra</i>		*				S	*
*? <i>Corrigola littoralis</i>				*	*	S	
Totals	23	20	21	21	19		
No. Weeds	10	11	11	11	8		
% Weeds	43	55	52	52	42		

fire intolerant communities. They are unfortunately the areas first colonised by weeds, especially after fire.

As a comparison, at Woodmans Point most of the *Callitris* Forest was burnt in summer 1990. A series of quadrats were established in this area in early 1992 (Table 2). Here the species diversity ranged from 19–23 species per 100m². However, the percentage of weeds ranged from 42–55%! Of particular concern was the appearance of two perennial shrub weeds, *Leptospermum laevigatum* (Victorian Tea Tree) and *Nicotiana glauca* (Tree Tobacco) as weeds in these sites. Grassy weeds invaded the open moss areas which were killed by the fire.

Currently we can observe that on the mainland weed invasion occurs markedly after fire in these communities. Some of these weeds are long lived shrubs that

could permanently alter these communities. Many shrubs and trees will be planted as amenity species in the developed areas of Garden Island and require considerable care in selection as is currently practised by the Navy.

2) Weeds on Garden Island

In Appendix 1 all recorded weeds of Garden Island are listed with notes on the major area of occurrence on the island and the species threat potential (this is based on information in Dixon and Keighery, 1995). In summary:

- the most serious weed of Garden Island is Arum lily
- another potentially serious weed is Bridal Creeper
- there are
 - 30 widespread weeds (*Homeria* and *Trachyandra* could be serious)
 - 9 beach weeds
 - 6 weeds of rocky headlands

(including *Lycium* and
Lavatera)

10 Settlement weeds

27 weeds with no data

11 "Extinct" weeds

6 weeds just persisting

4 very localized weeds
(*Agonis* needs to be removed)

(a) serious or potentially serious weeds—This information shows that there are five serious or potentially serious weeds present on the Island that require management attention. These are *Zantedeschia aethiopica* (Arum Lily), *Asparagus asparagoides* (Bridal Creeper), *Trachyandra divaricata* (Strap Lily) and *Homeria flaccida* (Cape Tulip).

Other potentially serious weeds of coastal woodlands in the Perth area and present on Garden Island are, *Brassica tournefortii* (Prickly Turnip), *Euphorbia peplus* (Petty Spurge), *Urtica urens* (Stinging Nettle) and the grasses *Avena barbata* (Wild Oats), *Bromus diandrus* (Great Brome) and *Ehrharta longiflora* (Annual Veld Grass). These seem to be present at low levels on the island, but require monitoring. The above weeds have replaced the native *Parietaria debilis* as an winter understory (and the moss swards and rarer spring annuals) in many island and coastal sites in Western Australia. Perhaps Tammar grazing is holding these weeds in check on Garden Island and the Navy's careful management of these native grazers is worthy of considerable praise as they are probably the key to successful management of palatable weeds on the island.

The potential for a weed to become serious can be illustrated by *Agonis flexuosa* (Peppermint). It is recommended that the *Agonis flexuosa* plants be removed as soon as practicable, as these are seeding, and already are major weeds in Kings Park and Yanchep. They will spread rapidly after fire into the woodlands. Continual vigilance is required to prevent the development of more serious weeds.

Both *Homeria* (Cape Tulip) and *Trachyandra* are unpalatable and could spread after disturbance, such as fire. Bridal Creeper is controlled by Tammar grazing. This could also explain the low numbers of the other listed annual weeds. *Lycium* (Boxthorn) and *Lavatera* (Tree Mallow) are serious weeds of rocky islets near Perth, and probably would only be of concern on headlands on Garden Island. The potato creeper (*Anredera cordifolia*) is a serious weed in Eastern Australian rainforest and along disturbed creeklines and swamps around Perth. It could be considered a low threat, but given that Arum Lily has similar preferences, it should be removed.

CONCLUSION

Garden Island was the site for the first settlement on the west coast of Western Australia in 1829. Since that time there have been continual introductions of alien plants onto the island. Garden Island, however, unlike Rottneest was not extensively cleared or altered by changing fire regimes and today contains a series of fire

intolerant plant communities. These are the *Melaleuca* and *Callitris* woodlands, and the *Acacia* shrublands. These simple communities are also very prone to weed invasion, especially species not palatable to Tammars. The current efforts to control such weeds are commended as is the quarantine of new weeds being introduced around the base. Efforts need to be directed to removing other invasive unpalatable weeds, such as *Homeria flaccida* present on the island.

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APPENDIX 1: ANNOTATED LIST OF GARDEN ISLAND NATURALISED PLANTS

Key

- { } Garden plants, listed in Marchant and Abbott (1981) but not apparently naturalised.
+ Naturalised plants not recorded previously from Garden Island.
* Naturalised plants only found around the northern bore and unlikely to spread further, apparently died out before re-survey in 1993.
McA McArthur, 1957, 1990, or McArthur and Bartle, 1981
M/A Marchant and Abbott, 1981

AGAVACEAE

Agave americana (Century Plant). Status unknown (in 1980 Management Plan), not recorded in McA or M/A. A very slowly spreading rhizomatous perennial, removed from Rottnest.

AIZOACEAE

+*Mesembryanthemum crystallinum* (Ice Plant). Common on Point Atwick headland only, may spread to base areas.

Tetragonia decumbens. Recorded by McA, M/A, common, widespread, but confined to beaches.

ALLIACEAE

Allium ampeloprasum (Wild Leek), recorded in M/A, this garden escape is found scattered on tracks around the Stirling Base. Seeds prolifically but few seedlings establish.

AMARYLLIDACEAE

Leucojeum aestivum (Snowflake), recorded in McA (1990), a garden escape that does not seed, spreading slowly by bulb divisions at Beacon Head.

Narcissus tazetta (Jonquil), listed in McA as *Njonquilla*, a garden escape, a few plants present at Beacon Head. Again this species is seed sterile, and poses little threat.

ANACARDIACEAE

Schinus terrebinthifolius (Brazilian Pepper), this species is listed in the 1980 Management Plan, but is not mentioned in M/A, but is recorded in

McA (1990), a few persisting individuals found around old settlement at Beacon Head. These should be removed as they are serious weeds of bushland around Perth (Dixon and Keighery, 1995) and the fruits are spread by birds..

ARACEAE

Zantedeschia aethiopica (Arum Lily), recorded in McA and M/A. This common serious weed has been the subject of several reports and papers (see Scott and Wykes, 1997) and a major control program.

ARAUCARIACEAE

{*Auricularia heterophylla* (Norfolk Island Pine)}

APIACEAE

+*Conium maculatum* (Hemlock), this is an uncommon weed found on roadverges in the Naval Base. It prefers highly disturbed sites and would probably not invade the bushland, but it is highly toxic.

APOCYNACEAE

{*Nerium oleander* (Oleander)}, this garden plant is again highly toxic and is being removed from Rottnest Island. There are a few persisting plants between Dance Head and Beacon Head. Although a prolific seeder very few plants growing from seed have been recorded on Rottnest Island (Keighery, 1986) probably not a threat.

Vinca major (Vinca), recorded in McA (1990) there are a few persisting plants

slowly spreading via rhizomes, at Beacon Head, not a threat.

ARALIACEAE

Hedra helix (Ivy), recorded in McA, status unknown.

ASCLEPIDACEAE

Gomphocarpus fruticosus (Swan Plant), recorded in McA, status unknown. A few plants seen at Beacon Head. Restricted to wetlands and very disturbed sites on Rottneest Island, and not a threat. (This is probably the species referred to as *Asclepias curassavica* (Red Head Cotton Flower) in McA, 1990, although feral populations of this species are present at Rockingham and it was a common garden plant, so it may have been present as well on the island).

ASPARAGACEAE

Asparagus (*Myrsiphyllum*) *asparagoides* (Bridal Creeper), recorded in McA and M/A, common potentially serious weed.

ASPHODELACEAE

Asphodelus fistulosus (Onion Weed), recorded in McA and M/A, a common weed of tracks and disturbed areas.

Trachyandra divaricata (Strap Lily), recorded in McA and M/A, a common weed of disturbed woodlands, verges, dunes and firebreaks.

ASTERACEAE

Arctotheca calendula (Cape Weed), recorded in McA and M/A, this is a scattered weed of roadverges, foredunes, picnic sites and headlands.

A. populifolia, recorded in McA and M/A, common on sandy beaches.

+*A. calendula* x *populifolia*, a rare hybrid, only 1 plant recorded, on beaches only.

Carduus pycnocephalus (Slender Thistle), recorded in M/A, still relatively common around the northern half of the Island in disturbed areas and regenerating valleys.

+*Cirsium vulgare* (Spear Thistle), recorded in M/A, a few persisting individuals found around old settlement at Beacon Head.

+*Conyza albida* (Tall Fleabane), recorded around Stirling Base and picnic areas at Herring Bay.

Conyza bonariensis (Flax Leaved Fleabane), recorded in McA, around Stirling Base and picnic areas at Herring Bay.

+*Conyza parva*, abundant on recent beach dunes at Broun Bay.

+*Cotula bipinnata* (Fern Cotula), recorded on roadverges around the Stirling Base.

Delarica odorata (Cape Ivy, previously *Senecio mikanioides*), recorded in McA (1990), persisting around Beacon Head. This species was given as likely to spread in McA (1990) but it has not done so, outside of wetlands on the coastal plain.

Dittrichia graveolens (Stinkwort), recorded in McA, a plant of very disturbed sites, found only on road verges. Has invaded the edges of salt lakes on Rottneest, but although unpalatable, it is unlikely to be a major weed on Garden Island as it is normally only found in highly disturbed sites such as road verges.

Hypochaeris glabra (Flatweed), recorded in McA and M/A, currently found only in picnic sites and around the Stirling Base, although a very common weed of bushland in the Perth area.

Osteospermum clandestinum (Stinking Roger), recorded in McA, but not re-found in this study.

+ *Pseudognaphalium luteo-album* (Jersey Cudweed), recorded on roadverges around the Stirling Base.

+ *Scenecio vulgaris* (Common Fireweed), recorded on roadverges around the Stirling Base.

Sonchus asper (Prickly Sowthistle), recorded in McA, found only in old clearings at Beacon Head, eaten by

Tammars.

Sonchus oleraceus (Sowthistle), recorded in McA and M/A, a widespread weed scattered throughout island, probably controlled by Tammars.

BASELLACEAE

Anredera cordifolia (Madeira Vine), recorded in 1980 Management Plan and McA (1990), around the old Stirling Base and at Beacon Head. This vine produces tuberous bulbils in the axils of the leaves and could spread.

BRASSICACEAE

+*Brassica tournefortii* (Prickly Turnip), recorded on dunes at Broun Bay, by the Stirling Base.

Cakile maritima (Sea Rocket), recorded by M/A, common around the island, but is restricted to beaches only.

Hymenobolus procumbens (Oval Purse), recorded in M/A, confined to rocky headlands, a very minor weed.

**Nasturtium officinale* (Water Cress), extinct

Sisymbrium orientale, recorded in M/A, but not relocated, status unknown.

CARYOPHYLLACEAE

Cerastium glomeratum (Chickweed), recorded in M/A, a scattered, but widespread minor weed in woodlands.

+*Minuartia mediterranea* (Sand Wort), recorded on dunes at Broun Bay, and on roadverges in the Stirling Base. Inconspicuous and perhaps more widespread.

Petrohagia velutina (Velvet Pink), recorded in M/A, a weed of rocky areas.

Polycarpon tetraphyllum (Allseed), recorded in M/A, headlands, valleys.

Sagina apetala (Common Pearlwort), recorded in M/A, headlands, dunes.

Silene gallica (French Catchfly), recorded in M/A, headlands, tracks, valleys.

+*Silene nocturna* (Mediterranean Catchfly), only recorded in Melaleuca Woodland at Second Head.

Stellaria media (Chickweed), recorded in M/A, widespread in deep valleys under Acacia.

CHENOPODIACEAE

Chenopodium murale (Nettle-leaved Goosefoot), recorded in McA, under Melaleuca Woodland at Second Head.

COLCHICACEAE

+*Ornithogalum arabicum* (Arabs Eye), A garden escape only recorded from a single site in valleys west of Stirling Base.

CONVOLVULACEAE

**Ipomaea indica* (Blue Morning Glory), recorded in McA and M/A as *Convolvulus* sp. Persisting around old sttlement at Beacon Head.

CRASSULACEAE

Crassula glomerata, recorded in M/A, scattered throughout island, especially common on fore dunes.

CUSCUTACEAE

Cuscuta epithymum (Dodder), recorded in McA(1990), common around picnic sites and at Broun Bay.

EUPHORBIACEAE

+*Euphorbia dendroides* (Tree Spurge), an uncommon weed of edges of tracks at Beacon Head.

+*Euphorbia paralias* (Sea Spurge), beaches only.

Euphorbia peplus (Petty Spurge), recorded in M/A, widespread common on headlands, in valleys, Acacia shrubland and beside tracks. Serious weed of coastal Acacia shrublands around Perth.

Ricinus communis (Castor Oil Plant), recorded in McA, M/A, disturbed areas around Beacon Head and the Stirling Base.

FUMARIACEAE

Fumaria muralis (Wall Fumitory), recorded in M/A, at Beacon Head, status unknown, but able to invade

Acacia shrublands in Bold Regional Park.

GENTIANACEAE

Centaurium erythraea (Centaury), recorded in McA, M/A, widespread but scattered records from headlands and woodlands.

GERANIACEAE

Erodium cicutarium (Crowsfoot), recorded in McA, M/A, scattered in woodlands.

Geranium molle (Doves Foot Cranesbill), recorded in M/A, status unknown.

Pelargonium capitatum (Rose Pelargonium), recorded in McA, M/A, scattered along verges, beaches.

IRIDACEAE

Iris germanica (German Iris), recorded in McA (1990), a garden escape, disturbed areas around Beacon Head and valleys west of Stirling Base. Does not seed, spreads by rhizomes, a minor weed.

Homeria ?miniata (Two Leaved Cape Tulip), recorded in McA and M/A, status unknown. However, this is a weed of heavy soils and since *Homeria flaccida* (Cape Tulip) is present within Stirling Base, the record of *H. miniata* is probably this species. Currently restricted in occurrence this is a very serious weed of coastal woodland communities and is toxic and unpalatable. It should be eradicated.

Watsonia species, recorded in McA and M/A, status unknown. Any *Watsonia* species should be eradicated.

JUNCACEAE

Juncus acutus (Spiny Rush), recorded from drainage basins and ovals in Stirling Base.

MALVACEAE

Lavatera arborca (Tree Mallow), recorded in McA, on rocky headlands, this species is a serious weed on the Safety Bay Islets.

MELIACEAE

Melia azedarach (Cape Lilac), recorded in McA, M/A, a few persisting trees from old plantings.

MORACEAE

Ficus carica (Fig), recorded in McA (1990), a few persisting trees from old plantings, a weed of wetlands so probably not able to spread on Garden Island.

MUSACEAE

**Musa sapientium* (Banana/Plantain)

MYRTACEAE

Agonis flexuosa (Peppermint), plants of this species recorded at Herring Bay, and between Second Head and Beacon Head, weedy and able to produce numerous seedlings. This species should be removed.

{*Eucalyptus gomphocephala* (Tuart)}, a few persisting trees remain, probably will not spread unless fire occurs, should be monitored.

Eucalyptus platypus, Recorded in McA, status unknown.

OXALIDACEAE

Oxalis pes-caprae, (Soursob), recorded in McA and M/A, status unknown, but could be a serious weed.

PAPAVERACEAE

Argemone ochroleuca, (Prickly Poppy), recorded in McA and M/A, status unknown. A weed of very disturbed sites.

PAPILLIONACEAE

Medicago polymorpha (Burr Medic), recorded in M/A, status unknown.

Melilotis indicus (Common Melilot), recorded in M/A, headlands.

Trifolium scabrum (Rough Clover), recorded in McA, status unknown.

PHYTOLACCACEAE

+*Phytolacca octandra* (Ink Weed), around the old settlement at Beacon Head.

POACEAE

+*Aira caryophyllea* (Silvery Hairgrass), often confused with *A. cupiana*, ?Widespread.

Aira cupiana, recorded in M/A, common weed of woodlands.

Avena barbata (Bearded Oat), recorded in McA and M/A, scattered throughout island on headlands, Stirling Base, valleys.

**Bambusa* sp (Bamboo), probably *Arundo donax* (Giant Reed), which is commonly referred to as Bamboo. Recorded in M/A, probably around old bores at Beacon Head.

Bromus diandrus (Great Brome), recorded in McA and M/A, scattered along tracks, base and headlands.

Bromus rubens (Red Brome), recorded in McA and M/A, status unknown.

Catapodium rigidum (Rigid Fescue), recorded in M/A, common on headlands, rare in woodlands.

Cynodon dactylon (Couch), recorded in M/A, woodlands around Stirling Base.

+*Digitaria sanguinalis* (Crab Grass), recorded on Tracks in Stirling Base.

Ehrharta longiflora (Annual Veld Grass), recorded in M/A, scattered in woodlands.

Eragrostis curvula (African Love Grass), recorded in McA, status unknown.

Hordeum leporinum (Barley Grass), recorded in M/A, status unknown.

Hordeum vulgare (Barley), recorded in M/A, status unknown.

Lagurus ovatus (Hare's Tail Grass), recorded in McA/M/A, headlands, woodlands.

Lolium rigidum (Wimmera Rye Grass), recorded in M/A, scattered along tracks, headlands.

Parapholis incurva (Coastal Barbgrass), recorded in M/A, headlands only.

Poa annua (Winter Grass), recorded in McA, M/A, tracks, scattered in woodlands.

Polypogon monspeliensis (Annual

barbgrass), recorded in McA, M/A, status unknown.

Stenotaphrum secundatum (Buffalo Grass), recorded in M/A, around Stirling Base.

+*Thinopyrum distichum* (Sea Wheat), scattered plants on beaches only.

Vulpia myuros (Rats Tail Fescue), recorded in M/A, valleys, woodlands.

POLYGONACEAE

Emex australis (Doublegee), recorded in McA and M/A, only on verges, very disturbed areas.

Rumex glomeratus (Dock), recorded in McA (1990), probably *R. conglomeratus*, at Beacon Head, status unknown.

PRIMULACEAE

Anagallis arvensis (Pimpernel), recorded in McA and M/A, common but minor weed of whole island.

+*Asterolinon linum-stellatum* (Asterolinon), Around Governor Stirling's Well.

PUNICACEAE

{*Punica granatum* (Pomegranate)}, extinct.

ROSACEAE

{*Crataegus* sp. (Hawthorn)}, extinct.

RUBIACEAE

Galium murale (Bedstraw), recorded in M/A, widespread weed of woodlands.

{*Ixora* sp. }, recorded in McA, status unknown.

Sherardia arvensis (Field madder), recorded in M/A, scattered in valleys and woodlands.

Verbascum virgatum (Green Mullein), recorded in McA, status unknown.

SCROPHULARIACEAE

**Cymbalaria muralis* (Ivy Leaved Toadflax), Status unknown recorded in 1980 Plan as occurring at old bore site, not in McA or M/A. This is possibly *Asarina* (*Maurandya barcalaiana*), which I have recorded at Beacon Head.

Dischisma arenarium, recorded in

McA,M/A, widespread weed of woodlands, beaches and headlands.

Asarina barcalaiana, (no common name), a summer annual to short lived perennial vine, at Beacon Head.

Parentucellia latifolium (Sticky Bartsia), recorded in M/A, status unknown.

SOLANACEAE

+*Lycium ferocissimum* (Boxthorn), Rocky headlands only, potentially serious weed.

Nicotiana glauca (Tree Tobacco), recorded in M/A, status unknown.

Solanum nigrum (Black Nightshade), recorded in McA,M/A, scattered throughout island.

TYPHACEAE

**Typha orientalis* (Bullrush), recorded in McA and M/A.

URTICACEAE

Urtica urens (Stinging Nettle), recorded in M/A, a scattered weed of Melaleuca Woodlands near coast.

VALERIANACEAE

Centranthus ?ruber (Spur Valerian), recorded in McA, status unknown, Probably *C. macrosiphon*, which is a common weed of coastal sands and limestones in the Perth area.

VITACEAE

{*Vitis vinifera* (Grape)}, extinct.

THE TOLERANCE TO 1080 OF THE RUFIOUS HARE-WALLABY *LAGORCHESTES HIRSUTUS*

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The Rufous Hare-Wallaby, *Lagorchestes hirsutus*, was formerly widespread throughout the spinifex deserts of central Australia (Lundie-Jenkins 1993). Wild populations are now known to occur only on Bernier and Dorre Islands in Western Australia (Gibson *et al.* 1994) and occupy less than 1% of the former range of the species (Johnson *et al.* 1989). A captive breeding program was established in Alice Springs in 1980 to enable reintroductions to occur (Gibson *et al.* 1994). The breeding stock consisted of Hare-Wallabies from the last known mainland population in the Tanami Desert (Gibson *et al.* 1994). Survival of wild populations (Lundie-Jenkins *et al.* 1993) and reintroductions (Gibson *et al.* 1994) of Hare-Wallabies have been seriously hampered by predation by Foxes (*Vulpes vulpes*) and feral Cats (*Felis catus*). Reintroductions of other Australian species of mammals to mainland sites have generally had poor records of success (Short and Smith 1994).

The most successful reintroduction programs have involved control of exotic predators by using 1080 baits (Short and Smith 1994). Many native Australian

species have evolved high tolerances to 1080, which occurs naturally in the plant genera *Gastrolobium* and *Acacia* (Twigg and King 1991). Introduced predators such as Cats (Eason and Frampton 1991) and Foxes (McIlroy and King 1990) are very susceptible to the poison.

Testing was conducted on four male Hare-Wallabies from the captive breeding program in Alice Springs, founded from the now extinct Tanami desert population. The animals were supplied by the Conservation Commission of the Northern Territory. They were individually housed in wooden and steel mesh cages (1200 by 900 by 580 mm), with straw bedding, in an air conditioned animal house (23±1°C). They were fed lucerne and kangaroo cubes. Food and water was supplied ad lib.

Animals were dosed intraperitoneally with increasingly large doses of 1080 in aqueous solution, with an interval of 38–88 days between doses (Table 1). Blood samples were collected from a lateral caudal vein before dosing and at 6, 12 and 24 hours after dosing to determine alterations in plasma citrate

Table 1. Dose rates of 1080 and survival of Rufous Hare-Wallabies, *Lagorchestes hirsutus*.

Dose (mg kg ⁻¹)	No. dosed	Died	Bled
2	4	0	yes
3	4	0	yes
5	4	0	yes
7.5	4	0	yes
10	2	0	no
15	4	0	yes
20	2	0	no
25	1	1	no

levels, which can be used to determine tolerance to 1080 in closely related species (Twigg and King 1991).

Animals were not bled at all dose levels (Table 1), as the stress of handling them can increase the response of animals to toxins and at high levels, can increase the likelihood of their death (Ellis 1967).

All Hare-Wallabies survived doses of 2–20 mg kg⁻¹ (Table 1). The only *L. hirsutus* given 25 mg kg⁻¹ died between 32 and 48 hours after it was dosed. Symptoms of 1080 poisoning were first observed 24 hours after dosing. Of the two animals dosed at 10 mg kg⁻¹, one

showed mild symptoms of 1080 poisoning, as did all animals dosed with 15 and 20 mg kg⁻¹.

Baseline (pre-dose) plasma citrate levels ranged from 25.0 to 34.7 µg ml⁻¹, and the elevation of citrate levels increased as the Hare-Wallabies received higher doses of 1080 (Table 2). There are no data on citrate levels for Hare-Wallabies dosed at 20mg kg⁻¹ or for the animal which died after receiving a dose of 25 mg kg⁻¹. The maximum elevation found in animals dosed at 15 mg kg⁻¹ (60% of the lethal dose) was 113 µg ml⁻¹. One male Hare-Wallaby of a different species, the Spectacled Hare-Wallaby (*L. conspicillatus*) survived a dose of 3 mg kg⁻¹, after which its plasma citrate level increased by over 160 µg ml⁻¹, and died after receiving 5 mg kg⁻¹ between 24 and 48 hours later. Its citrate level 24 hours after being dosed with 5 mg kg⁻¹ had increased by approximately 260 µg ml⁻¹ (Twigg 1982).

The tolerance to 1080 of the Rufous Hare-Wallaby is lower than that of some macropods from Western Australia which coexist with fluoroacetate-bearing vegetation, but is higher than that of other species,

Table 2. Mean changes in plasma citrate levels of Rufous Hare-Wallabies (*Lagorchestes hirsutus*) after being dosed with 1080.

Dose (mg kg ⁻¹)	No. dosed	Baseline (pre-dose)	Increase in citrate level (µg ml ⁻¹)		
			6 hours	12 hours	24 hours
2	4	29.4	15.5	24.9	15.5
3	4	34.7	47.8	34.1	-0.2
5	4	32.9	42.7	30.3	14.8
7.5	4	30.4	59.7	52.7	17.1
15	4	25.0	72.3	64.8	70.3

including the Spectacled Hare-Wallaby, which also occur in arid areas where *Gastrolobium* species are not abundant or do not occur (Twigg 1986; Twigg and King 1991). The relatively high tolerance of the Rufous Hare-Wallaby to 1080 could have been acquired as a result of their ancestral stock feeding on one or more *Gastrolobium* species which occur over much of the former range of the species which includes much of the Western Australian wheatbelt where many species of *Gastrolobium* occur, or from the Tanami Desert population feeding on *G. grandiflorum* which is found over a large part of central Australia, including the Tanami Desert (Twigg and King 1991). Bilbies (*Macrotis lagotis*) from the Tanami Desert also have a relatively high tolerance to 1080 (Twigg *et al.* 1990).

Baits used in Fox and Cat control programs generally consist of meat injected with a small amount (2.5–4.5 mg) of 1080. The Rufous Hare-Wallaby is herbivorous (Lundie-Jenkins *et al.* 1993) and is unlikely to eat meat baits designed for either Foxes or Cats. There is a demonstrated need for exotic predator control in areas of Australia where the Rufous Hare-Wallaby (Gibson *et al.* 1994) or other species of mammals (Short and Smith 1994) are reintroduced. The high sensitivity to 1080 of Foxes (McIlroy and King 1990) and Cats (Eason and Frampton 1991) relative to the relatively high tolerance of the Rufous Hare-Wallaby enabled 1080 to be used in a highly selective way in predator control programs. Single baits which would be lethal to the

predators can be manufactured. Even if they were eaten by Hare-Wallabies, no threat of lethal poisoning would be posed to them, as the amount of 1080 ingested would be well below a lethal dose for a Hare-Wallaby. Similar successful management programs using 1080 baits to control introduced carnivores and benefit native fauna (Kinnear *et al.* 1988; Friend 1990) have recently been conducted by the Department of Conservation and Land Management in Western Australia.

ACKNOWLEDGEMENTS

I am grateful to Geoff Lundie-Jenkins and Ken Johnson (CCNT) for supplying the Hare-Wallabies, Win Kirkpatrick, Bruce Martin and Laurie Twigg for their assistance in keeping, handling and bleeding them, and Malcolm McGrath for determining the plasma citrate levels.

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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

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W.A. Museum

Francis Street, Perth 6000

Telephone 9427 2788

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