IV Vertebrate Fauna

N.L. McKenzie, J.K. Rolfe, N.J. Hall and W.K. Youngson

Background

Biological survey work in the Norseman-Balladonia Study Area began in October 1977, although the standardised strategy of broad-scale survey used in the Eastern Goldfields regional survey was not fully developed until late-1978 (Biological Surveys Committee of Western Australia 1984, McKenzie 1984). In fact, the pit trapping methods required by these strategies were first tested during visits to the Norseman-Balladonia Study Area in April 1978 (Table 2).

These developments led to changes in the sampling strategy during the course of the Norseman-Balladonia survey. As a result, species accumulation curves could only be compiled for the Study Area as a whole.

Representative collections of mammal, amphibian and reptile voucher specimens are lodged in the W.A. Museum. Names used for all vertebrates in this report follow those currently applied to the W.A. Museum's collection.

This paper reports the results of our field survey and presents some preliminary analysis and interpretation, in the context of the inconsistent sampling design (Table 2).

Amphibians and Reptiles

Four amphibian species and 51 reptile taxa (47 species, two sub-species and two hybrids) were recorded in the Norseman-Balladonia Study Area during the course of our surveys (Table 3). In addition, Andrew Brown (CALM) reported a Death Adder (*Acanthophis antarticus*) on a granite outcrop at Mount Andrew (32°40'S 122°56'E) in the Dundas Nature Reserve, during September 1990. During the same month, he encountered another Death Adder and a Carpet Python (*Morelia spilotes*) on a granite outcrop at 32°55'20"S 123°05'40"E, just south of the Dundas Nature Reserve.

The accumulation curve of species versus campsite (Figure 4) suggests that the overall inventory of the survey areas was reasonably thorough. Nevertheless, the following additional species have been recorded in the Study Area: *Diplodactylus elderi, D. pulcher, Underwoodisaurus milii, Pygopus lepidopodus, Morethia adelaidensis, Pseudonaja modesta* and *Vermicella bertholdii* (W.A. Museum catalogue). The python *Aspidites ramsayi* should also occur in the Study Area.

A high proportion of congeneric and normally allopatric reptile species were recorded during the survey: *Varanus gouldii & V. rosenbergi, Delma australis & D. butleri, Ctenotus atlas & C. impar, Hemiergis i. initialis & H. i. brookeri, Cryptoblepharus plagiocephalus & C. virgatus clarus, Lerista dorsalis & L. muelleri, Ctenophorus cristatus & C. mckenziei,* and *Ctenophorus maculatus dualis & C. m. griseus.* These reflect the location of the Norseman-Balladonia Study Area, on the boundary of the Roe, Coolgardie and Eucla Botanical Districts. In some cases, hybrids between such species were recorded: *Pseudonaja affinis* x *nuchalis, Hemiergis i. initialis* x *brookeri* (Glen Storr, pers. comm.). The taxonomic status of the *Hemiergis* hybrid needs to be examined in more detail.

Table 2. Faunal survey of the Norseman-Balladonia Study Area: sampling dates and methods*.

1. Jyndabinbin Rocks Survey Area (Campsite 1).

Fauna Code	8-13 Oct, 1977	29 April - 4 May, 1978	30 Oct - 4 Nov, 1978	Lithological Surface
1/01	M,B,R	M,B,R,2P	Q (M¹,B,R,2P)	Qpf
1/02	½M,B,R	½M,B,R	-	Qra
1/03	M,B,R	M,B,R	Q (M¹,B,R,2P)	Qpl
1/04	½M,B,R	½M,B,R,2P	M¹,B,R,F,2P	Ag
1/05	M,B,R	M,B,R,2P	Q (M¹,B,R,2P)	Qqs
1/06	M,B,R	M,B,R	-	Ag
1/07	-	-	Q (B,R,2P)	Qpl
1/08	½M,B,R	½M,B,R,P	M¹,B,R,F,2P	Qra
1/09	M,B,R	M,B,R,P	Q (M¹,B,R,2P)	Qpl-Pa
1/10	M,B,R	M,B,R,P	M¹,B,R,P	Qqs
1/11	M,B,R	M,B,R	-	Qpl
1/12	½M,B,R	M,B,R,P	-	Qpl-Pa
1/13	M,B,R	M,B,R	-	Qqs

2. Boingaring Rocks Survey Area (Campsite 2).

Fauna Code	14-19 Oct, 1977	5-10 May, 1978	29 Sept - 2 Oct, 1987	Lithological Surface
2/15	M,B,R	M,B,R	Q (B,R)	Qpl
2/16	M,B,R	M,B,R,P	Q (B,R)	Qps
2/17	½M,B,R	½M,B,R	-	Qpl-TQo-Qra
2/18	½M,B,R	½M,B,R	-	Pc
2/19	M,B,R	M,B,R,P	-	Qpl
2/20	M,B,R	M,B,R,P	-	Qra
2/23	M,B,R	M,B,R	Q (B,R)	Qpl
2/24	M,B,R	M,B,R,2P	-	Qpl
2/25	½M,B,R	½M,B,R,P	-	Qpl-Pc
2/26	M,B,R	M,B,R,2P	Q (B,R)	Py
2/27	½M,B,R	½M,B,R,P	-	Qpl
2/28	M,B,R	M,B,R,P	Q (B,R)	Qps

Habitats more typical of adjacent districts occurred along the margins of the Study Area. Greenstone surfaces and "*Banksia*" sandplains are good examples. Most of these could not be sampled in the time available, but would have undoubtedly added species to the list; even the single visit to Campsite 5, in the south-eastern corner of the Study Area, added four species to our inventory. Based on their geographic range and known habitat preferences, a number of species may just penetrate the margins of the Study Area:

— *Delma fraseri, Ctenophorus ornatus, C. reticulatus, Eremiascincus richardsonii* - western edge.

— *Ctenophorus fordi, C. pictus, Tympanocryptus lineata, Rhinoplocephalus spectabilis* - eastern edge.

Table 2. (cont).

3. Other survey areas (Campsites 3,4,5).

Fauna Code	28 Feb - 5 Mar, 1978	7-12 Mar, 1978	24-29 Oct, 1978	Lithological Surface
3/01	M,B,R			Pm
3/02	M,B,R			Qpl
3/03	M,B,R			Qpl
3/04	M,B,R			Qpl
3/05	M,B,R			Qpl
3/06	M,B,R			Qpl-Pc
3/07	M,B,R			Qpl
3/08	M,B,R			Qps-Pl
3/09	M,B,R			Qra
3/10	$^1/_2$M,B,R			Pl
3/11	$^1/_2$M,B,R			Pl
4/12		M,B,R		Qps
4/14		M,B,R		Qpl
4/15		M,B,R		Qqs
5/01			Q (M^1,B,R)	Qpl
5/03			M^1,B,R	Qpl
5/04			Q (M^1,B,R)	Qqs
5/05			Q (M^1,B,R)	Qps
5/06			Q (M^1,B,R)	Qra

* Key:

M = Mammal trapline (14 Elliotts, 12 Break-backs, 4 Cages)
M^1 = Mammal trapline (9 Elliotts, 9 Break-backs, 3 Cages)
B = Bird searches
R = Reptile searches
P = Solitary pits
F = Fenced pit line of six pits (4 shallow, 2 deep) with ca. 50 m drift fence
Q = Fauna quadrat (fenced pit lines and, adjacent, a 200 metre x 200 metre bird quadrat) that was sampled daily for four days as described in Biological Surveys Committee of Western Australia (1984).

As noted previously by McKenzie *et al.* (1987), brief reptile surveys of this type do not provide exhaustive lists of frogs, snakes and goannas. Being the earliest of the Study Areas to be surveyed (Biological Surveys Committee of Western Australia 1984), pit-fence traps were only used during the final visits to survey areas (campsites) in the Norseman-Balladonia Study Area, and only at campsites 1, 2 and 5. Even for lizards, the individual quadrats were not sampled as thoroughly as they were in other Goldfields Study Areas. Inconsistent sampling effort probably explains why some quadrats appeared to be so poor in lizard species compared with quadrats either in the Widgiemooltha-Zanthus Study Area (Dell & How 1984), or on the south-eastern corner of the Eucla District (McKenzie *et al.* 1987) (Table 4). These sampling problems limit the scope and reliability of ecological comparisons made between the quadrats in this Study Area.

Table 3. Amphibians and Reptiles recorded in the Survey Areas (Campsites and associated traplines) of the Norseman-Balladonia Study Area. Overall lists for each visit to each Survey Area are headed: O77=October 1977, F78=February/March 1978, A78=April 1978, M78=May 1978, O78=October 1978, N78=November 1978, S87=September 1987.

Traplines	Camp 1																					Camp 2										
	1	2	3	4	5	6	7	8	9	10	11	12	13	O77	A78	N78	15	16	17	18	19	20	23	24	25
Limnodynastes dorsalis																									
Neobatrachus sp.						x								X	X					x					
Pseudophryne occidentalis						x				x				X	X					x					
Litoria cyclorhynchus																									
Crenadactylus o. ocellatus				x										X		X									
Diplodactylus granariensis						x									X										
D. intermedius																						x			
D. maini	x				x				x		x			X	X	X						x			
Gehyra variegata	x					x								X	X		x	x			x	x	x		
Heteronotia binoei	x	x	x			x								X	X	X	x			x			x		
Oedura reticulata	x										x				X										
Phyllodactylus marmoratus			x								x		x	X		X	x								
Delma australis											x			X				x							
D. butleri																									x
Lialis burtonis											x			X				x							
Ctenophorus adelaidensis chapmani	x													X	X										
C. cristatus	x		x		x	x			x	x	x		x	X	X	X	x	x					x	x	
C maculatus dualis																									
C. maculatus griseus																									
C. mckenziei																									
C. salinarum		x						x						X	X	X		x		x		x			
Pogona minor minor	x					x			x	x				X	X	X	x								
Gemmatophora norrisi																									
Moloch horridus									x			x			X	X	x					x	x		
Varanus gouldii				x	x											X		x							
V. rosenbergi										x						X									

Table 3 (cont).

27 O77 S87 26 28 M78	Camp 3 2 4 6 8 10 F78 1 3 5 7 9 11	Camp 4 14 F78 12 15	Camp 5 3 5 O78 1 4 6
x X X	x x X		
X X	x X		
x X X X	X	x X	x X
x X X X	x X		
x X X X	x X		
X	X		
X	x X		
X X			
X	x X		
X			x X
X X	X	X	
	x		
			x x X
	x X		
x x X X X	x x X	X	
X X	x X	X	x x X
			x X
x X X		x X	
X			

Table 3. (cont).

Traplines	Camp 1																				Camp 2									
	1	2	3	4	5	6	7	8	9	10	11	12	13		O77		A78		N78		15	16	17	18	19	20	23	24	25	
Ctenotus atlas									x		x		x		X		X		X			x								
C. impar																														
C. schomburgkii			x	x	x		x										X		X		x						x			
C. uber				x													X		X											
Cryptoblepharus plagiocephalus													x				X				x			x			x			
C. virgatus clarus																														
Egernia bos																			X											
E. richardi			x		x					x	x				X		X		X											
E. inornata									x								X		X											
Hemiergis initialis brookeri																						x					x			
H. i. initialis				x													X													
*H. i. initialis x brookeri**															X		X													
H. peronii																														
Lerista dorsalis							x												X		x									
L. muelleri	x								x						X		X		X		x		x				x	x		
L. picturata	x																		X		x	x					x			
L. tridactyla																														
Menetia greyii									x		x				X		X		X		x	x		x			x	x		
Morethia butleri	x		x								x				X		X		X		x	x		x			x	x		
M. obscura	x														X		X				x						x			
Cyclodomorphus branchialis									x				x		X		X		X			x						x	x	
Tiliqua occipitalis				x											X													x		
T. rugosa	x				x										X				X											
Ramphotyphlops australis																														
Rhinoplocephalus gouldii	x			x							x				X		X													
Notechis mastersii																														
Pseudonaja affinis						x									X				X											
P. affinis x nuchalis (R62217)																														
Vermicella bimaculata																			X											

* See text.

Table 3 (cont).

27 O77 S87 26 28 M78	Camp 3 2 4 6 8 10 F78 1 3 5 7 9 11	Camp 4 14 F78 12 15	Camp 5 3 5 O78 1 4 6
x X X	x x X	x X	
			x x X
x X X	x x X		x x x X
X X X	x X	x X	
X			
x X	x x X	X	x X
x x X X X	X	X	
X X X	x x x X		
X	x X		
X	x X		
X	x X		x X
X X X	x X		
X	x X		
x X X X	x X	x X	X
X X	x X	x X	x x x X
X	x X		
x X			X
X			
X	x X		
	x X		
x X			
			x X

Table 4. Comparison of lizard species richness recorded on quadrats sampled in and near the Norseman-Balladonia Study Area. Richnesses derived from only one session of drift-fence trapping are in brackets.

LANDFORM UNIT	STUDY AREAS Widgiemooltha -Zanthus[1]	Balladonia quadrats[2]	Norseman-Balladonia
Calcareous plain			
Qqs,Qpl,*Qpe*,**TQr**	16,13,12,*15,15*,(4)	10,7,16,**9,10**	(6,12,14,2,6)
Granite outcrop features			
Pmg,Px,Ag	13,11	—	(9)
Calcareous plain around granite outcrop			
Qqs-Qps	19	—	(9)
Salt lake features			
Qrl,Qra	(2)	—	(0)*
Qps,Qpf,Qas	13,18,(8,5)	—	(12,3,5)

[1] Dell & How (1984)

[2] McKenzie, Rolfe and Carter (1987)

* Other Qra samphire patches sampled over two or three seasons, but not with drift-fences, yielded 3 (trapline 1/02), 1 (1/08), 5 (2/20) and 1 (3/09) species (from Table 3).

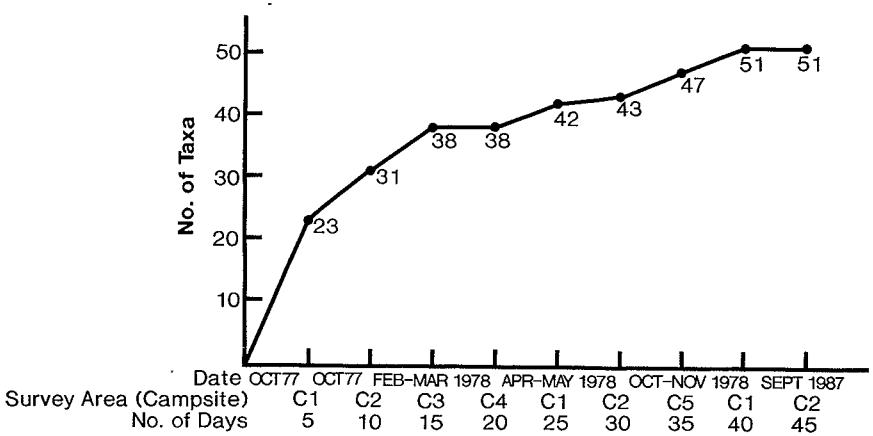

Figure 4 Species accumulation curve for reptiles recorded at survey areas in the Norseman-Balladonia Study Area during the study.

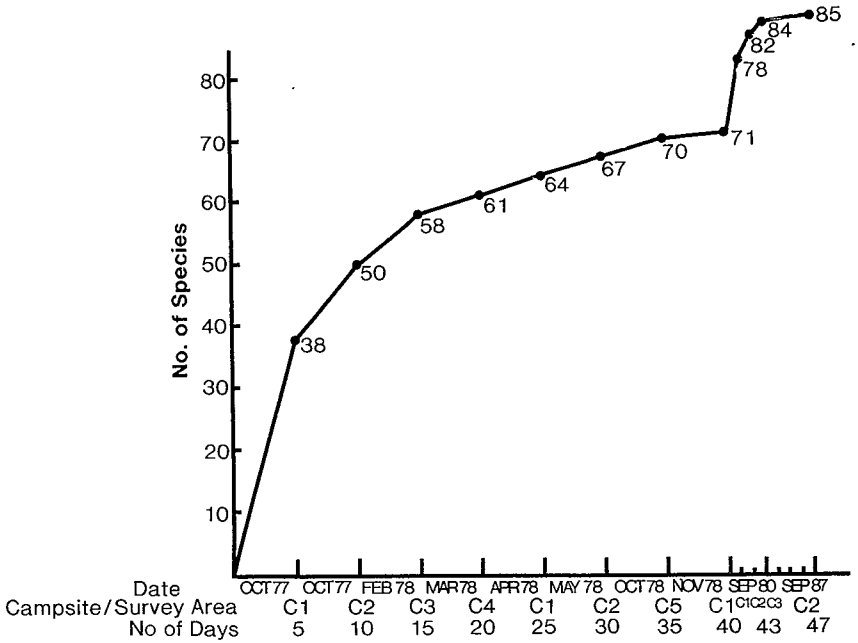

Figure 5 Species accumulation curve for birds recorded at survey areas in the Norseman-Balladonia Study Area during the study.

Birds

Eighty-five species of bird were recorded in the survey areas (campsites) of the Norseman-Balladonia Study Area during our survey. These comprised 55 passerines and 30 non-passerines. The species recorded from each sampled site, and from each survey area during each visit, are listed in Tables 5,6,7,8.

By November 1978, the species accumulation curve (Figure 5) suggested that few species remained to be detected in the survey areas. However, a visit to three of the survey areas by a different observer (Brenda Newbey) in September 1980, yielded a further 13 species on traplines and quadrats. This highlights the pitfalls of seasonally uncoordinated sampling of birds. In addition, many of the Study Area's birds favour habitats not present in the survey areas. The following birds were recorded by B. Newbey at sites other than the survey areas:

Great Cormorant (32°55'S 121°35'E)
Pacific Heron (32°25'S 123°35'E)
Wood Duck (32°55'S 121°35'E)
Mountain Duck (32°55'S 121°35'E)
Spotted Harrier (32°25'S 123°35'E)

Table 5. Birds recorded in the Jyndabinbin Rocks Survey Area (Campsite 1) of the Norseman-Balladonia Study Area.

	Traplines													Seasonal Lists[1]			
	1	2	3	4	5	6	7	8	9	10	11	12	13	O77	A78	N78	S80*
Emu						x			x			x			x		x
Whistling Kite														x			
Square-tailed Kite																	x
Wedge-tailed Eagle						x				x					x		x
Little Eagle														x			
Brown Falcon			x								x					x	x
Australian Kestrel										x							x
Australian Hobby	x														x		
Mallee Fowl	N									*							
Banded Plover										x	x			x			x
Common Bronzewing						x								x		x	
Purple-crowned Lorikeet	x	x	x	x	x									x	x	x	
Regent Parrot														x		x	x
Western Rosella															x		
Ring-necked Parrot	x		x		x						x			x	x	x	x
Mulga Parrot			x													x	
Pallid Cuckoo															x		
Boobook Owl	x					x								x	x		
Tawny Frogmouth	x				x									x			
Australian Owlet-nightjar	x	x												x	x		
Spotted Nightjar										x				x			
Rainbow Bee-eater	x				x									x		x	
Sacred Kingfisher														x			
Red-backed Kingfisher					x												x
Tree Martin											x				x	x	
Richard's Pipit										x	x						x
Black-faced Cuckoo-shrike			x			x	x		x		x			x	x	x	
Jacky Winter										x					x	x	
Red-capped Robin	x								x		x			x	x		x
Yellow Robin	x									x					x	x	
Golden Whistler	x	x		x						x				x	x	x	x
Gilberts Whistler					x						x						x
Grey Shrike-thrush	x		x	x	x			x	x		x			x	x	x	
Crested Shrike-tit					x												x
Crested Bellbird	x	x	x	x	x	x								x	x	x	
Willie Wagtail		x		x	x	x				x	x	x		x	x		x
Restless Flycatcher																	x
Chestnut Quail-thrush			x												x		x
Southern Scrub-robin					x									x			x
White-browed Babbler	x		x		x	x					x			x	x	x	x
Western Flyeater									x				x	x	x	x	
Weebill	x	x	x	x	x		x		x		x		x	x	x	x	x
Broad-tailed Thornbill	x			x	x	x	x				x	x		x	x	x	x
Shy Hylacola					x				x					x		x	
Redthroat	x			x			x	x	x					x	x	x	x

Table 5. (cont).

	Traplines													Seasonal Lists[1]			
	1	2	3	4	5	6	7	8	9	10	11	12	13	O77	A78	N78	S80*
Blue-breasted Fairy-wren								x									x
Brown Songlark																	x
Australian Sitella	x	x			x				x					x	x	x	x
Rufous Tree-creeper			x		x						x			x	x	x	x
Yellow-rumped Pardalote													x		x		
Striated Pardalote	x	x	x	x	x		x			x	x		x	x	x	x	x
Grey-breasted White-eye		x								x				x			x
Brown Honeyeater										x							x
White-eared Honeyeater	x	x			x	x			x		x			x	x	x	x
Yellow-plumed Honeyeater	x	x	x	x	x	x		x			x		x	x	x	x	x
Brown-headed Honeyeater		x		x	x			x		x	x			x	x	x	x
White-fronted Honeyeater	x							x								x	x
Yellow-throated Miner	x														x		
Spiny-cheeked Honeyeater	x															x	
Red Wattlebird	x	x	x		x	x					x	x	x	x	x	x	x
White-fronted Chat										x	x						x
Black-faced Wood-swallow					x									x		x	
Dusky Wood-swallow			x		x						x			x	x	x	x
Pied Butcherbird						x					x			x			x
Grey Butcherbird											x						x
Grey Currawong	x			x	x						x			x	x	x	x
Australian Raven																	x
Little Crow																	x

[1] O77 = October 1977, A78 = April 1978 and N78 = November 1978
* S80 = September 1980 (Brenda Newbey data)
N old nest..

Collared Sparrowhawk (32°55'S 121°35'E)
Galah (32°05'S 122°35'E)
Fan-tailed Cuckoo (32°05'S 121°55'E)
Welcome Swallow (32°55'S 121°35'E)
White-winged Triller (31°25'S 122°55'E)
Rufous Songlark (32°05'S 122°45'E)
Australian Magpie (32°25'S 121°45'E, 32°45'S 121°55'E, 32°55'S 121°35'E)

A further 43 bird species have been recorded in the Study Area (Table 9): 11 passerines and 32 non-passerines (including 19 nomadic or migratory waterfowl and littoral species). It is clear that our survey areas do not represent the wetlands of the Study Area. On the other hand, species such as the Brush Bronzewing, Elegant Parrot, Tawny-crowned Honeyeater, White-cheeked Honeyeater, White-browed Scrubwren and Carnaby's Black-Cockatoo would only occur along the southern margin of the Study

Table 6. Birds recorded at the Boingaring Rocks Survey Area (Campsite 2) of the Norseman-Balladonia Study Area.

	Traplines										Seasonal Lists[1]			
	15	16	18	19	23	24	25	26	27	28	O77	M78	S80*	S87
Emu		x											x	x
Square-tailed Kite					x									x
Little Eagle											x	x		
Australian Kestrel											x			
Australian Bustard												x		
Common Bronzewing			x		x							x	x	
Purple-crowned Lorikeet	x							x				x	x	
Ring-necked Parrot	x	x		x	x			x			x	x	x	x
Mulga Parrot	x										x			x
Black-eared Cuckoo				x			x	x					x	
Pallid Cuckoo	x			x									x	
Horsfield's Bronze Cuckoo				x									x	
Boobook Owl					x			x					x	
Tawny Frogmouth											x			
Australian Owlet-nightjar				x	x							x	x	
Spotted Nightjar													x	
Rainbow Bee-eater											x			
Sacred Kingfisher												x		
Red-backed Kingfisher				x	x								x	x
Tree Martin											x		x	
White-backed Swallow											x			
Richard's Pipit			x								x	x		
Black-faced Cuckoo-shrike	x	x		x		x					x	x	x	x
Jacky Winter	x			x	x	x		x				x	x	x
Hooded Robin	x										x	x		
Red-capped Robin					x						x	x		x
Yellow Robin				x		x					x	x	x	
Rufous Whistler								x						x
Golden Whistler	x			x	x			x				x	x	x
Gilberts Whistler													x	
Grey Shrike-thrush	x	x		x				x		x	x	x	x	x
Crested Shrike-tit	x											x		
Crested Bellbird	x			x			x	x			x	x	x	x
Willie Wagtail	x						x	x			x	x	x	
Restless Flycatcher								x					x	
Chestnut Quail-thrush	x	x		x								x	x	x
Southern Scrub-robin											x			
White-browed Babbler	x				x	x		x			x	x	x	x
Western Flyeater	x										x	x		
Weebill	x	x		x	x	x	x	x			x	x	x	x
Broad-tailed Thornbill	x		x	x	x	x	x	x			x	x	x	x
Yellow-rumped Thornbill											x	x	x	
Shy Hylacola							x					x		x
Calamanthus													x	
Redthroat								x			x	x	x	

Table 6. (cont).

	Traplines										Seasonal Lists[1]			
	15	16	18	19	23	24	25	26	27	28	O77	M78	S80*	S87
Blue-breasted Fairy-wren								x						x
Australian Sittella				x				x				x	x	
Rufous Tree-creeper	x			x					x		x	x	x	x
Mistletoebird	x													x
Striated Pardalote	x	x		x	x	x	x	x			x	x	x	x
Grey-breasted White-eye	x											x		
White-eared Honeyeater	x	x		x		x		x		x	x	x	x	x
Yellow-plumed Honeyeater	x	x		x	x	x	x	x	x		x	x	x	x
Brown-headed Honeyeater	x	x		x	x			x				x	x	x
White-fronted Honeyeater	x	x		x	x			x				x	x	x
Yellow-throated Miner	x		x	x							x		x	
Spiny-cheeked Honeyeater					x							x		x
Red Wattlebird	x	x		x	x	x	x	x	x	x	x	x		x
Crimson Chat							x						x	
Dusky Wood-swallow	x				x						x	x		x
Pied Butcherbird											x			
Grey Butcherbird	x	x		x	x			x			x	x	x	x
Grey Currawong	x	x		x				x			x	x	x	x
Australian Raven											x			
Little Crow			x								x			

[1] O77 = October 1977, M78 = May 1978 and S87 = September 1987
* S80 = September 1980 (Brenda Newbey data).

Area. These seven species may have been encountered if more visits had been made to the survey area at Campsite 5. A number are vagrants (e.g. Scarlet-chested Parrot, Black Honeyeater, Cattle Egret & Ground Cuckoo-Shrike). Unlike the mammals, there is no evidence to suggest that bird species have disappeared from the Study Area since European settlement (Saunders 1989).

Three exotic species have been recorded in the Study Area:

Laughing Turtle-dove (32° 15'S 121° 45'E = Norseman Town)
Domestic Pigeon (32° 15'S 121° 45'E = Norseman Town)
Common Starling (32° 15'S 121° 45'E = Norseman Town, 32° 45'S 121° 35'E).

When the 14 quadrats (see Table 2) were classified according to similarities in their passerine bird species composition, only two distinct groups could be distinguished (Figure 6). One group comprised the only quadrat on a samphire claypan (Salt Lake Features quadrat 5/06), and the other group comprised the remaining 13 quadrats and represented woodland, mallee and shrubland habitats on various non-saline substrates. The mixture of habitats included in the second group reflects the great extent and ubiquity of *Eucalyptus* woodlands in the Study Area, especially those of Calcareous Plains, in relation to the relatively small patches of the Study Area's other habitats.

Table 7. Birds recorded at the Campsite 3 Survey Area of the Norseman-Balladonia Study Area.

	Traplines											Seasonal Lists[1]		
	1	2	3	4	5	6	7	8	9	10	11	O77	F78	S80*
Emu		x											x	
Pacific Heron												x		
Black Duck														x
Square-tailed Kite														x
Brown Goshawk	x					x							x	x
Wedge-tailed Eagle	x												x	
Little Eagle	x									x			x	
Australian Kestrel	x				x								x	x
Australian Bustard													x	
Common Bronzewing	x			x					x				x	x
Mulga Parrot												x	x	x
Ring-necked Parrot	x		x		x			x					x	x
Black-eared Cuckoo	x													x
Pallid Cuckoo														x
Horsfield's Bronze Cuckoo														x
Boobook Owl	x												x	x
Australian Owlet-nightjar	x					x							x	
Rainbow Bee-eater													x	
Sacred Kingfisher												x		
Tree Martin	x				x						x		x	x
Richard's Pipit	x				x				x				x	x
Black-faced Cuckoo-shrike	x			x	x	x				x			x	
Jacky Winter				x	x								x	
Hooded Robin			x		x								x	
Red-capped Robin	x												x	
Yellow Robin													x	x
Golden Whistler	x													x
Rufous Whistler				x									x	
Grey Shrike-thrush	x		x			x				x	x		x	x
Crested Bellbird	x	x			x				x				x	x
Grey Fantail														x
Willie Wagtail	x				x								x	x
Chestnut Quail-thrush					x								x	
Southern Scrub-robin														x
White-browed Babbler		x	x										x	x
Western Flyeater													x	x
Weebill	x												x	x
Broad-tailed Thornbill	x	x	x	x	x			x	x	x			x	x
Yellow-rumped Thornbill	x									x	x		x	x
Redthroat	x													x
Blue-breasted Fairy-wren	x													x
Australian Sittella	x												x	x
Rufous Tree-creeper			x				x			x			x	
Striated Pardalote	x				x	x			x	x			x	x
Grey-breasted White-eye	x				x				x	x			x	x
White-eared Honeyeater	x					x							x	x

Table 7. (cont).

	Traplines											Seasonal Lists[1]		
	1	2	3	4	5	6	7	8	9	10	11	O77	F78	S80*
Yellow-plumed Honeyeater	x		x	x	x	x	x	x	x	x	x		x	x
Brown-headed Honeyeater	x	x							x				x	x
Spiny-cheeked Honeyeater										x			x	
Red Wattlebird	x						x		x				x	x
White-fronted Chat	x													x
Magpie Lark	x												x	
Dusky Wood-swallow			x		x		x				x		x	x
Pied Butcherbird	x			x								x		
Grey Butcherbird	x	x		x	x	x		x	x		x		x	x
Grey Currawong	x					x		x	x				x	x
Australian Raven	x													x

[1] O77 = October 1977 and F78 = February 1978
* S80 = September 1980 (Brenda Newbey data).

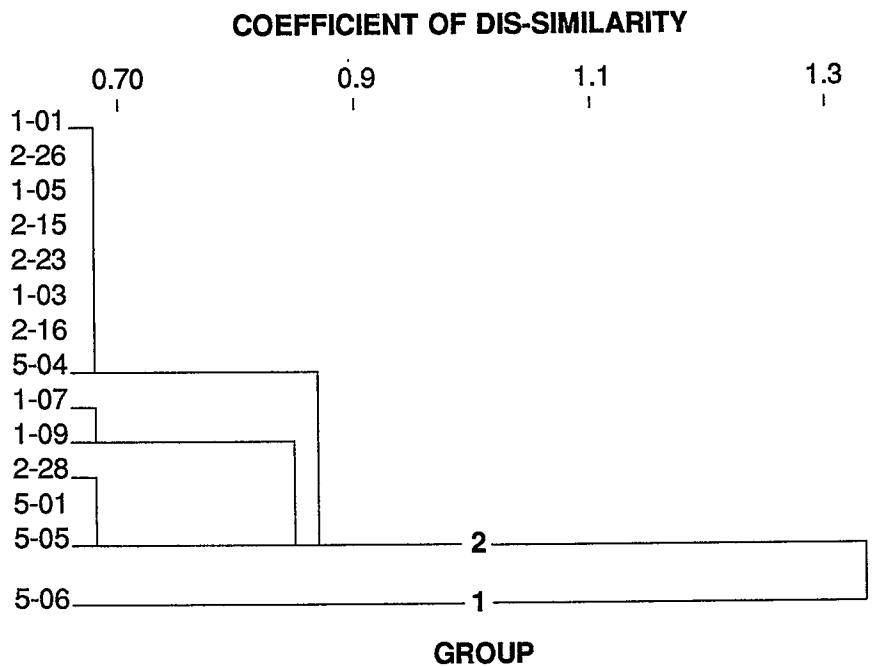

Figure 6 Quadrats in the Norseman-Balladonia Study Area classified according to similarities in their passerine bird species composition using the similarity coefficient of Czekanowski (1932) and "unweighted pair-group mean averaging" (UPGMA, Sneath and Sokal 1973).

Table 8. Birds recorded at Campsite 4 and 5 Survey Areas of the Norseman-Balladonia Study Area.

	CAMP 4 Traplines				CAMP 5 Traplines					
	12	14	15	M78[1]	1	3	4	5	6	O78[1]
Emu				x						x
Little Eagle					x					x
Mallee Fowl				*						
Banded Plover				x						
Purple-crowned Lorikeet		x		x			x			x
Western Rosella		x		x						
Ring-necked Parrot		x		x						x
Mulga Parrot				x						
Boobook Owl		x		x						x
Tawny Frogmouth		x		x						
Australian Owlet-nightjar		x		x						x
Spotted Nightjar		x		x						
Rainbow Bee-eater		x		x						x
Tree Martin		x		x						
Richard's Pipit				x						
Black-faced Cuckoo-shrike				x			x			x
Jacky Winter				x						
Yellow Robin		x		x				x		x
Golden Whistler					x					x
Grey Shrike-thrush		x		x			x	x		x
Crested Bellbird		x		x			x			x
Willie Wagtail		x		x						
Southern Scrub-robin							x			x
White-browed Babbler			x	x			x			x
Western Flyeater		x		x						
Weebill	x	x		x	x			x		x
Broad-tailed Thornbill				x	x		x	x		x
Shy Hylacola										x
Blue-breasted Fairy-wren							x			x
Australian Sittella				x			x			x
Rufous Tree-creeper		x	x	x						
Yellow-rumped Pardalote							x			x
Striated Pardalote	x	x	x	x						x
Grey-breasted White-eye					x					x
Singing Honeyeater				x						x
Purple-gaped Honeyeater					x					x
White-eared Honeyeater	x	x		x	x			x		x
Yellow-plumed Honeyeater		x	x	x			x			x
Brown-headed Honeyeater		x		x	x					x
White-fronted Honeyeater					x			x	x	x
New Holland Honeyeater								x		x
Western Spinebill								x		x
Spiny-cheeked Honeyeater				x						
Red Wattlebird		x		x	x		x			x
Masked Wood-swallow							x			x
Dusky Wood-swallow				x						x
Grey Butcherbird	x	x		x						
Grey Currawong		x		x						x

[1] M78 = March 1978 and O78 = October 1978
* old nest.

Table 9. Other bird species recorded from the Norseman-Balladonia Study Area by the R.A.O.U. Atlas (Blakers *et al.* 1984) during four time intervals: 1 = pre-1900; 2 = 1900-1950; 3 = 1951-1976; 4 = 1976-1981.

SPECIES	INTERVAL		
Malleefowl	3,4	Grey Teal	4
Stubble Quail	4	Australasian Shoveler	4
Little Button-quail	2,4	Black-shouldered Kite	3,4
Black-tailed Native-hen	2,3	Peregrine Falcon	4
Brush Bronzewing	4	Barn Owl	3
Crested Pigeon	3	Cockatiel	3,4
Australasian Grebe	3	Elegant Parrot	4
Little Black Cormorant	4	Scarlet-chested Parrot	3
Little Pied Cormorant	3	Budgerigar	3
Silver Gull	3,4	White-tailed Black-Cockatoo	2,3
Hooded Plover	2	Fairy Martin	3,4
Black-fronted Plover	2	Ground Cuckoo-shrike	2,3,4
Red-capped Plover	1,2,3	Chestnut-rumped Thornbill	3,4
Inland Dotterel	2,4	Slender-billed Thornbill	3,4
Red-necked Avocet	4	White-browed Scrubwren	4
Banded Stilt	2	White-winged Fairy-wren	2,3
Greenshank	2	Black Honeyeater	2
Common Sandpiper	3,4	Tawny-crowned Honeyeater	2,3,4
Straw-necked Ibis	2	White-cheeked Honeyeater	4
Black Swan	3,4	Zebra Finch	3,4
Pink-eared Duck	3	Torresian Crow	3,4
Chestnut Teal	2		

Certain woodland bird species were recorded in virtually every quadrat, although they were probably only commuting through the isolated mallee, shrubland and samphire habitats sampled. This result is more likely to reflect the mobility that flight allows these organisms than any differences in the way species partition habitats.

Passerine bird assemblages of quadrats in the Widgiemooltha-Zanthus Study Area (Dell & How 1984), and on the south-eastern corner of the Eucla District (Burbidge *et al.* 1987), had similar richness to their equivalents in the Norseman-Balladonia Study Area (Table 10) unless sampling was restricted to a single season. Quadrats sampled in only a single season cannot be analysed with those sampled during several seasons. Similarly, our sampling was incomplete for non-passerines such as raptors.

Mammals

Fifteen native and five introduced species of mammal were recorded in the Norseman-Balladonia Study Area during our survey (Table 11).

By identifying bone material from recent sub-fossil deposits in exposed sites, Baynes (1987) listed species that were likely to be extant in, and peripheral to, the Nullarbor at the time Australia was settled by Europeans, about 200 yrs ago. Three of these deposits were in the Norseman-Balladonia Study Area (Sites 30, 31 and 45 in Figure 46 of Baynes 1987).

Table 10. Comparison of total bird species richness (and passerine richness) recorded on quadrats sampled in and near the Norseman-Balladonia Study Area. Richnesses derived from only one season are in square brackets.

LANDFORM UNIT	STUDY AREAS		
	Widgiemooltha -Zanthus[1]	Balladonia quadrats[2]	Norseman-Balladonia
Calcareous plain			
Qqs,Qpl,Qpe,TQr	27(20),24(21), 16(15),22(14), 22(19),24(19), 25(21),20(16)	21(16),25(18), 33(26),32(25), 26(16)	25(20),15(11), 30(26),20(14), [5(5)],[10(9)], [13(12)]
Granite outcrop features			
Pmg,Px,Py,Ag	18(16),20(15), 18(12),24(17)	—	25(23)
Salt lake features			
Qrl,Qra,Qre	20(12),2(2)	—	[1(1)]
Qps,Qpf	—	—	26(8),13(11), 3(3),[8(8)]

[1] Dell & How (1984)
[2] Burbidge, Casperson & Fuller (1987)

The post-European introductions present in Bayne's bone deposits (*Mus musculus* and *Oryctolagus cuniculus*) are still extant in the Study Area.

Of the other sub-fossil records, 10 native species are still extant in the Norseman-Balladonia Study Area: *Tachyglossus aculeatus, Ningaui yvonnae, Sminthopsis murina* gp (= ?*dolichura), Cercartetus concinnus, Canis familiaris* (Dingo), *Pseudomys bolami, Notomys* sp. indet., *Chalinolobus morio, Eptesicus* sp. and *Nyctophilus major*. In addition, *Dasyurus geoffroyi* was last recorded in the Study Area about 15 years ago, and may still be extant there.

However, we did not find any evidence that the following species were still extant: *Phascogale calura, P. tapoatafa, Parantechinus apicalis, Perameles bougainville, Macrotis lagotis, Potorous platyops, Bettongia penicillata, Lagostrophus fasciatus, Onychogale lunata, Leporillus conditor* and *L. apicalis*.

All of the small mammals (< 35 g mean adult body weight) found in these deposits are still extant. Only one of the 11 medium-sized, homeothermic mammals (35 g - 4.5 kg) indigenous to the Study Area has persisted. McKenzie *et al.* (1992) report the same pattern of extinction in the Kurnalpi-Kalgoorlie Study Area (Figure 1), although the original mammal fauna they report was compiled from early museum records, and species reported by early European explorers, rather than from sub-fossil deposits. Our results are also consistent with the regional patterns of decline and extinction in Western Australia's mammal fauna that were quantified by Burbidge and McKenzie (1989).

The non-volant mammals recorded in the Norseman-Balladonia Study Area are listed by trapline in Table 12. Seven species of small ground-dwelling mammals were

recorded in the fenced pit-traps (Table 13). *Ningaui yvonneae* was recorded only on sandy surfaces associated with granite outcrops and salt-lake features. While *Notomys mitchellii* was generally recorded in the same habitats, it was more common in the *Melaleuca* shrublands on sandy loams and clay-loams associated with the outcrops. *Mus musculus* and *Sminthopsis crassicaudata* favoured the samphire claypans (Qra surface); *S. ?dolichura* and *Pseudomys bolami* usually occurred elsewhere (Table 13). The *Sminthopsis crassicaudata* on Quaternary sand at 2/28 may be an artefact of proximity to a samphire claypan. *Cercartetus concinnus* was the only species recorded on all surface-types sampled.

Bats were recorded at a variety of sites, although sampling was concentrated on semi-permanent pools at Jyndabinbin Rocks (Trapline 1/06) and Deralinya Ruins (33°03'S, 123°23'E). The second site is six kilometres south of the Study Area.

A total of seven bat species were recorded (Table 14); all of these occur throughout the Study Area. Although we did not record *Chalinolobus morio* from the eastern campsites, Boscacci *et al.* (1987) recorded this species in similar habitat 50 km to the north-east of Camp 2. The population of *Tadarida australis* from Jyndabinbin Rocks, Deralinya Ruins and Ponier Rock included individuals with a white thoracic or abdominal band, patch and/or stripe (Plate 16).

During the spring and early autumn field surveys, bats were numerous around the margins of small claypans and throughout the woodlands that are so widespread in the Study Area. Species foraging microhabitats were recorded at sites remote from pools.

Tadarida australis almost exclusively foraged in clear air above the vegetation canopy; on only one occasion were individuals observed foraging below the canopy. The vegetation at this site was a tall sparse Salmon Gum woodland where the only obstructions were tree-trunks, 30 to 40 metres apart, and the bottom of the canopy was more than 10 metres above a sparse shrub layer.

Mormopterus planiceps was usually recorded 10 to 15 metres above the ground, foraging in the clear air around the margins of the woodland stands; most were recorded around the edges of clearings, such as claypans.

Chalinolobus gouldii was the most common bat. It was often observed foraging along vehicle tracks or around and between the tree canopies of the open woodland, at altitudes between 4 and 15 metres. It was not seen to fly between branches, through tree canopies or between shrubs.

Eptesicus regulus was often seen flying in the same air space as *Chalinolobus gouldii* but was noted approaching to within less than a metre from the foliage. Unlike *C. gouldii*, it often attempted to elude our spotlight by flying between branches and sections of the lower canopy.

Nyctophilus geoffroyi foraging behaviour was observed by attaching bio-luminescent beads to an individual that had been captured in a mist net. It fluttered between the bushes, about 1.5 to 2 metres above the ground, occasionally dropping sharply towards or onto the ground. Elsewhere in Australia, similar foraging behaviour has been reported for this species (Dwyer 1965, O'Neil & Taylor 1987, McKenzie & Start 1989).

Table 11. Mammals recorded during the survey of the Norseman-Balladonia Study Area (listed by season).

CAMP	1			2			3	4	5
MONTH & YEAR*	O77	**A78**	N78	O77	**M78**	S87	M78[1]	M78[1]	O78
Macropus fuliginosus	x	x		x			x	x	x
Cercartetus concinnus			x			x			x
Ningaui yvonneae						x			
Sminthopsis ?dolichura		x			x				
S. crassicaudata		x			x	x			x
Pseudomys bolami		x		x			x		
Notomys mitchellii	x	x	x	x			x		x
Mus musculus	x	x	x		x		x		x
Eptesicus regulus	x	x	x	x			x	x	
Chalinolobus gouldii	x	x	x				x	x	
C. morio	x		x						
Nyctophilus geoffroyi	x	x		x			x		x
N. major	x	x		x			x		
Mormopterus planiceps	x		x	x				x	
Tadarida australis	x	x	x		x		x	x	
Felis catus	x	x		x			x		
Canis dingo	x			x			x		
Vulpes vulpes		x							
Camelus dromedarius	x	x		x	x		x	x	
Oryctolagus cuniculus	x	x			x		x		

* O77 = October 1977, A78 = April 1978, M78 = May 1978, O78 = October 1978, N78 = November 1978, S87 = September 1987

[1] M78 = March 1978.

Table 12. Non-volant mammals recorded during the survey of the Norseman-Balladonia Study Area (listed by trapline).

CAMP	1						2						3			4		
TRAPLINE	1	3	5	8	11		15	18	20	24	26	28	1	8	10	1	5	
	2	4	6	9	12		16	19	23	25	27		5	9		4	6	
Macropus fuliginosus	x		x	x									x	x				
Cercartetus concinnus		x	x				x	x	x	x	x	x				x	x	
Ningaui yvonneae							x			x		x						
Sminthopsis ?dolichura	x			x	x					x	x	x						
S. crassicaudata			x						x			x						x
Pseudomys bolami					x				x	x	x			x				
Notomys mitchellii	x	x		x	x		x				x			x			x	
Mus musculus	x	x		x	x				x			x	x					x
Felis catus	x			x											x			
Canis dingo	x							x							x			
Vulpes vulpes	x																	
Camelus dromedarius		x			x			x						x				
Oryctolagus cuniculus		x	x	x				x	x		x	x		x	x			

Table 13. Small non-volant mammal data matrix re-ordered as a 2-way table according to Czekanowski (quadrat) and Twostep (species) association measures (Czekanowski 1932, Austin & Belbin 1982, respectively), and the UPGMA sorting strategy (Belbin 1987). Quadrat codes are printed vertically.

	QUADRAT CODES			
	1125	1522	12255	2222
	////	////	/////	////
	0010	0022	01200	2222
	1965	8608	55314	4567
Cercartetus concinnus	*	**	*****	****
Ningaui yvonneae	*	*		*
Pseudomys bolami		*		**
Sminthopsis ?dolichura	**			****
Notomys mitchellii	****	*		*
Sminthopsis crassicaudata		****		
Mus musculus	**	****		
GROUP*	1	2	3	4

*1 = sand deposits around salt lakes/granite apron
2 = samphire and adjacant slope
3 = calcareous plains
4 = granite apron and surrounds

Table 14. Insectivorous bats recorded in the Norseman-Balladonia Study Area during the field survey. Species are listed for each fauna sampling site near each of the five campsites.

CAMP	**1**	**2**	**3**	**4**	**5**
TRAPLINE	1 2 3 4 5 6 8 9 11	18 20 24 25	1 Der	14	6
Eptesicus regulus	x x x x x	x x	x x	x	
Chalinolobus gouldii	x x x x x		x	x	
C. morio	x				
Nyctophilus geoffroyi	o o x	o	x		x
N. major	o x o	o	x		
Mormopterus planiceps	x x x	x x		x	
Tadarida australis	x x x x x x	x	x	x	

o = pit trap specimen
Der = Deralinya Ruins (dam: 33° 03'S 123° 23'E)

Fenton (1972), McKenzie & Rolfe (1986), Aldridge & Rautenbach (1987) and Norberg (1987) report consistent relationships between bat foraging microhabitat and wing morphology. The relatively low aspect ratio and wing loading of the two *Nyctophilus* species (Fullard *et al.* 1991) indicates a surface-gleaning foraging strategy and probably explains why four specimens of *Nyctophilus major* and five *N. geoffroyi* were captured in pit traps.

References

Aldridge, H.D.J.N. & Rautenbach, I.L. (1987). Morphology, echolocation and resource partitioning in insectivorous bats. *J. Anim. Ecol.* **56**, 763-778.

Austin, M.P. & Belbin, L. (1982). A new approach to the species classification problems in floristic analysis. *Aust. J. Ecol.* 7, 75-89.

Baynes, A. (1987). The original mammal fauna of the Nullarbor and southern peripheral regions: evidence from skeletal remains in superficial cave deposits.In: *A biological survey of the Nullarbor Region, South and Western Australia.* (Eds: N.L. McKenzie & A.C. Robinson) pp. 139-152. Dept Environment and Planning, Adelaide.

Belbin, L. (1987). PATN Reference Manual, User's Guide, Command Manual and Example Manual. CSIRO Division of Wildlife and Ecology, Canberra.

Biological Surveys Committee of Western Australia (1984). The biological survey of the Eastern Goldfields of Western Australia. Part 1. Introduction and methods. *Rec. West. Aust. Mus.* Supplement No. **18**, 1-19.

Blakers, M., Davies, S.J.J.F. & Reilly, P.N. (Eds) (1984). *The Atlas of Australian Birds: Royal Australasian Ornithologists Union.* Melbourne University Press, Carlton.

Boscacci, L.J., McKenzie, N.L. & Kemper, C.M. (1987). Mammals. In: *A biological survey of the Nullarbor Region, South and Western Australia.* (Eds: N.L. McKenzie & A.C. Robinson) pp 103-137. Dept Environment and Planning, Adelaide.

Burbidge, A.A., Casperson, K.D. & Fuller, P.J. (1987). Birds. In: *A biological survey of the Nullarbor Region, South and Western Australia.* (Eds: N.L. McKenzie & A.C. Robinson) pp. 153-178. Dept Environment and Planning, Adelaide.

Burbidge, A.A. & McKenzie, N.L. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* **50**, 143-198.

Czekanowski, J. (1932). Coefficient of racial likeness, und durchschnittliche differenz. *Anthrop. ANZ* **9**, 227-249.

Dell, J. & How, R.A. (1984). Vertebrate fauna. In: A biological survey of the eastern Goldfields of Western Australia. Part 2. Widgiemooltha-Zanthus Area. *Rec. West. Aust. Mus.* Supplement No. **18**, 57-81.

Dwyer, P.D. (1965). Flight patterns of some eastern Australian bats. *Victorian Naturalist* **82**, 36-41.

Fenton, M.B. (1972). The structure of aerial-feeding bat faunas as indicated by ears and wing elements. *Can. J. Zool.* **50**, 287-296.

Fullard, J., Koehler, K., Surlykke, A. & McKenzie, N.L. (1991). Ecolocation and flight morphology of insectivorous bats in southwestern Australia. *Aust. J. Zool.* **39**, 427-438.

McKenzie, N.L. (1984). Survey methods for nature conservation by the Western Australian Department of Fisheries and Wildlife — a current view. In: *Survey methods for nature conservation — proceedings of a workshop, Adelaide 1983.* (Eds: K. Myers, C.R. Margules & I. Musto), Vol.2. pp 88-117. CSIRO Div. Water & Land Resources, Canberra.

McKenzie, N.L. & Rolfe, J.K. (1986). Structure of bat guilds in the Kimberley mangroves, Australia. *J. Anim. Ecol.* **55**, 401-420.

McKenzie, N.L., Rolfe, J.K. & Carter, D. (1987). Reptiles and Amphibians. In: *A biological survey of the Nullarbor Region, South and Western Australia.* (Eds: N.L. McKenzie & A.C. Robinson) pp. 179-210. Dept. Environment and Planning, Adelaide.

McKenzie, N.L. & Start, A.N. (1989). Structure of bat guilds in mangroves: environmental disturbance and determinism. In: *Patterns in the Structure of Mammalian Communities.* (Eds: D.W. Morris, Z. Abramski, B.J. Fox & M.R. Willig), pp 167-178. Spec. Publ. Mus. Texas Tech. Univ. No. **28**. Lubbock, Texas.

McKenzie, N.L., Rolfe, J.K. & Youngson, W.K. (1992). Vertebrate Fauna. In: A biological survey of the Eastern Goldfields of Western Australia. Part 8. Kurnalpi-Kalgoorlie Study Area. *Rec. West. Aust. Mus.* Supplement No. **41**.

Norberg, U.M. (1987). Wing form and flight mode in bats. In: *Recent Advances in the Study of Bats.* (Eds: M.B. Fenton, P. Racey & J.M.V. Rayner) pp 43-56. Cambridge Press, Cambridge.

O'Neil, M.G. & Taylor, R.J. (1987). Observations on the flight patterns and foraging behaviour of Tasmanian bats. *Aust. Wildl. Res.* **13**, 427-432.

Saunders, D.A. (1989). Bird faunas and habitat fragmentation. *Biological Conservation* **50**, 99-135.

Sneath, P.H.A. & Sokal, R.R. (1973). *Numerical taxonomy: the principles and practice of numerical classification.* W.H Freeman, San Francisco.

V Acknowledgements

We are grateful to the Curator of the Western Australian Herbarium for making available facilities generally, and to K.F. Kenneally and members of the technical staff for aiding the processing of the specimens.

We record our appreciation to the Director and staff of the W.A. Museum, in particular D.J. Kitchener, J. Henry, L.A. Smith and G.M. Storr, for their assistance with identification and curation of the vertebrate specimens.

Assistance with the identification of the plants was provided by T.E.H. Aplin, M.I.H. Brooker, R. Carolin, R.J. Chinnock, B.J. Conn, D.A. Cooke, H.J. Eichler, J.W. Green, H.J. Hewson, S.D. Hopper, K.F. Kenneally, N.S. Lander, D.J. McGillivray, T.D. Mcfarlane, N.G. Marchant, B.R. Maslin, K.R. Newbey, G. Perry, B.L. Rye, P.S. Short, H.R. Toelken, M. Trudgen, J.G. West, P. Weston and P.G. Wilson.

Assistance in vertebrate sampling was provided by A.P. Brown, J. Blackwood, K.E. Cashin, P. Crabb, R.A. How, S.M. McKenzie, B. Newbey and C.A. Rolfe.

Brenda Newbey compiled and collated the vegetation data sheets to produce the first drafts of Appendices 1 and 2. A.P. Brown and S.D. Hopper (CALM) allowed access to unpublished data on orchids. Figures and maps were drawn up by J. Forster and C. Leonard (Land Information Branch, CALM). S. Kent (Geological Survey, Mines Department of W.A.) critically reviewed the text concerning geology and landform units in Part II (Physical Environment).

R.A. How, W.F. Humphries, J. Dell and K.R. Newbey provided useful discussion. The Australian Bureau of Meteorology, Perth, provided the climatic data. We thank R.J. Begg, A. Eastman and K.E. Cashin for assistance with the prolonged and often uncomfortable field program and, in the case of the last two, for help with data compilation. A major portion of the manuscript was typed by R. Hick.