

The birds of “Koobabbie” in the northern wheatbelt of Western Australia (1987–2011) and the contribution of the farm to conservation of the region’s avifauna

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This paper is dedicated to the late John Doley (1937–2007), whose wise counsel and hard work contributed greatly to the conservation programme on Koobabbie.

The avifauna of *Koobabbie*, a 7 173 ha wheat and sheep property in the northern wheatbelt of Western Australia with 41.5% the property under remnant native vegetation, was monitored on a weekly basis from May 1987 to December 2011. Recorded during this period were 131 species, comprising 55 residents, seven regular visitors, 14 irregular visitors and 55 vagrants. Fifteen species declined over the 25 years, with one species being extirpated and two species increased. Two other species increased until early this century and then declined. The avifauna of *Koobabbie* was compared with that of the Northern Agricultural Catchment Council region, in the middle of which region the property is located. *Koobabbie* comprehensively represented the region’s avifauna and contributed significantly to conservation of the region’s avifauna. This study demonstrates the importance of continuous long-term datasets from a single locality. The need to set up a network of such monitoring sites over much of Australia in order to provide information for management of natural resources is discussed.

Keywords: Conservation on private property; avifauna of agricultural areas; annotated bird lists

INTRODUCTION

KOOBABBIE is a 7 173 ha wheat and sheep property in the Waddy Forest district of the northern wheatbelt of Western Australia (WA). The property was uncleared when it was taken up for agriculture by Alison Doley’s grandparents in 1906. Since then it has been farmed by three generations of the same family. Alison and John, her late husband, took over management in 1966. As explained by Doley (1995, 2003), management of *Koobabbie* is aimed at achieving ecological and economical sustainability with 41.5% of the property retaining native vegetation and nature conservation as an important management objective. Surveys of the flora and fauna of the property have been undertaken and several threatened or priority species have been identified. *Koobabbie* has the only known populations of *Eremophila koobabbiensis* and *Tecticornia* sp. Coorow, a salt-tolerant succulent plant, a population of *Ptilotus fasciculatus*, a species of herb presumed extinct until rediscovered on the property in 1987, and also a breeding population of the endangered Carnaby’s Cockatoo (nomenclature follows Christidis and Boles 1994; bird scientific names are given on Table 1). There is also a breeding population of Major Mitchell’s Cockatoo, a species specially protected under Western Australian Government legislation.

In 1987 the CSIRO Division of Wildlife and Rangelands Research commenced a project to map the distribution of birds throughout the wheatbelt of WA. This project involved 187 observers collecting data on which species of bird occurred on their property each week from 1987 to 1990. Of these 187 people, 79 collected data for each year of the project. The project was described by Saunders (1993) and the results were published as an atlas of changes in the distribution and abundance of birds of the wheatbelt (Saunders and Ingram 1995). Alison and John Doley contributed data from *Koobabbie* throughout the project and continued collecting data using the same protocol until the present. Their 25 years of data on the birds on their 7 173 ha property provide an opportunity to examine the changes that have taken place in the avifauna of the extensively-cleared northern wheatbelt of WA, and to assess the property’s contribution to the conservation of the avifauna of the area covered by the Northern Agricultural Catchment Council (NACC), the regional natural resource management body in whose area *Koobabbie* is located.

This paper describes the avifauna of *Koobabbie* from 1987 to 2011; examines changes in the avifauna over that period; explores the reasons for those changes; compares the avifauna of *Koobabbie* with that known historically from the NACC region to assess the importance of

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Name	Habitat	Range	Koobabbie AvRR 1988-2011	Koobabbie RR Range	Koobabbie Status	Koobabbie Change	NACC List rate 1903-1979	RAOU Atlas 1 1977-1981	Birds Aust Atlas 2 1998-2002	Change between atlases	Woopenatty Av RR 1987-2002	Woopenatty Status
Australasian Bittern <i>Botaurus poiciloptilus</i>	Sw	NACC					2					
Little Bittern <i>Ixobrychus minutus</i>	Ri	S NACC					1					
Australian White Ibis <i>Threskiornis molucca</i>		NACC							0.05			
Siraw-necked Ibis <i>Threskiornis spinicollis</i>	Fm	NACC	0.04	0-0.19	Irr Vis UnC		7	0.13	0.06		0.20	Irr Vis
Glossy Ibis <i>Plegadis falcinellus</i>		W NACC							0.01			
Yellow-billed Spoonbill <i>Platalea flavipes</i>		NACC	0.00	0-0.06	Vag		1	0.02	0.06		0.06	Vag
Royal Spoonbill <i>Platalea regia</i>		W NACC	0.00	0-0.02	Vag							
Black Swan <i>Cygnus atratus</i>	Ri, Sl, Sw	NACC	0.01	0-0.09	Vag		7	0.15	0.07		0.03	Vag
Freckled Duck <i>Stictonetta naevosa</i>		NACC					2	0.01				
Australian Shelduck <i>Tadorna tadornoides</i>	Fm, Ri, Sl, Sw, Da	NACC	0.59	0.25-0.81	Reg Vis C		9	0.39	0.23		0.54	Reg Vis
Pacific Black Duck <i>Anas superciliosa</i>	Ri, Sw	NACC	0.06	0-0.27	Vag	Decline	9	0.31	0.23		0.32	Res
Grey Teal <i>Anas gracilis</i>	Ri, Sl, Sw, Da	NACC	0.46	0.02-0.94	Res C	Decline	7	0.29	0.18		0.50	Res
Chestnut Teal <i>Anas castanea</i>	Ri, Sw	NACC	0.00	0-0.02	Vag		1	0.01			0.00	Vag
Australasian Shoveller <i>Anas rhynchos</i>	Sw	NACC	0.01	0-0.15	Vag		2	0.06	0.03		0.02	Vag
Pink-eared Duck <i>Malacorhynchus membranaceus</i>	Sl, Da	NACC	0.01	0-0.06	Vag		2	0.05	0.04		0.13	Reg Vis
Hardhead <i>Aythya australis</i>	Ri, Da	NACC	0.01	0-0.09	Vag		4	0.05	0.03		0.04	Irr Vis
Australian Wood Duck <i>Chenonetta jubata</i>	Fm, Ri, Sw, Da	NACC	0.80	0.21-1.00	Res C		5	0.09	0.12		0.68	Res
Blue-billed Duck <i>Oxyura australis</i>		NACC					2	0.02	0.01			
Musk Duck <i>Biziura lobata</i>	Sl	NACC					3	0.05	0.06			
Black-shouldered Kite <i>Elanus axillaris</i>	Fm	NACC	0.21	0-0.85	Res UnC		7	0.18	0.14		0.49	Res

Table 1 continued overleaf

Table 1 — continued

Name	Habitat	Range	Koobabbie AvRR 1988–2011	Koobabbie RR Range	Koobabbie Status	Koobabbie Change	NACC List rate 1903–1979	RAOU Atlas 1 1977–1981	Birds Aust Atlas 2 1998–2002	Change between atlases	Woopenatty Av RR 1987–2002	Woopenatty Status
Letter-winged Kite <i>Elanus scriptus</i>		NACC					1					
Square-tailed Kite <i>Lophotinia isura</i>		SE NACC					1	0.01				
Whistling Kite <i>Haliastur sphenurus</i>	Ri, Sw	NACC	0.00	0–0.02	Vag		8	0.16	0.07		0.05	Vag
Black-breasted Buzzard <i>Hamirostra melanosternum</i>		NW NACC										
Brown Goshawk <i>Accipiter fasciatus</i>	Wl, Fm	NACC	0.04	0–0.22	Vag		8	0.07	0.05		0.10	Res
Collared Sparrowhawk <i>Accipiter cirrocephalus</i>		NACC	0.00	0–0.04	Vag		9	0.03	0.03		0.02	Vag
Wedge-tailed Eagle <i>Aquila audax</i>	Wl, Ma, Sh, Fm	NACC	0.75	0.53–0.90	Res C		11	0.33	0.24		0.72	Res
Little Eagle <i>Hieraaetus morphnoides</i>	Wl, Fm	NACC	0.02	0–0.17	Vag		10	0.14	0.07		0.21	Res
Swamp Harrier <i>Circus approximans</i>	Sw	NACC					1		0.02			
Spotted Harrier <i>Circus assimilis</i>	Sh, Fm, Sl	NACC	0.09	0–0.35	Res 1987–2000; Vag 2000–		8	0.05	0.02		0.17	Irr Vis
Black Falcon <i>Falco subniger</i>		NACC					1					
Peregrine Falcon <i>Falco peregrinus</i>	Fm	NACC	0.04	0–0.19	Vag		4	0.01	0.03		0.01	Vag
Australian Hobby <i>Falco longipennis</i>	Wl, Fm	NACC	0.20	0.06–0.48	Res UnC	Decline	9	0.06	0.05		0.11	Res
Brown Falcon <i>Falco berigora</i>	Wl, Fm	NACC	0.14	0.04–0.35	Res UnC		11	0.17	0.13		0.84	Res
Nankeen Kestrel <i>Falco cenchroides</i>	Wl, Fm	NACC	0.83	0.44–1.00	Res C	Decline	11	0.70	0.42		0.91	Res
Buff-banded Rail <i>Gallinallus philippensis</i>	Sw	NACC					1					
Baillon's Crake <i>Porzana pusilla</i>	Sw	NACC					1					
Malleefowl <i>Leipoa ocellata</i>	Ma	E NACC					8	0.03	0.02		0.01	Vag
Stubble Quail <i>Coturnix pectoralis</i>	Fm	NACC	0.43	0.06–0.75	Res C		7	0.05	0.03		0.35	Res
Painted Button-quail <i>Turnix varia</i>		NACC	0.00	0–0.02	Vag		3					

Table 1 — continued

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Little Bunting-quail <i>Turnix velox</i>		NACC	0.03	0–0.19	Vag		3		0.01		0.11	Irr Vis
Black-tailed Native-hen <i>Gallinula ventralis</i>	Sw, Da	NACC	0.02	0–0.25	Vag		5	0.08	0.05		0.20	Irr Vis
Eurasian Coot <i>Fulica atra</i>	Ri, Sw	NACC					7	0.14	0.13		0.08	Irr Vis
Dusky Moorhen <i>Gallinula tenebrosa</i>		S NACC	0.00	0–0.05	Vag			0.01	0.01			
Purple Swamphen <i>Porphyrio porphyrio</i>	Sw	NACC					1		0.02			
Australian Bustard <i>Ardeotis australis</i>	Fm, Sl	NACC	0.01	0–0.06	Vag		8	0.10	0.01	Decline	0.01	Vag
Bush Stone-curlew <i>Burhinus grallarius</i>	Wl, Ma	NACC	0.00	0–0.06	Vag		5	0.01			0.01	Vag
Banded Lapwing <i>Vanellus tricolor</i>	Fm, Sl	NACC	0.51	0.21–0.77	Res C		12	0.31	0.07	Decline	0.55	Res
Red-kneed Dotterel <i>Erythronyx cinctus</i>	Sl	NACC	0.00	0–0.02	Vag		1	0.04	0.01		0.02	Vag
Black-fronted Dotterel <i>Elsayornis melanops</i>	Ri, Sl	NACC	0.00	0–0.02	Vag		7	0.14	0.08		0.23	Res
Greater Sand Plover <i>Charadrius leschenaulti</i>	Sl	GOAST NACC					1					
Red-capped Plover <i>Charadrius ruficapillus</i>	Sl	NACC	0.05	0–0.17	Irr Vis UnC	Decline	2	0.13	0.07			
Inland Dotterel <i>Charadrius australis</i>	Fm	NACC	0.01	0–0.03	Vag		1	0.05				
Hooded Plover <i>Thinornis rubricollis</i>	Sl	NACC	0.02	0–0.03	Vag		1					
Red-necked Stint <i>Charadrius ruficollis</i>	Sl	NACC					1	0.04	0.04			
Curlew Sandpiper <i>Charadrius ferruginea</i>	Sl	W NACC					1	0.01	0.01			
Sharp-tailed Sandpiper <i>Charadrius acuminata</i>	Sl	W NACC					1	0.01	0.01			
Black-winged Stilt <i>Himantopus himantopus</i>	Sl, Da	NACC	0.08	0–0.35	Irr Vis UnC		7	0.18	0.13		0.15	Reg Vis
Banded Stilt <i>Cladorhynchus leucocephalus</i>	Sl, Sw	NACC	0.03	0–0.17	Irr Vis UnC		4	0.03	0.02			
Red-necked Avocet <i>Recurvirostra novaehollandiae</i>	Sl	NACC	0.03	0–0.19	Irr Vis UnC		3	0.03	0.04		0.00	Vag

Table 1 continued overleaf

Table 1 — continued

Name	Habitat	Kooabbie			NACC List rate 1903-1979	RAOU Atlas 1 1977-1981	Birds Aust Atlas 2 1998-2002	Change between atlases	Woopennatty Av RR 1987-2002	Woopennatty Status
		AvRR 1988-2011	Kooabbie RR Range	Kooabbie Status						
Wood Sandpiper										
<i>Tringa glaricola</i>	SI	NACC		2						
Common Greenshank										
<i>Tringa nebularia</i>	SI	NACC		2	0.04	0.03				
Common Sandpiper										
<i>Actitis hypoleucos</i>	Ri	NACC		2	0.05	0.05		0.03	Irr Vis	
Silver Gull										
<i>Larus novaehollandiae</i>	SI	NACC	0-0.02	2	0.17	0.16				
Whiskered Tern										
<i>Chlidonias hybridus</i>	SI	NACC	0-0.04		0.01	0.01				
Rock Dove										
<i>Columba livia</i>	Fm	NACC	0-0.11	1	0.09	0.02		0.01	Vag	
Laughing Turtle-Dove										
<i>Streptopelia senegalensis</i>	Fm	COMMEN SAL	0-0.50	1	0.14	0.20		0.19	Res	
Peaceful Dove										
<i>Geopelia striata</i>		N NACC		2	0.04	0.04				
Diamond Dove										
<i>Geopelia cuneata</i>		N NACC	0-0.02		0.03	0.01		0.02	Vag	
Common Bronzewing										
<i>Phaps chalcoptera</i>	Wl, Ma, Sh	NACC	0.10-0.60	12	0.23	0.20		0.98	Res	
Brush Bronzewing										
<i>Phaps elegans</i>	Sh	SW NACC		2		0.01				
Crested Pigeon										
<i>Ocyphaps lophotes</i>	Wl, Ma, Sh, Fm	NACC	0.92-1.00	9	0.60	0.56		1.00	Res	
Red-tailed Black-Cockatoo										
<i>Calyptrornis banksii</i>	Wl, Fm	NACC	0.60-1.00	8	0.31	0.15		0.77	Res	
Carnaby's Cockatoo										
<i>Calyptrornis latirostris</i>	Wl, Sh, Fm	NACC	0.43-0.67	8	0.32	0.13	Decline	0.00	Vag	
Galah										
<i>Cacatua roseicapilla</i>	Wl, Ma, Fm	NACC	1.00	12	0.99	0.94		1.00	Res	
Western Corella										
<i>Cacatua pastinator</i>	Wl, Fm	NACC	1.00	9	0.14	0.11		0.86	Res	
Little Corella										
<i>Cacatua sanguinea</i>	Wl, Fm	NACC	0-0.02	1	0.11	0.13		0.07	Vag	
Major Mitchell's Cockatoo										
<i>Cacatua leadbeateri</i>	Wl, Ma, Fm	E NACC	0.71-1.00	4	0.08	0.02				
Purple-crowned Lorikeet										
<i>Glossopsitta porphyrocephala</i>	Wl, Sh	S NACC		4	0.01					
Regent Parrot										
<i>Polytelis anthopeplus</i>	Wl	NACC	0-0.27	8	0.04	0.02	Increase	0.00	Vag	

Table 1 — continued

Name	Habitat	Range	Koobabbie AvRR 1988–2011	Koobabbie RR Range	Koobabbie Status	Koobabbie Change	NACC List rate 1903–1979	RAOU Atlas 1 1977–1981	Birds Aust Atlas 2 1998–2002	Change between atlases	Woopenatty Av RR 1987–2002	Woopenatty Status
Cockatiel												
<i>Nymphicus hollandicus</i>	Wl, Fm	NACC	0.21	0–0.81	Irr Vis to 2007; Res UnC 2007–	Increase	4	0.19	0.07		0.06	Irr Vis
Budgerigar												
<i>Melopsittacus undulatus</i>	Wl, Fm	NACC	0.03	0–0.19	Vag		2	0.02	0.03		0.04	Irr Vis
Western Rosella												
<i>Platycercus icterotis</i>	Wl	S NACC					3	0.02	0.02			
Australian Ringneck												
<i>Barnardius zonarius</i>	Wl, Ma, Fm	NACC	1.00	1.00	Res C		12	0.85	0.98		1.00	Res
Mulga Parrot												
<i>Psephotus varius</i>	Wl, Sh	N&E NACC	0.03	0–0.21	Vag		5	0.06	0.11			
Red-capped Parrot												
<i>Purpureicephalus spurius</i>		S NACC						0.01	0.03			
Elegant Parrot												
<i>Neophema elegans</i>	Wl, Fm	NACC	0.00	0–0.06	Vag		3	0.01	0.01		0.00	Vag
Bourke Parrot												
<i>Neophema bourkii</i>		N NACC						0.01	0.01			
Rainbow Lorikeet												
<i>Trichoglossus haemotodus</i>		S NACC							0.01			
Pallid Cuckoo												
<i>Cuculus pallidus</i>	Wl, Ma, Fm	NACC	0.12	0–0.35	Reg Vis UnC		11	0.28	0.15		0.33	Reg Vis
Fan-tailed Cuckoo												
<i>Cacomantis flabelliformis</i>	Wl	NACC					7	0.06	0.05		0.02	Irr Vis
Black-eared Cuckoo												
<i>Chrysococcyx osculans</i>	Wl	NACC					7	0.06	0.04		0.01	Vag
Horsfield's Bronze-Cuckoo												
<i>Chrysococcyx basalus</i>	Wl	NACC	0.02	0–0.19	Irr Vis UnC		10	0.16	0.13		0.06	Reg Vis
Shining Bronze-Cuckoo												
<i>Chrysococcyx lucidus</i>	Wl	NACC	0.03	0–0.13	Irr Vis UnC		7	0.04	0.03		0.01	Irr Vis
Southern Boobook												
<i>Ninox novaeseelandiae</i>	Wl	NACC	0.30	0.08–0.71	Res C		10	0.07	0.04		0.20	Res?
Barn Owl												
<i>Tyto alba</i>	Wl, Ma, Fm	NACC	0.30	0–0.88	Res C		5	0.04	0.05		0.02	Vag
Tawny Frogmouth												
<i>Podargus strigoides</i>	Wl	NACC	0.08	0–0.25	Res UnC	Decline	11	0.04	0.04		0.03	Vag
Australian Owllet-nightjar												
<i>Aegotheles cristatus</i>	Wl	NACC	0.05	0–0.19	Res UnC		7	0.02	0.08		0.02	Vag
Spotted Nightjar												
<i>Eurostodapus argus</i>	Ma	NACC	0.00	0–0.04	Vag		6	0.02	0.01		0.00	Vag
Fork-tailed Swift												
<i>Apus pacificus</i>	Aerial	W NACC					5	0.01	0.01		0.00	Vag

Table 1 continued overleaf

Table 1 continued

Name	Habitat	Kooabbie			NACC List rate 1903-1979	RAOU Atlas 1 1977-1981	Birds Aust Atlas 2 1998-2002	Change between atlases	Woopenatty Av RR 1987-2002	Woopenatty Status
		Range	AvRR 1988-2011	Kooabbie RR Range						
Laughing Kookaburra <i>Dacelo novaeguineae</i>	Wl, Ri	W NACC	0.01	0-0.10	2	0.15	0.16	0.12	Vag	
Red-backed Kingfisher <i>Todiramphus pyrrolopygia</i>	Wl	N&E NACC			5	0.03	0.02	0.03	Irr Vis	
Sacred Kingfisher <i>Todiramphus sanctus</i>	Wl	NACC	0.01	0-0.08	8	0.10	0.10	0.15	Reg Vis	
Rainbow Bee-eater <i>Merops ornatus</i>	Ma, He, Fm, Ri, Sl	NACC	0.03	0-0.16	9	0.23	0.13	0.37	Reg Vis	
White-backed Swallow <i>Cheramoeca leucosternus</i>		NACC	0.02	0-0.09	10	0.32	0.09	0.31	Res	
Welcome Swallow <i>Hirundo neoxena</i>	Wl, Fm	NACC	0.88	0.62-1.00	11	0.73	0.60	0.86	Res	
Tree Martin <i>Hirundo nigricans</i>	Wl, Fm	NACC	0.92	0.77-1.00	12	0.40	0.54	0.81	Res	
Fairy Martin <i>Hirunda ariel</i>		NACC	0.02	0-0.40	5	0.05	0.03	0.03	Irr Vis	
Richard's Pipit <i>Anthus novaeseelandiae</i>	Fm	NACC	0.99	0.92-1.00	12	0.74	0.32	1.00	Res	
Western Bowerbird <i>Ptilorhynchus guttatus</i>		NE NACC					0.01			
Black-faced Cuckoo-shrike <i>Coracina novaehollandiae</i>	Wl, Ma, Fm	NACC	0.54	0.28-0.91	12	0.70	0.57	0.86	Res	
Ground Cuckoo-shrike <i>Coracina maxima</i>		E NACC			4			0.00	Vag	
White-winged Triller <i>Lalage suevii</i>	Wl, Sh	NACC	0.03	0-0.10	7	0.22	0.13	0.19	Reg Vis	
Scarlet Robin <i>Petroica multicolor</i>	Sh	S NACC			3	0.07	0.05			
Red-capped Robin <i>Petroica goodenovii</i>	Wl, Ma, Sh	NACC	0.23	0.08-0.44	11	0.49	0.50	0.79	Res	
Hooded Robin <i>Melanodryas cucullata</i>		NACC			5	0.03	0.02			
White-breasted Robin <i>Eopsaltria georgiana</i>		NACC				0.03	0.05			
Western Yellow Robin <i>Eopsaltria griseogularis</i>	Ma	NACC	0.00	0-0.02	7	0.03	0.02	0.00	Vag	
Jacky Winter <i>Microeca fascians</i>		NACC			9	0.02	0.02	0.00	Vag	
Golden Whistler <i>Pachycephala pectoralis</i>	Wl, Ma	NACC			9	0.07	0.07	0.01	Vag	

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Rufous Whistler <i>Pachycephala rufiventris</i>	Wl, Ma, Sh	NACC	0.20	0.06–0.34	Res C		12	0.48	0.60		0.47	Res
Grey Shrike-thrush <i>Colluricincla harmonica</i>	Wl, Ma, Sh	NACC	0.21	0.08–0.35	Res C		12	0.32	0.51	Increase	0.86	Res
Crested Shrike-tit <i>Falcoenctus frontatus</i>		S NACC					1					
Crested Bellbird <i>Oreocia gutturalis</i>	Ma, Sh	NACC	0.10	0–0.31	Res UnC to 2002; Vag since	Decline	10	0.17	0.24			
Restless Flycatcher <i>Myiagra iniqueta</i>		S NACC					3	0.02				
Grey Fantail <i>Rhipidura fuliginosa</i>	Wl, Ma, Sh	NACC	0.18	0–0.63	Reg Vis C		10	0.38	0.56		0.31	Reg Vis
Willie Wagtail <i>Rhipidura leucophrys</i>	Wl, Ma, Sh, Fm	NACC	0.97	0.93–1.00	Res C		12	1.00	0.96		1.00	Res
Chiming Wedgebill <i>Psophodes occidentalis</i>		N NACC						0.01	0.02			
Chestnut Quail-thrush <i>Cinlosoma castaneotus</i>		N NACC					2	0.01				
Chestnut-breasted Quail-thrush <i>Cinlosoma castarothorax</i>		NE NACC							0.01			
Southern Scrub-robin <i>Drymodes brunneopygia</i>	Sh	N&E NACC	0.01	0–0.13	Res 1995–2007? Sc		7	0.05	0.03			
White-browed Babbler <i>Pomatostomus superciliosus</i>	Ma, Sh	NACC	0.13	0–0.33	Res UnC	Decline	9	0.15	0.18		0.00	Vag
Grey-crowned Babbler <i>Pomatostomus temporalis</i>		N NACC							0.02			
Little Grassbird <i>Megalarus gramineus</i>	Sw, Sl	W NACC	0.00	0–0.02	Vag		1	0.01	0.02			
Clamorous Reed-Warbler <i>Acrocephalus stentoreus</i>	Sw	NACC					2	0.03	0.04		0.00	Vag
Rufous Songlark <i>Cinloramphus mathewsi</i>		NACC	0.01	0–0.06	Vag		5	0.11	0.09		0.15	Reg Vis
Brown Songlark <i>Cinloramphus cruralis</i>	Fm	NACC	0.36	0.04–0.69	Res C		9	0.18	0.08	Decline	0.29	Reg Vis
Splendid Fairy-wren <i>Malurus splendens</i>	Sh	NACC					8	0.25	0.42	Increase	0.75	Res
Variiegated Fairy-wren <i>Malurus lamberti</i>	He	NACC	0.04	0–0.19	Res UnC		4	0.14	0.28	Increase	0.14	Res
Blue-breasted Fairy-wren <i>Malurus pulcherrimus</i>	Sh	NACC					4	0.06	0.05		0.00	Vag

Table 1 continued overleaf

Table 1 — continued

Name	Habitat	Range	Koobabbie AvRR 1988–2011	Koobabbie RR Range	Koobabbie Status	Koobabbie Change	NACC List rate 1903–1979	RAOU Atlas 1 1977–1981	Birds Aust Atlas 2 1998–2002	Change between atlases	Woopenatty Av RR 1987–2002	Woopenatty Status
Red-winged Fairy-wren <i>Malurus elegans</i>		S NACC					1		0.01			
White-winged Fairy-wren <i>Malurus leucopertus</i>	Sh, Sl	NACC	0.21	0.06–0.48	Res C		11	0.22	0.18		0.07	Res
Southern Emu-wren <i>Stipiturus malachurus</i>	Sh	W NACC					1		0.01			
Redthroat <i>Pyrrholaemus brunneus</i>	Sh	NACC	0.00	0–0.02	Vag	Increase/ decline	8	0.06	0.10		0.03	Vag
Weebill <i>Smicrornis brevirostris</i>	Wl, Ma	NACC	0.43	0–0.98	Res C		12	0.25	0.59	Increase	0.21	Res
Western Gerygone <i>Gerygone fusca</i>	Wl, Ma, Sh	NACC	0.00	0–0.04	Vag		9	0.31	0.47		0.01	Vag
Inland Thornbill <i>Acanthiza apicalis</i>	Ma, Sh	NACC	0.00	0–0.04	Vag		12	0.22	0.24		0.12	Res?
Chestnut-rumped Thornbill <i>Acanthiza uropygialis</i>	Wl, Ma, Sh	NACC	0.02	0–0.06	Res UnC		9	0.12	0.24	Increase	0.30	Res
Yellow-rumped Thornbill <i>Acanthiza chrysorrhoa</i>	Wl, Sh, Fm	NACC	0.76	0.38–1.00	Res C		12	0.55	0.62		0.93	Res
Slaty-backed Thornbill <i>Acanthiza robustirostris</i>		N NACC						0.01	0.01			
Western Thornbill <i>Acanthiza inornata</i>		NACC	0.00	0–0.02	Vag		4	0.05	0.05			
Southern Whiteface <i>Aphelocephala leucopsis</i>		N NACC					1	0.03	0.12	Increase		
White-browed Scrubwren <i>Sericornis frontalis</i>	Sh	NACC	0.00	0–0.02	Vag		8	0.11	0.22	Increase		
Shy Heathwren <i>Hylacola cauta</i>	Ma, Sh	N&E NACC					6					
Rufous Fieldwren <i>Calamanthus campestris</i>	Sh	N NACC					9	0.02	0.02			
Varied Sittella <i>Daphoenositta chrysoptera</i>	Sh	NACC					3	0.04	0.02			
Rufous Treecreeper <i>Climacteris rufa</i>	Wl	NE NACC					4	0.01	0.01			
Red Wattlebird <i>Anthochaera carunculata</i>	Wl, Ma, Sh	NACC	0.06	0–0.21	Reg Vis UnC		10	0.22	0.30		0.70	Res
Little Wattlebird <i>Anthochaera chrysoptera</i>		S NACC	0.05	0–0.15	Irr Vis UnC		5	0.07	0.05		0.03	Vag

Table 1 — continued

Name	Habitat	Range	Koobabbie AvRR 1988–2011	Koobabbie RR Range	Koobabbie Status	Koobabbie Change	NACC List rate 1903–1979	RAOU Atlas 1 1977–1981	Birds Aust Atlas 2 1998–2002	Change between atlases	Woopenatty Av RR 1987–2002	Woopenatty Status
Spiny-cheeked honeyeater	Ma, Sh	NACC	0.17	0–0.38	Res C		10	0.22	0.34		0.92	Res
<i>Acanthagenys rufogularis</i>	Wl, Ma, Sh, Fm	NACC	1.00	1.00	Res C		12	0.31	0.35		0.94	Res
Yellow-throated Miner	Sh	NACC	0.21	0–0.40	Res C		11	0.53	0.90	Increase	0.50	Res
<i>Manorina flavigula</i>	Sh	NACC					8	0.02	0.02		0.00	Vag
Singing Honeyeater	Wl	NACC					2	0.07	0.10			
<i>Lichenostomus virescens</i>	Wl	S NACC					3		0.01		0.01	Vag
White-eared Honeyeater	Wl	N NACC					1	0.01				
<i>Lichenostomus leucotis</i>	Ma, Sh	NACC	0.00	0–0.06	Vag		8	0.06	0.06		0.03	Vag
White-plumed Honeyeater	Wl, Ma	S NACC					4					
<i>Lichenostomus penicillatus</i>	Wl, Ma	S NACC					11	0.49	0.81	Increase	0.94	Res
Yellow-plumed Honeyeater	Wl, Ma, Sh	NACC	0.60	0.13–0.94	Res C	Increase/ decline	2	0.07	0.09			
<i>Lichenostomus plumulus</i>	Sh	S NACC					5	0.12	0.21	Increase	0.01	Vag
Brown-headed Honeyeater	Sh	NACC	0.01	0–0.19	Vag		7	0.06	0.07		0.01	Vag
<i>Meliphrephus brevirostris</i>	Sh	NACC	0.02	0–0.15	Vag		9	0.14	0.09		0.00	Vag
White-naped Honeyeater	Sh	NACC	0.00	0–0.02	Vag		2		0.02		0.00	Vag
<i>Meliphrephus lunatus</i>	Sh	NACC					2	0.01	0.01		0.00	Vag
Brown Honeyeater	Sh	NACC	0.00	0–0.02	Vag		2	0.08	0.06			
<i>Lichmera indistincta</i>	Sh	S NACC					3	0.08	0.02		0.02	Vag
New Holland Honeyeater	Sh, He, Fm, Sl	NACC	0.01	0–0.10	Irr Vis UnC		1	0.01	0.13	Decline	0.35	Res
<i>Phylidonyris novaehollandiae</i>	Sh	NACC	0.24	0.08–0.24	Res C		10	0.32	0.13		0.35	Res
White-cheeked Honeyeater	Sh	NACC										
<i>Phylidonyris nigra</i>	Sh	NACC										
White-fronted Honeyeater	Sh	NACC										
<i>Phylidonyris albigrons</i>	Sh	NACC										
Tawny-crowned Honeyeater	Sh	NACC										
<i>Phylidonyris melanops</i>	Sh	NACC										
Pied Honeyeater	Sh	NACC										
<i>Certhionyx variegatus</i>	Sh	NACC										
Black Honeyeater	Sh	NACC										
<i>Certhionyx niger</i>	Sh	NACC										
Western Spinebill	Sh	S NACC										
<i>Acanthorhynchus superciliosus</i>	Sh	NACC										
Crimson Chat	Sh	NACC										
<i>Ephianura tricolor</i>	Sh	NACC										
Orange Chat	Sh	NACC										
<i>Ephianura aurifrons</i>	Sh, He, Fm, Sl	NACC										
White-fronted Chat	Sh, He, Fm, Sl	NACC										
<i>Ephianura albifrons</i>	Sh, He, Fm, Sl	NACC										

Table 1 continued overleaf

Table 1 continued

Name	Habitat	Range	Koobabbie AvRR 1988-2011	Koobabbie RR Range	Koobabbie Status	Koobabbie Change	NACC List rate 1903-1979	RAOU Atlas 1 1977-1981	Birds Aust Atlas 2 1998-2002	Change between atlases	Woopenatty Av RR 1987-2002	Woopenatty Status
Mistletoe Bird												
<i>Dicaeum hirundinaceum</i>	Wl, Ma	NACC					7	0.11	0.15		0.53	Res
Striated Pardalote												
<i>Pardalotus striatus</i>	Wl	NACC	0.76	0.46-0.94	Res C		11	0.29	0.60	Increase	0.62	Reg Vis
Spotted Pardalote												
<i>Pardalotus punctatus</i>	Ma	S NACC					2	0.01	0.01			
Silvereye												
<i>Zosterops lateralis</i>	Ma, Sh	NACC	0.05	0-0.42	Vag		9	0.32	0.46		0.45	Reg Vis
Zebra Finch												
<i>Taeniopygia guttata</i>	Ma, Sh	N NACC	0.14	0-0.53	Res UnC		7	0.21	0.19		0.29	Reg Vis
Australian Magpie-lark												
<i>Grallina cyanoleuca</i>	Wl, Fm	NACC	1.00	0.92-1.00	Res C		12	0.84	0.78		1.00	Res
Masked Woodswallow												
<i>Artamus personatus</i>		NACC					4	0.03	0.01		0.03	Irr Vis
White-browed Woodswallow												
<i>Artamus superciliosus</i>		NE NACC					1					
Black-faced Woodswallow												
<i>Artamus cinereus</i>	Wl, Sh, Fm	NACC	0.73	0.33-0.93	Res C	Decline	12	0.52	0.29		0.93	Res
Little Woodswallow												
<i>Artamus minor</i>		N NACC					1	0.03	0.01			
Dusky Woodswallow												
<i>Artamus cyanopterus</i>		NACC					3	0.03	0.02			
Grey Butcherbird												
<i>Cracticus torquatus</i>	Wl, Sh	NACC	0.08	0-0.23	Res UnC	Decline	11	0.27	0.27		0.67	Res
Pied Butcherbird												
<i>Cracticus nigrogularis</i>	Wl, Fm	NACC	1.00	0.92-1.00	Res C		11	0.45	0.35		0.99	Res
Australian Magpie												
<i>Gymnorhina tibicen</i>	Wl, Fm	NACC	1.00	0.92-1.00	Res C		12	0.80	0.59		1.00	Res
Grey Currawong												
<i>Strepera versicolor</i>		NACC					7	0.05	0.07		0.06	Vag
Australian Raven												
<i>Corvus coronoides</i>	Wl, Ma, Fm	NACC	1.00	0.92-1.00	Res C		12	0.71	1.00		1.00	Res
Little Crow												
<i>Corvus bennetti</i>	Fm	NACC	0.05	0-0.27	Irr Vis UnC		8	0.09	0.07		0.06	Vag
Torresian Crow												
<i>Corvus orru</i>		N NACC						0.01	0.01			
# species recorded			131				191	181	185		131	

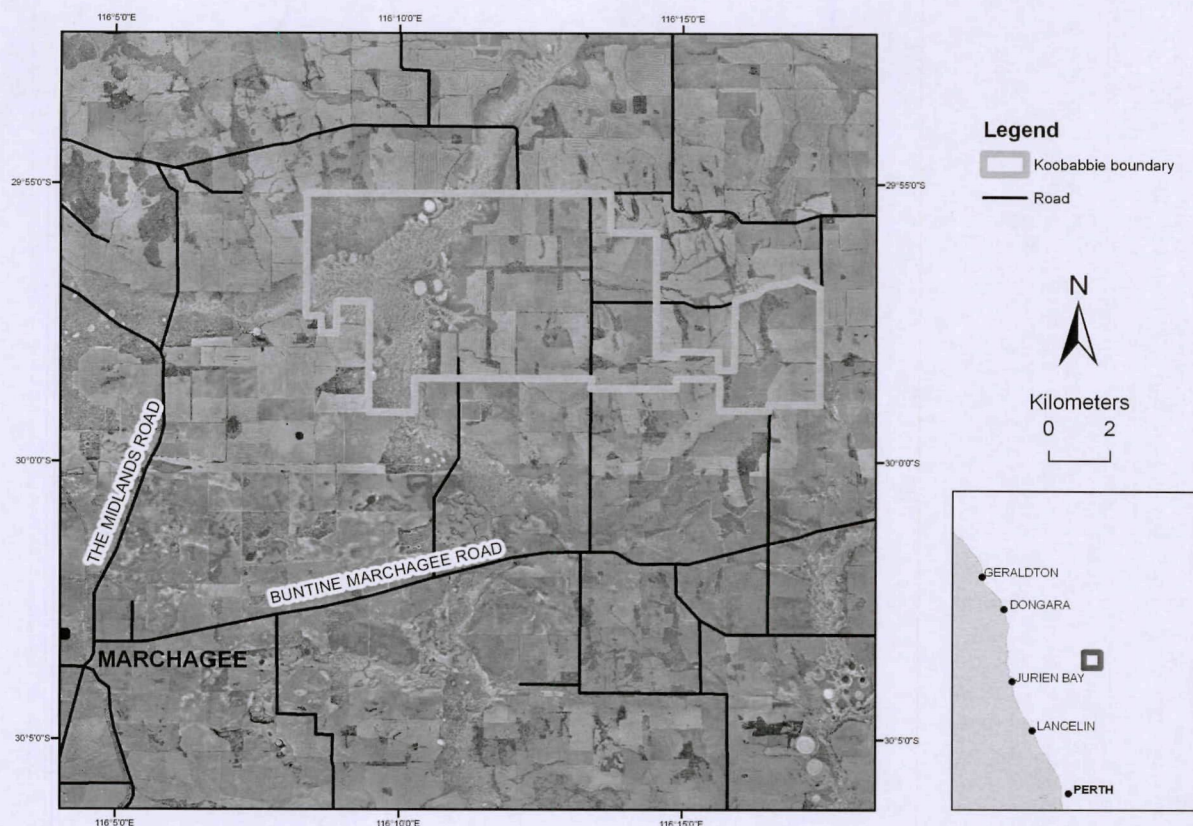


Fig. 1. Satellite image of *Koobabbie* showing property boundaries, extent of native vegetation and roads. The darker shade of the southern half of the scene is an artefact, as that part of the image was from a satellite pass at a different season than the northern half.

Koobabbie in conservation of the region's avifauna; and draws attention to the long-term dataset and its availability for further analyses.

METHODS

Study area

Koobabbie (29°56'S; 116°09' E) is located in the northwest corner of the Buntine-Marchagee Natural Diversity Recovery Catchment (Western Australian Department of Environment and Conservation 2008). The region has a Mediterranean climate of hot, dry summers and cool, wet winters. *Koobabbie* has a mean annual rainfall of 337 mm (1911–2011 rainfall records from *Koobabbie*) and 76% of the rain falls between April and September (late Austral autumn to early spring). January is the hottest month (mean daily maximum temperature 36.0° C and minimum 18.5° C; data from nearest temperature recording station at Carnamah, Australian Bureau of Meteorology website <http://www.bom.gov.au> accessed 9th August 2012) and July is the coolest (15.6° C and 4.6° C).

Native vegetation remains on 2 857 ha (41.5%) of *Koobabbie* (Figure 1) and varies with soil and drainage. The heavily weathered Darling Scarp (300 m above sea level) passes through the eastern part of *Koobabbie* with

drainage to the west (most of the property) and the east (Doley 1995 Figure 1; Doley 2003 Figure 1). There are a range of soil types on the property. The deep, yellow, sandy soils are characterized by trees of Sandplain Cypress *Callitris arenaria* (nomenclature follows <http://florabase.dec.wa.gov.au/> accessed 5 January 2013) and Sandplain Woody Pear *Xylomelum angustifolium*, and tussock *Ecdeiocolea monostachya*. The yellow sands over gravel support trees of Desert Gum *Eucalyptus eudesmioides*, Stiff-leaved Mallee *E. rigidula*, *E. moderata* and Pear-fruited Mallee *E. pyriformis* and shrubs of *Allocasuarina campestris*, *A. acutivalvis*, *Grevillea petrophiloides*, Flame Grevillea *G. eriostachya*, *Petrophile shuttleworthiana* and *Hakea scoparia*. These soil types have been mostly cleared of native vegetation. The gravel ridges support *Allocasuarina campestris*, *A. acutivalvis*, *Acacia neurophylla* and the shrub *Gastrolobium parviflorum*, which is toxic to domestic livestock. As a result these areas are fenced off from livestock. Throughout the property there are granite and dolerite outcrops that retain native vegetation of York Gum *E. loxophleba*, Flute Horn Mallee *E. stowardii*, Ewart's Mallee *E. ewartiana*, Jam *Acacia acuminata*, *Allocasuarina campestris*, *Melaleuca sclerophylla* and a population of *Chorizema humile*, a species of declared rare flora under Western Australian legislation. Light grey

sand over gravelly clay supports *E. loxophleba*, Narrow-leaved Red Mallee *E. foecunda*, Emu Tree *Hakea francisiana* and *A. campestris*. Red and grey clay loam valley soils were regarded by early settlers as the most fertile and have been heavily cleared, as was the Morrell (*E. longicornis* and *E. myriadena*) country adjoining the salt lake system. In the extensive timber belts are remnants of the original vegetation, woodlands of Salmon Gum *E. salmonophloia*, Gimlet *E. salubris* and *E. loxophleba* with an understory of *Acacia hemiteles*, Manna Wattle *A. microbotrya*, *A. aestivalis*, Gorada *Melaleuca lateriflora*, Broom Bush *M. uncinata*, and the only known populations of *Eremophila koobabbiensis* (Figure 1). The western portion of *Koobabbie* is dominated by 1 864 ha of uncleared salt lake country which is not used for agricultural production. The sandy rises around the lakes support *Eucalyptus loxophleba*, Cowcowing Mallee *E. brachycorys*, *Acacia eremaea*, *Chamelaucium* sp. Winchester (C. Chapman s.n. PERTH 07879180), *M. adnata*, *M. uncinata*, *M. thyoides*, *M. lateriflora*, *Darwinia diosmoides* and 20 species of orchids, including the declared rare flora *Caladenia drakeoides*. The sand plain has a wide variety of shrubby species, including *Perossonia chapmanii*, *Callitris arenaria*, *Verticordia halophila*, Compacted Featherflower *V. densiflora* and Acorn Banksia *Banksia prionotes*. The salt lake playas and samphire flats support six species of *Halosarcia*, including the only known population of a species formerly called *H. koobabbiensis*, now known as *Tecticornia* sp. Coorow (P. G. Wilson 12750) (<http://florabase.dec.wa.gov.au/search/current/14020> accessed 9th August 2012). The management of *Koobabbie* is described in detail in Doley (1995, 2003) which includes maps of the property and its soil profile.

Rainfall 1987–2011

In the period 1987 to 2011 at *Koobabbie*, eight years had rainfall greater than 10% more than

the mean annual rainfall, seven had rainfall \pm 10% of the mean and 10 had rainfall more than 10% below the mean (Figure 2). The wettest year was 1999, with rainfall 66% greater than the mean, and 1994 and 2007 the driest with rainfall 41% below. The first half of the period of observations was the wettest with eight out of 13 years (1987–1999) being wetter than the mean. The second half of the observation period (2000–2011) was very dry with only one year out of the 12 being more than 5% wetter than the mean (Figure 2).

Northern Agricultural Catchment Council region

The NACC natural resource management region extends $>4^\circ$ of latitude, north from Gingin (31°S) to north of the mouth of the Murchison River (27°S), and $>3^\circ$ of longitude at the centre of its north-south axis ($115\text{--}118^\circ\text{E}$). *Koobabbie* is located close to the centre of the NACC region on the east-west axis and in the lower third on the north-south axis (Figure 3). The region incorporates Beard's (1976a,b,c) Geraldton, Dongara and Perenjori map sheets and part of the Geraldton Sandplains and Avon Wheatbelt biogeographic regions (Thackway and Cresswell 1995). Much of the region has been extensively cleared of native vegetation for broadscale agriculture, both cereal cropping and domestic livestock. In many districts $<10\%$ of the pre-clearing vegetation remains. It is a transitional region between the uncleared arid zone to the north and northeast and higher rainfall zone to the south. Its avifauna has elements of the arid zone and more mesic southwest WA bird communities (Serventy and Whittell 1976).

Bird data from *Koobabbie*

From the first week in May 1987 until the end of 2011, when they were on the property, the

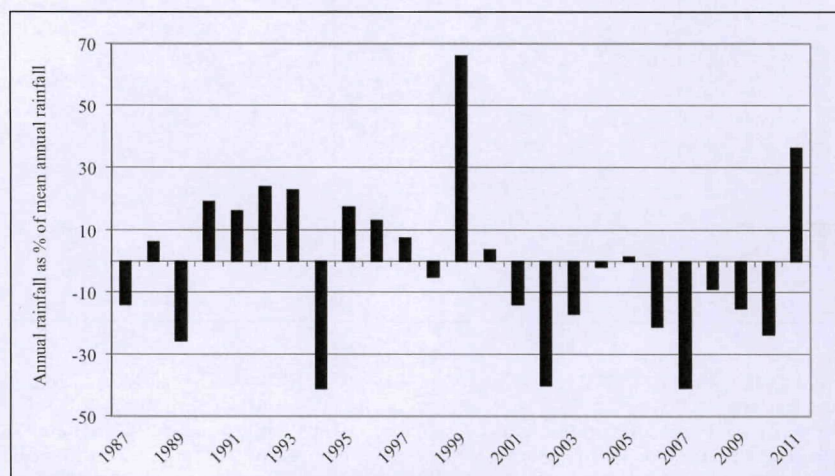


Fig. 2. Annual rainfall for *Koobabbie* (1987–2011) as a percentage of the 100 year mean annual rainfall for the property.

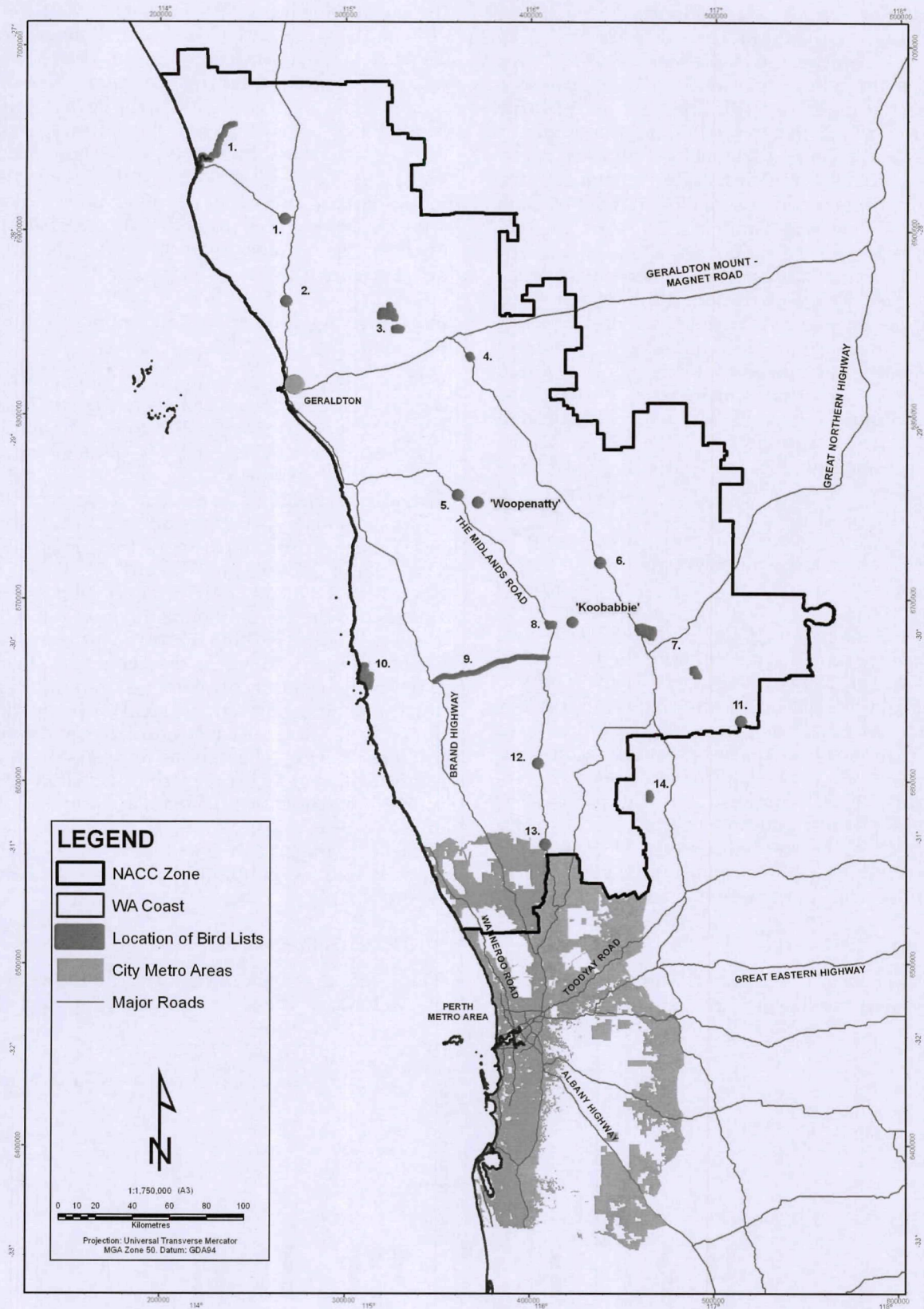


Fig. 3. Northern Agricultural Catchment Council area, location of *Koobabbie* and *Woopenatty* and location of sites with published bird lists: 1. lower Murchison River and 32 km of the banks and surrounds of the Murchison River from the mouth, upstream to Wilgia Mia Pool and Mt View Station, near Ajana; 2. Northampton; 3. East Yuna and Bindoo Hill Nature Reserves, and surrounding areas; 4. Wilroy Nature Reserve; 5. Yandanooka; 6. Caron; 7. Buntine, Nugadong and East Nugadong Nature Reserves and Nugadong Forest Reserve; 8. Marchagee Nature Reserve; 9. Marchagee Track; 10. Cockleshell Gully Reserve and adjacent areas; 11. Bunketch; 12. Moora and the district within a radius of 48 km around the town; 13. Moore River around the settlement of Mogumber; and 14. Wongan Hills.

Doleys collected data on every species of bird seen each week. Data were recorded in a booklet prepared by CSIRO Division of Wildlife and Rangelands Research for its 1987–1990 bird atlas (Saunders and Ingram 1995). This booklet provided a list of all species known to have occurred in the central wheatbelt and divided the year into 12 months and each month into four weeks; that is, each year had 48 weeks of potential observations. Any species seen on *Koobabbie* that was not listed on the booklet was added to the list. The Doleys also made extensive notes about their observations at the back of each year's booklet. These notes, together with the raw presence data, are available in Supplementary Table 1 lodged on the journal website at <http://pcb.murdoch.edu.au>. The data recorded each week consisted of a tick for every species seen that week. For example, one Red-capped Robin seen once during a week was recorded as a tick, as were 100 Galah seen every day of a week.

As no estimate of abundance can be obtained from such presence data, a recording rate (could also be called frequency of occurrence) was calculated for each species for each year. The recording rate was the total number of weeks in a particular year a species was recorded, divided by the total number of weeks of observations. For example, if the Doleys were absent for two weeks one year, recording rates that year were calculated for 46 weeks of observations. If a species was recorded in all 46 weeks, the recording rate was 1.0. The average recording rate for each species was calculated for the 24 years of data from 1988 to 2011. Data from 1987 were not used in calculating average recording rates as there was not a full year of observations.

Based on their pattern of occurrence on *Koobabbie*, species have been classified subjectively following the classification of Saunders and McAleer (2012) as:

Resident = present all year;

Regular Visitor = not present all year, but conform to a regular pattern of occurrence;

Irregular Visitor = not present all year or every year, but when present, are present during similar months as previously; and

Vagrant = rare occurrence, conforming to no pattern.

Assessments of change in occurrence of species over the period 1988 to 2011 at *Koobabbie* were made by analysing annual recording rates over time and searching for any patterns using regression modelling with Excel statistical packages. In addition, annual recording rates were analysed against annual rainfall for

Koobabbie and against annual rainfall for the previous year to look for any correlations between rainfall and recording rates. A species was assessed as declining or increasing if there was a significant ($P < 0.05$) negative or positive correlation between recording rates and time.

Historical bird data for Northern Agricultural Catchment Council region

Historical data on the avifauna of the NACC region were obtained from published annotated bird lists covering the period from 1903 to 1979 (Figure 3). Working from north to south, the first was Sedgwick and Crosbie Morrison's (1949) annotated list of all species observed from the lower Murchison River (27°42'S; 114°13' E) during a campout by the Royal Australasian Ornithologists Union (RAOU) in the last two weeks of September 1948. This survey covered about 32 km of the banks and surrounds of the Murchison River from the mouth, upstream to Wilgia Mia Pool. This list also includes observations made while stopping at Mt View Station, near Ajana (27°57'S; 114°38' E) en route to the campout. The second list was of birds at Northampton (28°21'S; 114°38' E) made by the RAOU party when they stayed briefly en route to and from the campout and recorded as an appendix in Sedgwick and Crosbie Morrison's paper cited above. The third list was from East Yuna and Bindoo Hill Nature Reserves, and surrounding areas (28°25'S; 115°12' E) (Dell and McGauran 1981). Surveys by the Western Australian Museum (WAM) of these two reserves were conducted over the course of 11 days in May 1976 and six days in October 1976. These observations were supplemented by data from McGauran, a resident who provided daily sightings of birds from December 1972 to December 1976. The fourth list was from Wilroy Nature Reserve (28°38'S; 115°38' E) collected during surveys over eight days in July 1975, six days in May and six days in September 1976 by WAM (Dell 1979a). The fifth was a list of birds from Yandanooka (29°18'S; 115°33' E) and surrounding districts by Milligan (1905) during his "annual holiday" in September 1904. He stated that his trip was "to ascertain the southern and western limits of northern species, the northern limits of southern species, and the distribution of species generally." Milligan noted that his list concentrated only on selected species and did not record all species that were observed. The sixth list was Sedgwick's (1953) account of the avifauna of Caron (29°37'S; 116°19' E) and a radius of 3.2 km of the town during his time as school teacher in 1947 and 1948. The seventh was from Buntine, Nugadong and East Nugadong Nature Reserves and Nugadong Forest Reserve (29°58'S; 116°37' E) collated during surveys by WAM over 10 days in August/September 1972, eight days in May

1973, 13 days in June 1975, seven days in April/May and six days in November 1976, and four days in July 1977 (Dell 1979b). The eighth was from Marchagee Nature Reserve (29°57'S; 116°04' E) during WAM surveys over six days in July 1975, five days in May and four days in September 1976, and one day in July 1977 (Dell 1979c). In addition, data were drawn from visits to the reserve by a colleague (Glen Storr) over eight visits between July 1954 and August 1965. The ninth was from the length of the Marchagee Track (60 km) (30°15'S; 116°00' E) during WA Department of Conservation and Land Management surveys over an unspecified number of days during October 1977, May, June, July, September and December 1978, January, March, April, May, July, August, September, October and November 1979 (Halse *et al.* 1985). The tenth was from WAM surveys of Cockleshell Gully Reserve (30°09'S; 115°02' E) and adjacent areas, including coastal areas and offshore islets. The data were collected over: two days in October 1970; 20 days in October/November 1973; 17 days in May 1974; three days in March 1975 and one day in May 1976. In addition, the list incorporated data obtained during 42 trips to the coastal area from 1970 to 1976 (Dell and Johnstone 1977). As our paper does not concern itself with coastal birds, all recordings by Dell and Johnstone of strictly coastal (e.g., Rock Parrot *Neophema petrophila*) and sea birds were deleted from their list. The eleventh list was from Bunketch (30°26'S; 117°09' E) and its surrounds compiled by Reid (1951) from 24th November 1950 to 18th January 1951. The twelfth list was of the birds of Moora (30°38'S; 116°00' E) and the district within a radius of 48 km around the town. This was compiled by Orton and Sandland (1913), two residents of the district. No information is given about the period over which observations were collected. The thirteenth list was from the Moore River around the settlement of Mogumber (31°20'S; 116°30' E) and was based on two reports. The first reported on observations made in late September and early December 1903 by Lawson (1905). The second was by Loaring and Serventy (1952) who spent a week in the district in August 1950. The fourteenth list was compiled for the Wongan Hills from two sources. The first reported observations made by Milligan (1904a, b) during a two-week trip from New Norcia (30°58'S; 116°13' E) to the Wongan Hills (30°42'S; 116°34' E) (56 kms) in the first two weeks of October 1903. The second source was based on 21 surveys conducted by the members of the Western Australian Naturalists' Club between 1973 and 1976 (Aug, Oct, Nov 1973; Feb, Apr, Jun, Jul, Sep, Oct, Nov, Dec 1974; Feb, Mar, Apr, May, Jul, Oct, Nov, Dec 1975; and Mar, Jul 1976) and also included notes D. L. Serventy made during a visit in May 1957 and

from a WAM survey over six days in August 1975 (de Rebeira and de Rebeira 1977). The Wongan Hills are just to the east of the south-eastern boundary of the NACC region (Figure 3), but this list has been included as the vegetation, soils and climate are similar to the areas in the south-eastern corner of the NACC region.

Bird lists collated by Reid (1951), Sedgwick (1953), WAM, Department of Conservation and Land Management and de Rebeira and de Rebeira (1977) used subjective status categories for some of the species they listed: rare; scarce; uncommon; moderately common; common; and very common. As it was not clear how these authors assigned species to each of the six categories, in presenting their observations in Supplementary Table 2 only three categories have been used: scarce, incorporating the rare and scarce categories; uncommon; and common incorporating the moderately common, common and very common categories. Other authors did not provide any information on status. Very little information was provided as to whether species were resident, visitors or vagrants and so it is impossible to use observations from these lists to classify species with regard to their residency or otherwise.

To indicate the range of each species within the NACC region, a list rate has been calculated, based on the number of lists on which a species was recorded. As Milligan's (1905) list of birds of the Yandanooka region was selective, and that of Sedgwick and Crosbie Morrison (1949) from Northampton was based on two brief stays, observations from these lists have been excluded in calculating list rates, which are based on the other 12 annotated lists. The range of each species within the NACC was then checked against ranges indicated at <http://spatialecology.jcu.edu.au/AustralianBirds/> accessed in September 2012.

Other sources of information on birds in the NACC region

Three other sources of data on birds in the NACC were available. The first two were from RAOU and Birds Australia atlases. The first atlas was conducted from 1977 to 1981 inclusive (Blakers *et al.* 1984). Observers provided data on presence of species at a particular site at a particular time or length of time, but provided no measure of abundance. A total of 16 357 records from the NACC region were obtained. An observation of a species in a specific location at one time constituted one record. The second bird atlas was conducted from 1998 to 2002 inclusive (Barrett *et al.* 2003). Observers contributing data to this atlas were encouraged to use 2 ha searches. However data were also

provided from incidental searches with no time or area limits. A total of 54 451 records from the second bird atlas were obtained from the NACC region.

The third source of data was from Tony McAleer who collected data on the presence of birds on his 7 293 ha wheat and sheep property *Woopennatty* (29°21'S; 115°39'E) (Figure 3) 80 km north-west of *Koobabbie* from October 1987 to the end of 2002. McAleer commenced his data collection during the CSIRO bird atlas project and continued when that project ceased at the end of 1990. He collected data using the same protocol as did the Doleys and had 28 739 records. Recording rates for each species were calculated using the same methods as for the Doleys' data and were obtained from Saunders and McAleer (2012, Table 1) and from the dataset lodged on the journal website at <http://pcb.murdoch.edu.au>.

Comparisons between different data sets

Data from the two bird atlases were collected using different methods, as were the Doleys' data. The Doleys' were collected over 1 177 recording weeks (data from 1987 have been excluded). Galah, Western Corella, Australian Ringneck and Yellow-throated Miner were the most recorded species. As all were recorded during every recording week they have recording rates of 1.00. Wedge-tailed Eagle was recorded during 881 weeks with a recording rate of 0.75 (i.e., 881/1177). The Doleys' recording rates for each species were calculated in a sense relative to the four most recorded species.

Direct comparisons may be made between Doleys' data and those of McAleer as they were collected using the same protocols over similar sized properties. Crude comparisons with the Doleys' and McAleer's data and those obtained from bird atlas records for the NACC region from the periods 1977–1981 and 1998–2002 may be made by using recording rates for each species relative to the most recorded species for each atlas period. This follows the method of Saunders and McAleer (2012) in which the recording rate for the bird atlases was the total number of records for a particular species divided by the number of records for the species most recorded during that period. For example, in the period 1977–1981 Willie Wagtail had the most records (548) from the NACC region, so its recording rate was 1.00 and Wedge-tailed Eagle had 181 records for a recording rate of 0.33 (181/548). In the second atlas period, Australian Raven had the most records (1 934) from the NACC region and its recording rate was 1.00, while Wedge-tailed Eagle had 466 records so its recording rate was 0.24. Assessment of change in occurrence of species

between the two atlas periods have been made by comparing recording rates; any that differed by more than 30% between atlas periods, provided one was equal or more than 0.10, were deemed by us to be significant.

In addition to using different methods of data collection, there were differences in the times observers collected data. For example, apart from the time the Doleys were away from their property, they collected data every week and a total of 35 347 records were collected over the 25 years. Examining the percentage of records obtained each month (with all years combined) it is clear that data collection was even throughout the year. This was also the case with McAleer's 28 739 records. The even pattern of data collection by the Doleys and McAleer is in contrast to records obtained by the two bird atlases where 48% of the 16 357 records from Atlas 1 were obtained from July to October inclusive and 53% of the 54 451 records from Atlas 2 (Figure 4) compared with 38% for the same period by the Doleys and 36% by McAleer. The cooler periods of winter and spring were obviously more favourable bird watching periods for those contributing to the bird atlases and are potential biases, particularly with respect to regular visitors.

RESULTS

Avifauna of *Koobabbie*

During the period from the beginning of May 1987 to the end of December 2011, 131 species were recorded at *Koobabbie*: 55 residents, seven regular visitors, 14 irregular visitors and 55 vagrants (Table 1). Eighty-nine percent of the species recorded had been recorded in the first ten years of observations. Fifty-four (98%) of the resident species had been recorded by 1990 and all had been recorded by 1995. All of the regular visitors had been recorded by 1988, and all of the irregular visitors by 1999 (Figure 5), by which time 95% of the total species had been recorded and only vagrants were recorded subsequently.

Over half of the 55 species of vagrant were recorded during three weeks (0.3% of total recording weeks) or less of the recording weeks and 43 species were recorded during 20 weeks (1.2%) or less. Pacific Black Duck was the most recorded vagrant; 68 weeks (6%).

Annual recording rates of 15 species declined (Figure 6), while two increased (Figure 7) over the 25 years. Thirteen of the species whose recording rates declined were residents (Emu [$p < 0.005$; $R^2 = 0.70$], Australasian Grebe [$p < 0.05$; $R^2 = 0.19$], White-faced Heron [$p < 0.005$; $R^2 = 0.65$], Grey Teal [$p < 0.05$; $R^2 = 0.19$], Australian Hobby [$p < 0.005$; $R^2 = 0.41$],

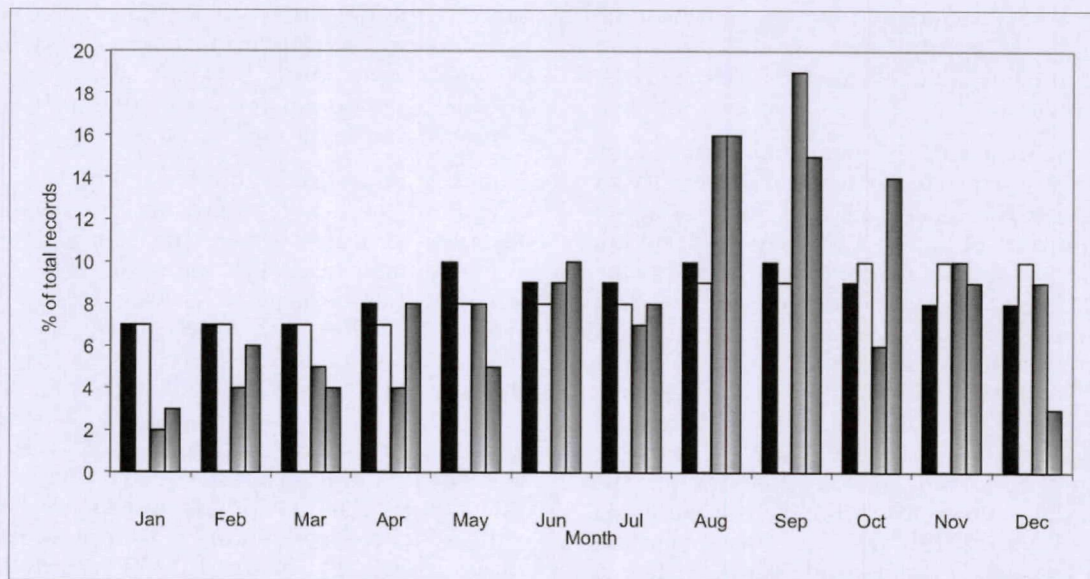


Fig. 4. Percentage of total records each month for data from: *Koobabbie* (N = 35,347) (black bars); *Woopenatty* (N = 28,739) (white bars); Royal Australasian Ornithologists Union Bird Atlas 1 (N = 16,357) (first grey and white bar each month); and Birds Australia Bird Atlas 2 (N = 54,451) (second grey and white bar each month).

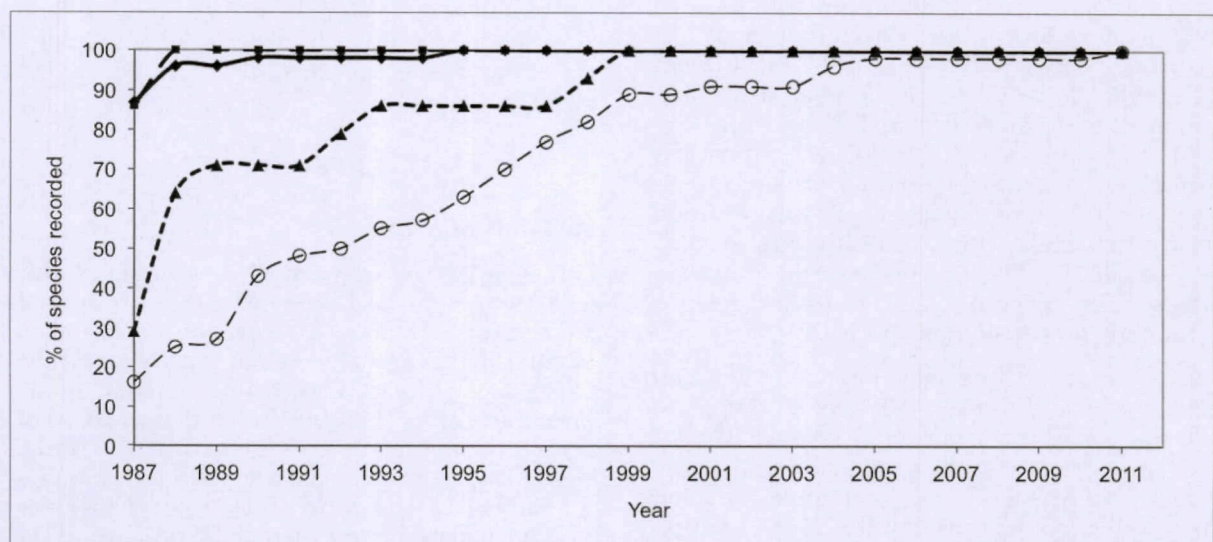


Fig. 5. Percentage accumulation of resident species (diamonds), regular visitors (squares), irregular visitors (triangles) and vagrants (circles) recorded at *Koobabbie* May 1987 to 2011 inclusive.

Nankeen Kestrel [$p < 0.005$; $R^2 = 0.31$], Tawny Frogmouth [$p < 0.01$; $R^2 = 0.27$], Welcome Swallow [$p < 0.005$; $R^2 = 0.37$], Black-faced Cuckoo-Shrike [$p < 0.05$; $R^2 = 0.25$], Crested Bellbird [$p < 0.0005$; $R^2 = 0.66$], White-browed Babbler [$p < 0.0005$; $R^2 = 0.61$], Black-faced Woodswallow [$p < 0.0005$; $R^2 = 0.71$] and Grey Butcherbird [$p < 0.0005$; $R^2 = 0.35$]). The other two species were one irregular visitor (Red-capped Plover [$p < 0.0005$; $R^2 = 0.45$]) and one vagrant (Pacific Black Duck [$p < 0.05$; $R^2 = 0.22$]). The recording rates of one species of resident (Cockatiel [$p < 0.0005$; $R^2 = 0.45$]) and one irregular visitor (Regent Parrot [$p < 0.01$; $R^2 = 0.30$]) increased over time. Four species

changed status over the 25 years: Australasian Grebe was resident until 1998 and vagrant subsequently; Spotted Harrier was resident until 2000 and then vagrant; Crested Bellbird was resident until 2002 and then seen only during three weeks subsequently (now considered extirpated from the property); and Cockatiel was an irregular visitor until 2007 and resident subsequently.

Annual recording rates of six species were significantly positively correlated with total annual rainfall (Figures 8a & b): White-faced Heron ($p = 0.01$; $R^2 = 0.26$); Australian Shelduck ($p < 0.005$; $R^2 = 0.41$); Australian Wood Duck ($p < 0.005$; $R^2 = 0.37$); Horsfield's Bronze-

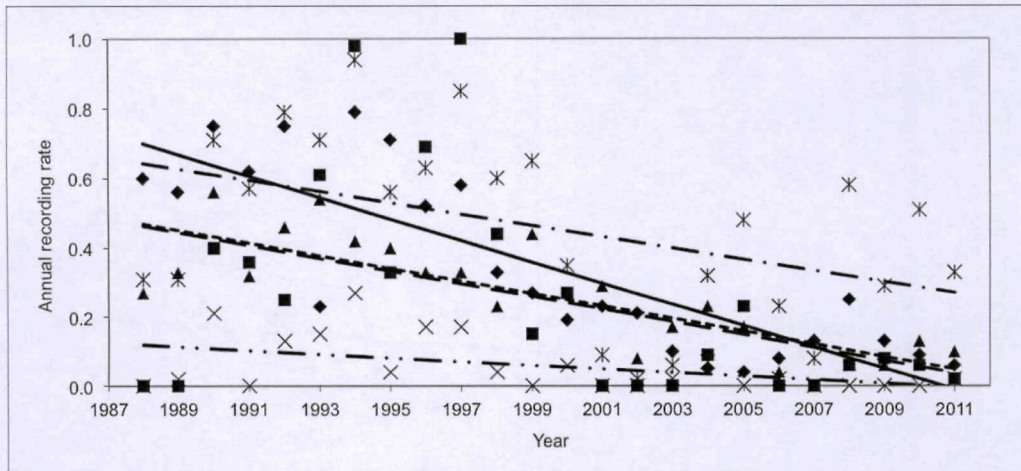


Fig. 6a. Significant negative first order polynomial functions between annual recording rates and year (1988–2011) for Emu (diamonds, unbroken line), Australasian Grebe (squares, broken line), White-faced Heron (triangles, dotted line), Grey Teal (asterisks, dashed line with one dot) and Pacific Black Duck (diagonal crosses, dashed line with two dots). Note that regression lines for Australasian Grebe and White-faced Heron are superimposed.

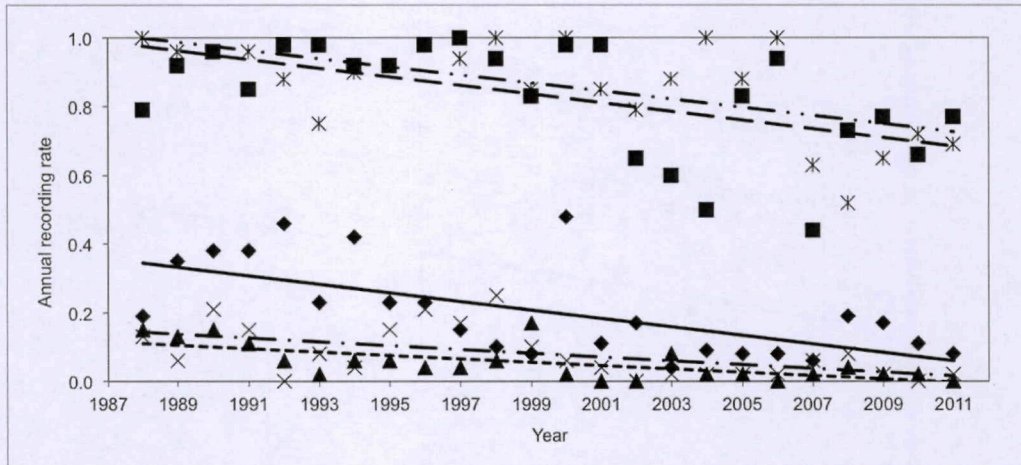


Fig. 6b. Significant negative first order polynomial functions between annual recording rates and year (1988–2011) for Australian Hobby (diamonds, unbroken line), Nankeen Kestrel (squares, broken line), Red-capped Plover (triangles, dotted line), Tawny Frogmouth (diagonal crosses, dashed line with one dot) and Welcome Swallow (asterisks, dashed line with two dots).

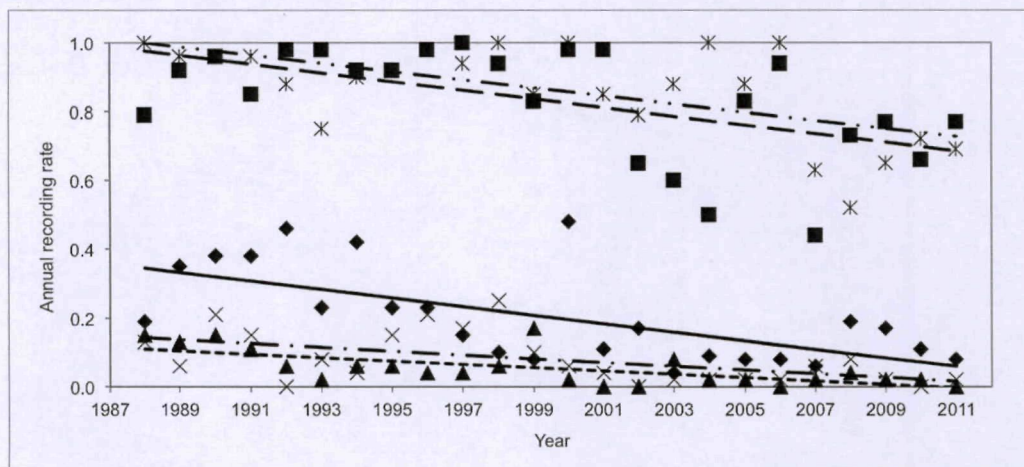


Fig. 6c. Significant negative first order polynomial functions between annual recording rates and year (1988–2011) for Black-faced Cuckoo-shrike (diamonds, unbroken line), Crested Bellbird (squares, broken line), White-browed Babbler (triangles, dotted line), Black-faced Woodswallow (diagonal crosses, dashed line with one dot) and Grey Butcherbird (asterisks, dashed line with two dots).

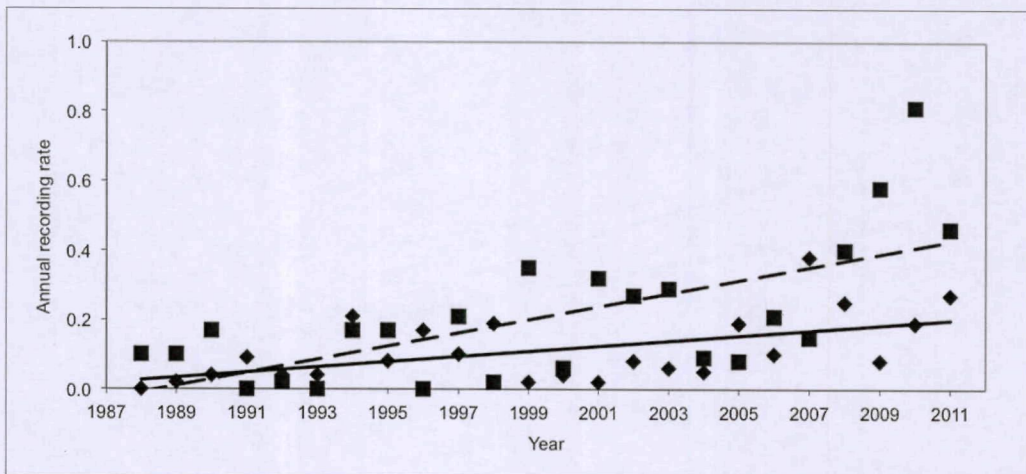


Fig. 7. Significant positive first order polynomial functions between annual recording rates and year (1988–2011) for Cockatiel (squares, broken line) and Regent Parrot (diamonds, unbroken line).

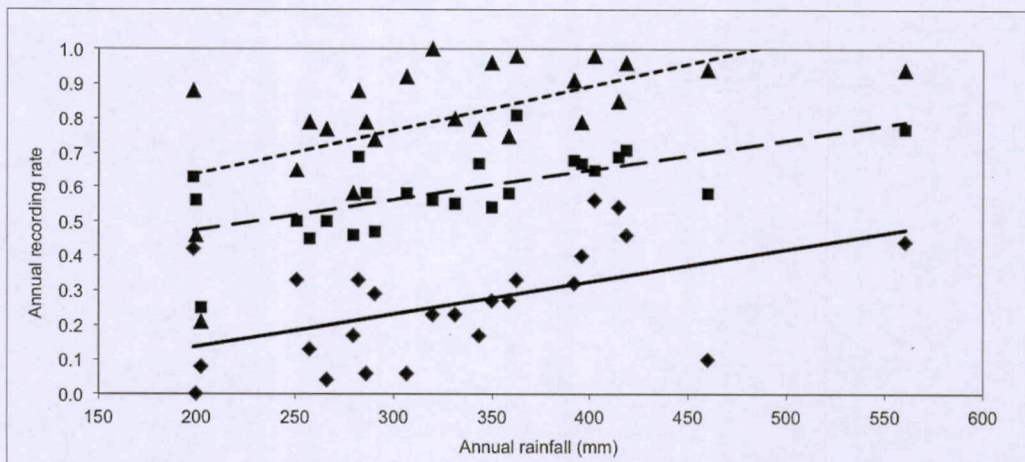


Fig. 8a. Significant positive first order polynomial functions between annual recording rates and total annual rainfall (mm) for *Koobabbie* for White-faced Heron (diamonds, unbroken line), Australian Shelduck (squares, broken line) and Australian Wood Duck (triangles, dotted line).

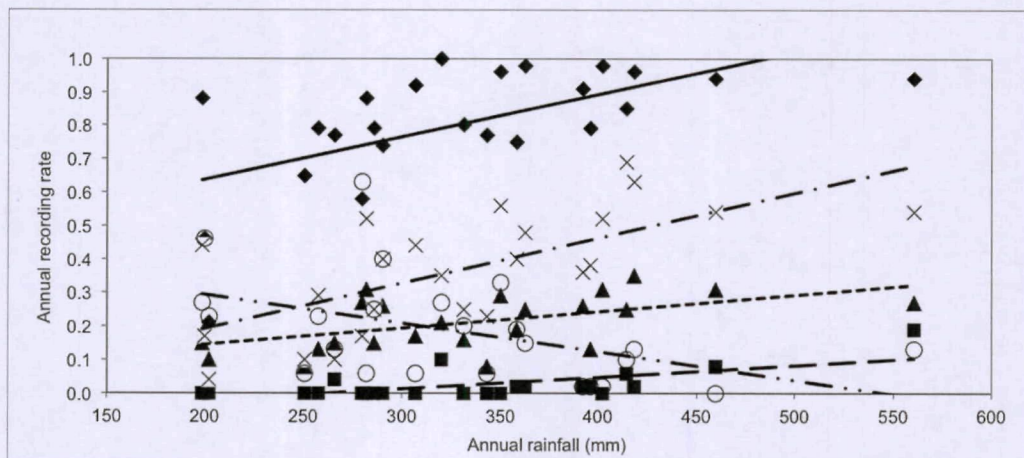


Fig. 8b. Significant positive first order polynomial functions between annual recording rates and total annual rainfall (mm) for *Koobabbie* for Australian Wood Duck (diamonds, unbroken line), Horsfield's Bronze-Cuckoo (squares, broken line), Grey Shrike-thrush (triangles, dotted line) and Brown Songlark (diagonal crosses, broken line with one dot) and significant negative first order polynomial function between annual recording rates and total annual rainfall (mm) for Grey Fantail (circles, broken line with two dots).

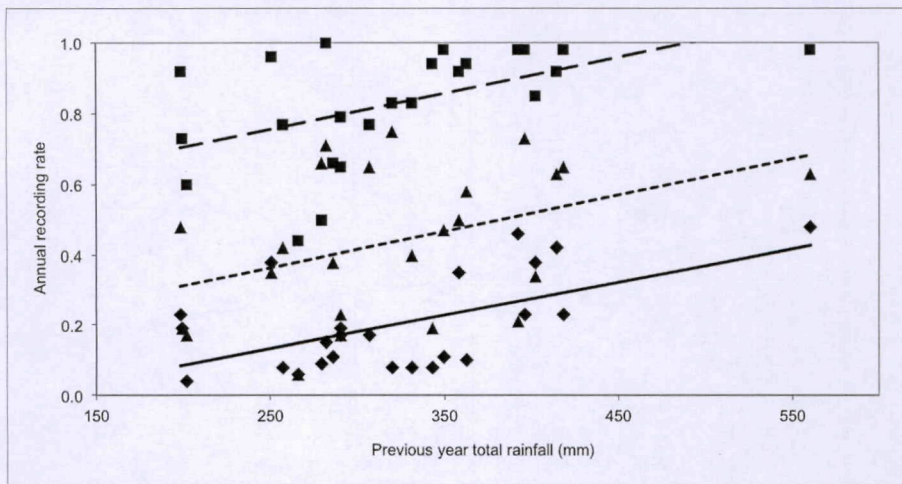


Fig. 9. Significant positive first order polynomial functions between annual recording rates and total annual rainfall for the previous year at *Koobabbie* for Australian Hobby (diamonds, unbroken line), Nankeen Kestrel (squares, broken line) and Stubble Quail (triangles, dotted line).

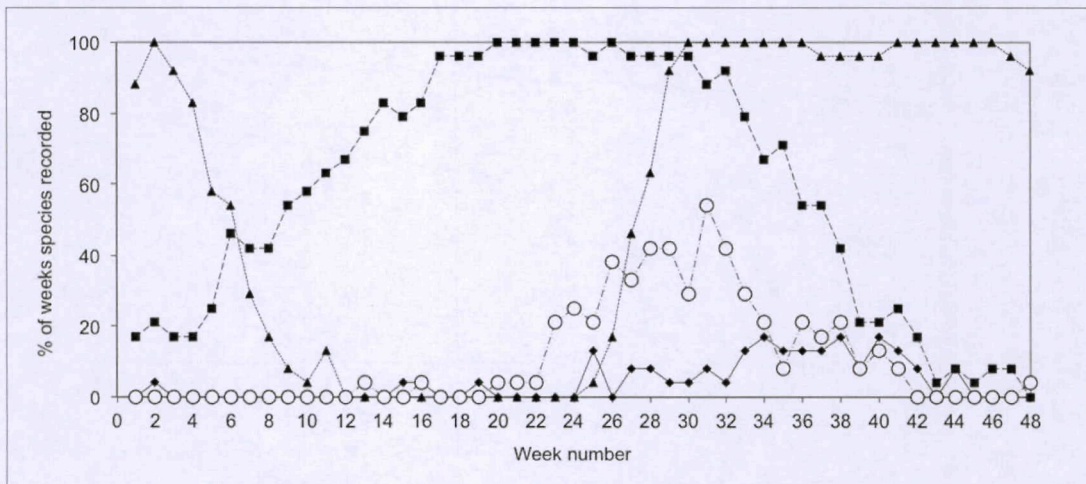


Fig. 10a. Seasonal pattern of occurrence of White-necked Heron (diamonds, unbroken line), Australian Shelduck (black squares, broken line), Carnaby's Cockatoo (triangles, dotted line) and Pallid Cuckoo (circles, dashed line with one dot).

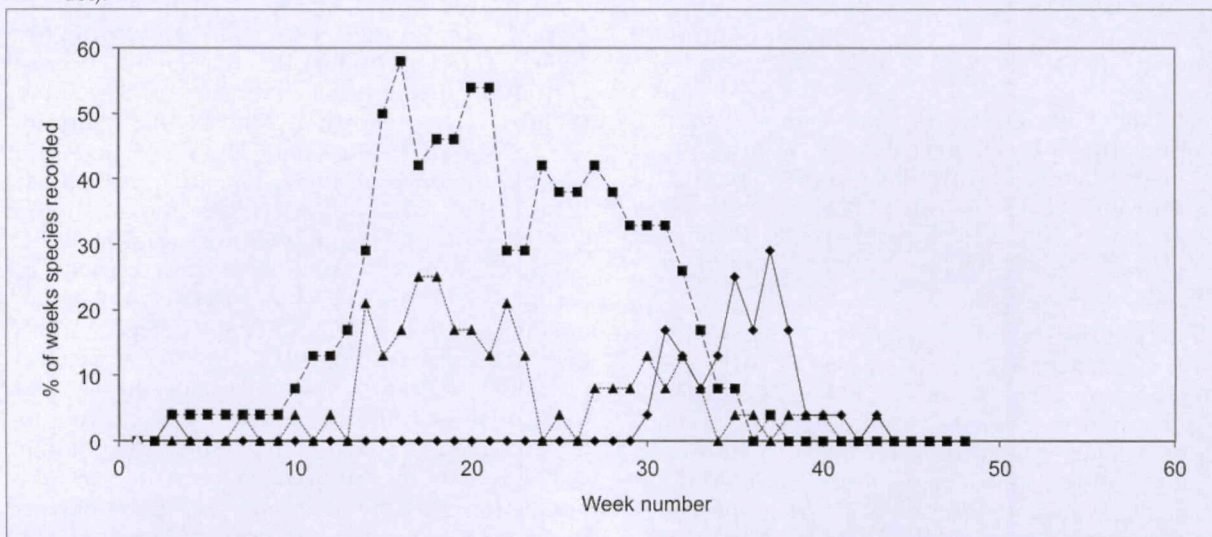


Fig. 10b. Seasonal pattern of occurrence of White-winged Triller (diamonds, unbroken line), Grey Fantail (squares, broken line) and Red Wattlebird (triangles, dotted line).

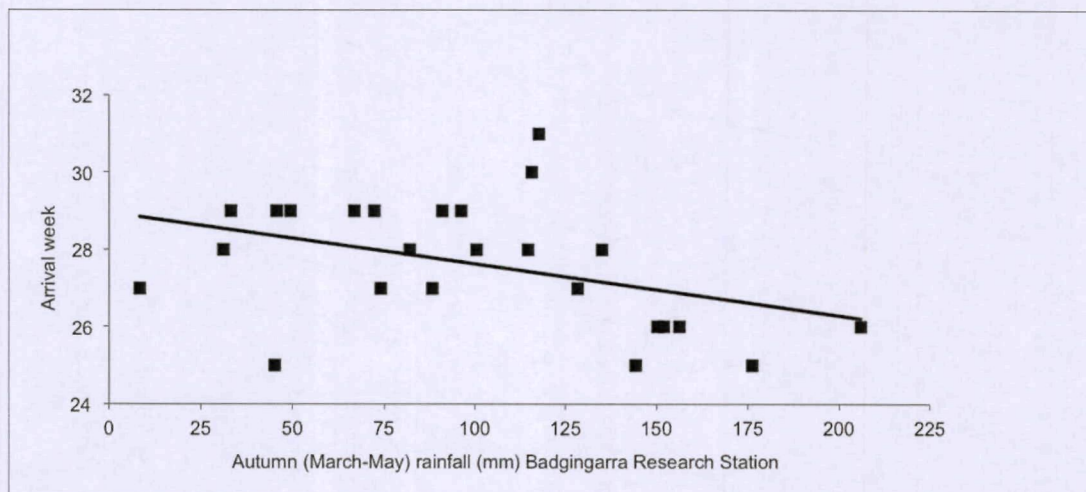


Fig. 11. Significant positive first order polynomial functions between week of arrival of Carnaby's Cockatoo at *Koobabbie* each year and total autumn (March–May) rainfall at Badgingarra Research Station (1987–2011). Rainfall at Badgingarra has been used as the birds spend their non-breeding season near the coast, rather than around *Koobabbie*.

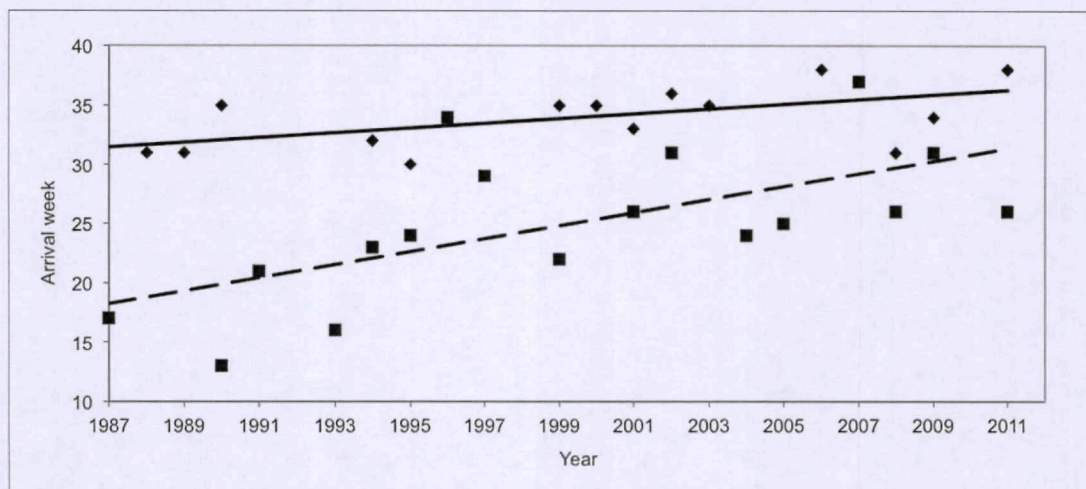


Fig. 12. Significant positive first order polynomial functions between week of arrival of Pallid Cuckoo (squares, broken line) and White-winged Triller (diamonds, unbroken line) at *Koobabbie* each year (1987–2011).

Cuckoo ($p < 0.0005$; $R^2 = 0.46$); Grey Shrike-Thrush ($p < 0.01$; $R^2 = 0.29$); and Brown Songlark ($p < 0.0005$; $R^2 = 0.44$). One species, Grey Fantail ($p < 0.025$; $R^2 = 0.23$) was negatively correlated with total annual rainfall (Figure 8b). Three species were significantly positively correlated with total annual rainfall for the previous year; Australian Hobby ($p < 0.005$; $R^2 = 0.33$); Nankeen Kestrel ($p < 0.01$; $R^2 = 0.27$); and Stubble Quail ($p < 0.05$; $R^2 = 0.16$) (Figure 9).

Three species of legislative conservation concern occurred on *Koobabbie*. Two had breeding populations: Carnaby's Cockatoo, a regular visitor, listed as endangered under federal legislation and rare/likely to become extinct under state legislation, and Major Mitchell's Cockatoo, a resident, listed as specially protected under state legislation. Peregrine Falcon, a vagrant, is also listed as specially protected under state legislation.

There were seven species of regular visitor to *Koobabbie*. Six of these occurred there during the cooler, wetter period of the year: White-necked Heron an uncommon visitor July to November (Figure 10a); Australian Shelduck a common visitor March to October (Figure 10a); Pallid Cuckoo an uncommon visitor July to October (Figure 10a); White-winged Triller an uncommon visitor September and October (Figure 10b); Grey Fantail a common visitor April to September (Figure 10b); and Red Wattlebird an uncommon visitor May to August (Figure 10b). Over the period 1988–2011, the arrival week of Carnaby's Cockatoo ranged from the second week in July (1995) to the third week in August (2001) (Figure 10a) and was the only regular visitor remaining on *Koobabbie* over the summer, departing anytime from the second week in January (2001) to the last week in March (1992, 1994, 2006). The arrival time of Carnaby's Cockatoo at *Koobabbie* was significantly correlated

($p < 0.05$; $R^2 = 0.17$) with total autumn rainfall (March to May) on the coast where they spend the non-breeding season; the wetter the autumn, the earlier the cockatoos arrived at *Koobabbie* to commence breeding (Figure 11).

Two species of regular visitor demonstrated a significant trend of later arrival over the period 1987–2011. Pallid Cuckoo arrived at *Koobabbie* around week 18 in the late 1980s and around week 31 at present ($p < 0.01$; $R^2 = 0.40$) and White-winged Triller arrived around week 31 in the early 1980s and around week 36 at present ($p < 0.05$; $R^2 = 0.33$) (Figure 12). There were no significant changes in the departure dates of these species. Nor was there any indication in

change of arrival and departure dates for the other regular visitors over time (Supplementary Table 1).

Annual recording rates of two species of resident, Weebill ($p < 0.005$; $R^2 = 0.41$) (Figure 13a) and Brown Honeyeater ($p < 0.0005$; $R^2 = 0.79$) (Figure 13b), increased from 1987 until 2001 and then declined.

Comparison between *Koobabbie* and combining bird records from *Koobabbie* and *Woopenatty* and the 12 NACC lists 1903–1979

A total of 191 species were recorded on the 12 published lists for the NACC region (1903–

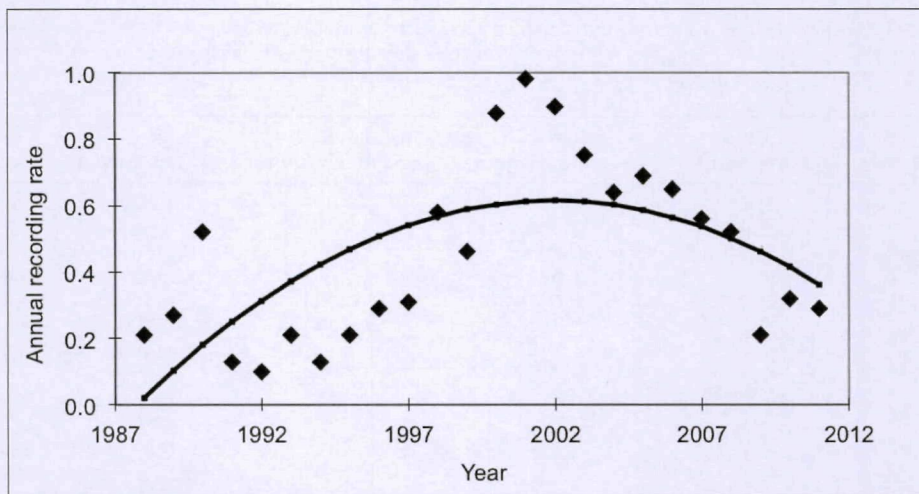


Fig. 13a. Significant second order polynomial between annual recording rate and year (1988–2011) for Weebill (diamonds) with fitted curve (squares).

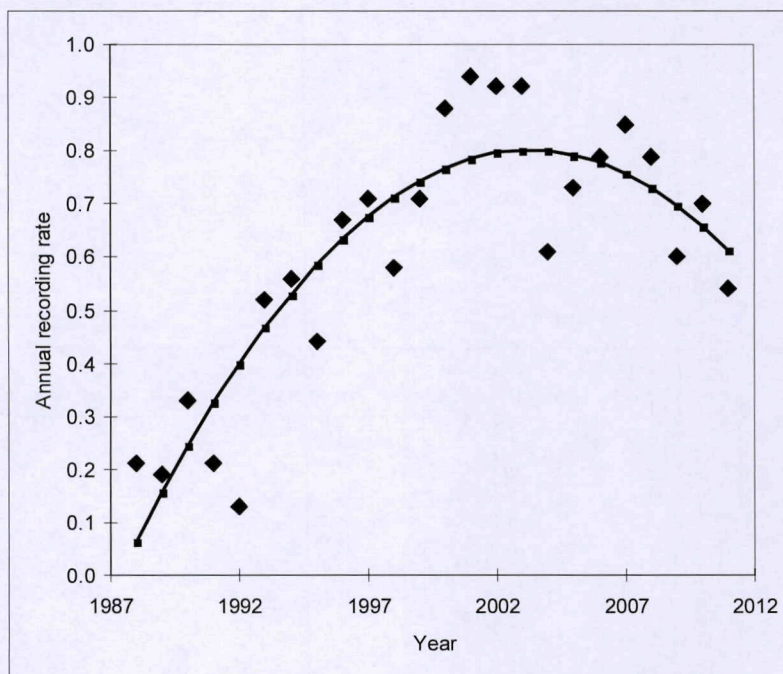


Fig. 13b. Significant second order polynomial between annual recording rate and year (1988–2011) for Brown Honeyeater (diamonds) with fitted curve (squares).

1979). Of the 93 species recorded on seven or more of these 12 lists, 82 (88%) were recorded on *Koobabbie* (Table 2). All 42 species recorded on 10 or more lists were recorded on *Koobabbie*, three of the 16 species recorded on nine lists were not recorded at *Koobabbie* (Jacky Winter, Golden Whistler and Rufous Fieldwren), three of

15 recorded on eight lists were not recorded at *Koobabbie* (Malleefowl, Splendid Fairy-wren and White-eared Honeyeater) and five of 20 species on seven lists were not recorded on *Koobabbie* (Eurasian Coot, Fan-tailed Cuckoo, Black-eared Cuckoo, Mistletoe Bird and Grey Currawong) (Table 1).

Table 2. Comparison between number of species recorded on 12 bird lists from the NACC region (1903–1979) (see text for sources) and on *Koobabbie* (1987–2011) (*K*), *Woopennatty* (1987–2002) (*W*) and bird lists combined for *Koobabbie* and *Woopennatty* (*K & W*). # species is the number of species that are listed (e.g., 19 species were listed on all 12 lists, but 30 were listed on only one list); # *K* residents, regular visitors, irregular visitors, vagrants or not recorded are the number of the # species in each category recorded on *Koobabbie* (e.g., of the 19 species recorded on all 12 lists, 18 were recorded as residents and one as a vagrant on *Koobabbie*). # *W* residents, regular visitors, irregular visitors, vagrants or not recorded are the number of the # species in each category recorded on *Woopennatty*. # *K & W* residents, regular visitors, irregular visitors, vagrants or not recorded are the number of the # species in each category recorded on *Koobabbie* and *Woopennatty* combined. Note where a species was recorded as resident on one property, but in another category on the other property, it has been listed under resident. If it was recorded as regular visitor on one property, but irregular visitor, vagrant or not recorded on the other property, it has been listed under regular visitor. If it was recorded as irregular visitor on one property, but as vagrant or not recorded on the other property, it has been listed under irregular visitor. If it was recorded as vagrant on one property, but not recorded on the other property, it has been listed under vagrant.

# lists spp recorded	# species	# <i>K</i> residents	# <i>K</i> regular visitors	# <i>K</i> irregular visitors	# <i>K</i> vagrants	# not recorded <i>K</i>
12	19	18 (95%)			1 (5%)	
11	13	12 (92%)	1 (8%)			
10	10	5 (50%)	2 (20%)	2 (20%)	1 (10%)	
9	16	6 (38%)	1 (6%)	1 (6%)	5 (31%)	3 (19%)
8	15	2 (13%)	1 (7%)	3 (20%)	6 (40%)	3 (20%)
7	20	6 (30%)	2 (10%)	3 (15%)	4 (20%)	5 (25%)
6	2				1 (50%)	1 (50%)
5	13	2 (15%)		1 (8%)	7 (54%)	3 (23%)
4	15	3 (20%)		1 (6%)	4 (27%)	7 (47%)
3	14			2 (14%)	4 (29%)	8 (57%)
2	24	1 (4%)		1 (4%)	5 (21%)	17 (71%)
1	30				10 (33%)	20 (67%)
Totals	191	55	7	14	48	67
# lists spp recorded	# species	# <i>W</i> residents	# <i>W</i> regular visitors	# <i>W</i> irregular visitors	# <i>W</i> vagrants	# not recorded <i>W</i>
12	19	19 (100%)				
11	13	10 (77%)	2 (15%)		1 (8%)	
10	10	7 (70%)	2 (20%)			1 (10%)
9	16	5 (31%)	4 (25%)		6 (38%)	1 (6%)
8	15	3 (20%)	1 (7%)	1 (7%)	9 (59%)	1 (7%)
7	20	5 (25%)	4 (20%)	4 (20%)	6 (30%)	1 (5%)
6	2				1 (50%)	1 (50%)
5	13	1 (8%)	1 (8%)	3 (23%)	6 (46%)	2 (15%)
4	15	1 (6%)		4 (27%)	4 (27%)	6 (40%)
3	14			1 (7%)	4 (29%)	9 (64%)
2	24		2 (8%)	2 (8%)	4 (17%)	16 (67%)
1	30	1 (3%)			5 (17%)	24 (80%)
Totals	191	52	16	15	46	62
# lists spp recorded	# species	# <i>K & W</i> residents	# <i>K & W</i> regular visitors	# <i>K & W</i> irregular visitors	# <i>K & W</i> vagrants	# not recorded <i>K & W</i>
12	19	19 (100%)				
11	13	12 (92%)	1 (8%)			
10	10	9 (90%)	1 (10%)			
9	16	7 (44%)	3 (19%)		5 (31%)	1 (6%)
8	15	4 (26%)	1 (7%)	3 (20%)	7 (47%)	
7	20	8 (40%)	3 (15%)	4 (20%)	5 (25%)	
6	2				1 (50%)	1 (50%)
5	13	2 (15%)	1 (8%)	4 (31%)	5 (38%)	1 (8%)
4	15	3 (20%)		4 (27%)	5 (33%)	3 (20%)
3	14			3 (21%)	4 (29%)	7 (50%)
2	24	1 (4%)	1 (4%)	3 (13%)	5 (21%)	14 (58%)
1	30	1 (3%)			9 (30%)	20 (67%)
Totals	191	66	11	21	46	47

Combining the records from *Koobabbie* and *Woopennatty* and comparing them with the records of the 12 NACC lists (1903–1979) reveals that of the 93 species recorded on seven or more of the lists, 92 (99%) were recorded on one, two or on both properties (Table 2). Species recorded on six lists or less are likely to be vagrants, or species that only occur over part of the NACC region, rather than over the whole region. Major Mitchell's Cockatoo is an example. It occurs only on the eastern third of the NACC region and was a breeding resident on *Koobabbie*, but not recorded on *Woopennatty*. Letter-winged Kite is another example. It was recorded on one NACC region list (1903–1979) (Supplementary Table 2), that of East Yuna and Bindoo Hill nature reserves as scarce, but was not recorded on either property, nor on either bird atlas.

DISCUSSION

Avifauna of *Koobabbie* 1987–2011

Koobabbie lies in the northern part of the Western Australian wheatbelt, which is the most extensively cleared part of the state. In some districts more than 90% of the original vegetation has been cleared. This extensive and rapid removal of native vegetation has had a major impact on the biota. The decline of the wheatbelt avifauna has been well documented (Kitchener *et al.* 1982; Saunders 1989; Saunders and Ingram 1995). Two hundred and nine species of bird (including vagrants) have been recorded from the wheatbelt; 95 species have declined in range and/or abundance since European settlement and 34 have increased in range and/or abundance (Saunders and Ingram 1995). Similar declines in birds have also taken place throughout all of Australia's extensively cleared agricultural zones. The reasons for this widespread decline relate to loss and fragmentation of habitat, change in ecosystem function, changes in land use, introduction of exotic species and changes in climate (Ford and Howe 1980; Recher and Lim 1990; State of the Environment Advisory Council 1996; Recher 1999; Ford *et al.* 2001; Mac Nally *et al.* 2009; Ford 2011).

The avifauna of *Koobabbie* illustrates a pattern of change consistent with that shown by a number of studies (see references above) across southern Australia in the wheat-sheep zones. What makes the *Koobabbie* data unique is the long term nature of the data collection (25 years) by residents using the same protocols over the same area. With over 40% of *Koobabbie* under native vegetation, with extensive revegetation taking place, and with a variety of habitats in addition to the cleared farmland, it is not surprising that 76 species of bird are either

resident, regular visitor or irregular visitor with another 55 species recorded as vagrant. This total of 131 compares favourably with the 166 species (97 residents, regular or irregular visitors and 69 species of nomads or vagrants) recorded from the much larger area of the one degree of latitude (31–32°S) and longitude (117–118°E) around the shire of Kellerberrin in the central wheatbelt of WA (Saunders and Curry 1990). The total from *Koobabbie* is similar to the 141 species recorded between 1953 and 2008 from the 27 000 ha of remnant vegetation comprising Dryandra Woodland in the southern wheatbelt of WA (Fulton 2013) and the 131 recorded from *Woopennatty*, a property of similar size to *Koobabbie* and about 80 km to the north-west (Saunders and McAleer 2012).

Over the 25 years of observations on *Koobabbie* there have been changes in the avifauna, with five times as many species declining as increasing. Thirteen of these were residents. Emu declined steadily over the 25 years, with a recording rate of around 0.60 in the late 1980s and early 1990s and around 0.10 recently. The species breeds in the salt lake county on the western half of the property, but forages over neighbouring properties where they are shot as pests of cereal crops. The change in recording rate for Emu between the two bird atlases also revealed a decline over the NACC region, again as a result of them being pest of agriculture. Australasian Grebe changed status from resident in the period to 1998 and then vagrant from then on. This species also underwent a significant decline ($p < 0.005$; $R^2 = 0.44$) between 1987 and 2002 on *Woopennatty* and it was not recorded there during 2002. This change in status on both properties corresponds with a period of declining rainfall. There was no indication of change in this species between the two atlases which were conducted over periods when average annual rainfall was below the long-term mean. White-faced Heron, Grey Teal, Australian Hobby, Nankeen Kestrel, Tawny Frogmouth, Welcome Swallow, Black-faced Cuckoo-shrike, Crested Bellbird, White-browed Babbler, Black-faced Woodswallow and Grey Butcherbird, all residents on *Koobabbie*, declined over the recording period. Examination of the data from *Woopennatty* for these species demonstrated significant declines in recording rates for three species over the period 1991 to 2002; Grey Teal ($p < 0.05$ $R^2 = 0.41$), Australian Hobby ($p < 0.005$ $R^2 = 0.65$) and Grey Butcherbird ($p < 0.001$ $R^2 = 0.70$). On *Woopennatty* there were no trends in recording rates for Nankeen Kestrel, Tawny Frogmouth, Welcome Swallow, Black-faced Cuckoo-shrike or Black-faced Woodswallow, while recording rates for White-faced Heron increased ($p < 0.005$ $R^2 = 0.47$). Crested Bellbird was resident on *Koobabbie*

until 2002, seen during three weeks subsequently and has not been recorded on the property since 2008. White-browed Babbler declined strongly and has been recorded during only five weeks since 2007. Crested Bellbird was not recorded on *Woopanatty* and White-browed Babbler was recorded there only once (Saunders and McAleer 2012). Both of these species have declined throughout the wheatbelt (Saunders and Ingram 1995; Saunders and Nicholls 2008). There were no indications of a decline in any of these species between the two atlas periods in the NACC region.

Two species increased on *Koobabbie*; Regent Parrot and Cockatiel. Serventy and Whittell (1976) noted that Regent Parrot had increased in range and abundance with European settlement of the wheatbelt and the species was classified as vermin in a number of shires in the early part of the 20th century. It then underwent a marked decline (de Rebeira and de Rebeira 1977). Saunders and Ingram (1995) noted that over the period 1987–1990 the species was being seen more often and may have been increasing in numbers. Its occurrence on *Koobabbie* may be indicative of this increase. Cockatiel changed from being an irregular visitor to a resident by 2008. Brown Honeyeater and Weebill, both increased until the early 2000s and then declined (Figure 13). They were the only species that showed this increase and then decline. The reasons for this pattern of occurrence are not known, but the increases occurred during the wettest period of the study and the declines during the driest.

Recording rates of three species positively correlated with total annual rainfall, White-faced Heron and Australian Wood Duck, both residents and Australian Shelduck, a regular visitor, are associated with wetlands. The other three species positively correlated with total annual rainfall, residents Grey Shrike-thrush and Brown Songlark, and Horsfield's Bronze-Cuckoo, an irregular visitor, were not associated with wetlands. Two raptors, Australian Hobby and Nankeen Kestrel, and Stubble Quail, all residents, were positively correlated with the previous year's total annual rainfall. It is possible that previous year's rainfall has a positive influence on their food supply or perhaps, recording rates were higher post-wet years due to greater breeding success during wet years.

Chambers (2008) and Smith and Smith (2012) examined trends in the timing of migration of 20 species bird at Middlesex in the extreme south-west of Western Australia (1973–2000) and 16 species at Blaxland, west of Sydney (1980 to 2011), respectively. Chambers found that five species were arriving earlier and four later, with four species departing later and three earlier.

The Smiths reported that six species were arriving significantly earlier, and no species was arriving significantly later. The only two species of regular visitor to *Koobabbie* (Pallid Cuckoo and White-winged Triller) which demonstrated significant changes in arrival dates, are now arriving later than they did in the late 1980s. No species showed any change in departure dates. Chambers (2008) reported that at Middlesex there was no significant trend in date of arrival of Pallid Cuckoo and a significant trend towards earlier departure. However, at *Koobabbie* this species is now arriving later, with no change in departure over time, and therefore staying for shorter periods. Similarly, White-winged Triller is arriving later, but the change in nowhere as great as the change exhibited by Pallid Cuckoo (4.6 weeks compared with 12.6 weeks 1988–2011). As the migratory paths of these two species are not known, it is not possible to provide reasons for these changes.

With permission of the Department of Environment and Conservation, management of *Koobabbie* involves the control of any exotic species (including feral Cat *Felis catus*, Red Fox *Vulpes vulpes* and turtle-doves) and over-abundant native species (including Galah and Western Corella). The two mammals are predators of native fauna and the two native birds are major competitors for nesting hollows used by the endangered Carnaby's Cockatoo and specially protected Major Mitchell's Cockatoo, in addition to being pests of cereal crops. From 1st January 1996 to 25th March 2012, this control programme had seen the removal of 33 Cat, 323 Fox, 4 266 Western Corella and 10 115 Galah. Three species not native to Western Australia were recorded as vagrants on *Koobabbie*; Rock Dove (11 recording weeks), Laughing Turtle-Dove (27 weeks) and Laughing Kookaburra (12 weeks). The first two are not native to Australia and the latter is native to eastern Australia. Only the Laughing Turtle-Dove showed any tendency to establish itself on *Koobabbie*. This species was recorded in March 2007 and was on the property for much of that year, during which time a successful control campaign was undertaken. None have been seen since.

***Koobabbie's* role in conservation of the avifauna of the NACC region**

Koobabbie is located near the centre of the NACC region (Figure 3) and 88% of the 93 species recorded on seven or more of the NACC published lists (1903–1979) were recorded on *Koobabbie*. This high representation of the region's avifauna makes the property an important area for bird conservation.

The analyses we conducted on the *Koobabbie* data are relatively simple. It is possible that

more complicated analyses examining recording rates in relation to factors such as temperature, changes in extent of native vegetation or revegetation may provide more information on changes in occurrence over time than the correlations with rainfall undertaken by us.

Importance of long-term monitoring

The datasets from *Koobabbie* and *Woopennatty* illustrate the importance of having long-term bird monitoring sites to assess change over time and provide information on regional avifaunas. Over the 25 years of data collection at *Koobabbie*, it took 12 years to record all residents, regular and irregular visitors (Figure 5). Similarly, over 16 years at *Woopennatty*, it took seven years to achieve the same result (Saunders and McAleer 2012). Data collection over shorter periods, as with the two bird atlases (five years) and the CSIRO wheatbelt atlas (three and a half years) will not provide a complete account of an area's bird community. Continuous monitoring, as occurred on both properties, provides greater resolution on changes in occurrence not necessarily revealed by monitoring at intervals, as was done by the two bird atlases. In addition, site based monitoring demonstrates that changes in species at one site may not be occurring at another site in the same region and when conducted by residents collection of data is not subject to the biases demonstrated by the bird atlas data (Figure 4).

As pointed out by Saunders and McAleer (2012), regional natural resource management (NRM) organisations, of which there are 58 in Australia, should consider setting up a series of sites throughout their regions to monitor the biota over time. Birds are suitable candidates for monitoring as they provide reliable information on condition of vegetation associations and bird watchers can make significant contributions, as has been the case with the Canberra Ornithologists Group's monitoring of the city's avifauna since July 1981 (Canberra Ornithologists Group 2000; Veerman 2002), the two national bird atlases and the CSIRO wheatbelt atlas. Such sites should include all habitats and all land tenures, not relying only on areas set aside as public conservation areas. The Bureau of Meteorology weather monitoring sites provide a model for such an approach and show the importance of regional long term data. NRM organisations could set up incentives for data collection by landholders at strategic places throughout their region, taking into account variation in environmental conditions in the region. In the case of the NACC, such sites need to take account of the fact that the region is a transition zone between the more mesic southwest and the arid north and east. In this

region, at a minimum, sites should be located at the mouth of the Murchison River, East Yuna and Bindoo Hill nature reserves, *Woopennatty*, *Koobabbie*, Lesueur National Park (which incorporates Cockleshell Gully Reserve) and the Moore River. Obviously resources are needed to provide incentives to collect data and to provide a central point for lodging and analysing the data. Such data are needed to assess priorities for conservation management, revegetation programmes and for assessing the efficacy of management. Until such a system of monitoring and analysis is set up, we will continue to waste precious resources on natural resource management without any way of assessing how effectively those resources have been spent.

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