

Birds of the Doolgunna and Mooloogool Rangelands, northeast Gascoyne Region, Western Australia

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Abstract. Doolgunna and Mooloogool are former pastoral leases relinquished to the Western Australian Department of Environment and Conservation, destocked in the early 2000s and now managed as conservation reserves. Surveys by volunteers of BirdLife Western Australia in 2003 and 2011 and by the Western Australia Naturalists' Club in 2007 listed a total of 105 species. Richness values on Doolgunna for 2003, 2007 and 2011 were 72, 49 and 73 species, respectively. Richness values on Mooloogool for the three years were 68, 37 and 52 species. There appeared to be a relationship between richness and rainfall totals of the two months prior to the winter sampling periods. Turnover on Doolgunna averaged 48%, while at Mooloogool turnover averaged 56% between the three years, highlighting the large number of nomadic species found in these arid-zone habitats, especially in wet years. Individual plot richness ranged from a high of 37 species in a riverine woodland site on Doolgunna during 2011 to lows of 13 species in a hummock grassland site on Mooloogool in 2007 and two 2007 Doolgunna mulga-dominated upland sites with 11 species. Community avifauna patterns determined by Detrended Correspondence Analysis on plot frequency data were primarily related to vegetation community type, with assemblages related to mulga-dominated uplands, riverine margin sites and hummock grasslands, and secondarily to annual variation in bird assemblage composition. Large numbers of singleton observations and the large percentage turnover of species between sample years highlight the need for multiple samples over a range of seasons to ensure the detection of uncommon bird species, which may require special management and conservation objectives.

Keywords. Arid-zone bird communities, avifauna richness, bird/vegetation interactions, mulga/bird associations, turnover rates

Introduction

Regional avifauna studies of the Carnarvon Basin (Burbidge *et al.* 2000) to the southwest of Doolgunna and Mooloogool and the Pilbara (Burbidge *et al.* 2010) to the northwest indicate that species exhibit habitat selection for particular vegetation and habitat attributes. In these studies, while individual sites average about 20 species per sample, richness varies greatly. In the Carnarvon Basin, single sample site richness ranged from 9 to 56 species (Burbidge *et al.* 2000). The Burbidge *et al.* (2010) study of the Pilbara biogeographic region recorded a site richness range from 3 to 49 species, with riparian sites

generally harbouring the greatest richness and sapphire flats the poorest. In the Carnarvon Basin, the broad biogeographic pattern in the population of birds was broadly related to climatic factors, with substrate and vegetation characteristics operating at a more local scale. In the Pilbara study, however, vegetation parameters were of primary importance to avifauna community structure, with particular species recorded most commonly in particular vegetation types. Three bird surveys by volunteers of BirdLife Western Australia (2003 and 2011) and by the Western Australian Naturalists' Club (2007) have been undertaken. The objectives of this study were to record the birds of the Doolgunna and

Mooloogool Rangelands, document similarities and differences between the three year's surveys and to determine possible bird assemblage/vegetation type interactions.

Methods

The northeastern Gascoyne region conservation reserves of Doolgunna and Mooloogool are centred 120 km and 80 km northeast of Meekatharra, respectively (Figure 1). The climate is arid subtropical with a mostly late summer–early autumn rainfall maximum (<http://www.bom.gov.au/climate>). Although no climatic records are available for Doolgunna and Mooloogool Stations, the long-term mean annual rainfall at the nearest, long-term weather station (Meekatharra Airport, 26.61°S 118.54°E) is 237.7 mm yr⁻¹ with the highest monthly mean total of 37 mm yr⁻¹ in February. Rainfall events in the arid north of Western Australia, however, can be widely variable across relatively small distances. Summer and total annual rainfall in the region is most typically influenced by the number of cyclonic rainfall events (Van Vreeswyk *et al.* 2004). Winter rainfall totals relate to the number of southern latitude rain fronts. The warmest month is January with a mean maximum temperature of 38.3°C and a mean minimum of 24.3°C. The coldest month is July with mean maximum and mean minimum temperatures of 19.0°C and 7.4°C, respectively. Rainfall at Doolgunna in May and June, just prior to the 2003, 2007 and 2011 avifauna sampling periods, were 20.0 mm, 6.0 mm and 11.8 mm, respectively. The reserves are mainly underlain by the Archaean Yilgarn Block, composed mainly of gneisses and granites with minor enfolded belts of metamorphic sedimentary and igneous rocks with the northern part of the Doolgunna reserve overlapping onto the geology of the Gascoyne Block (Beard 1976). Soils are generally red-brown hardpan acidic soils, typical of *Acacia* semi-desert scrub. Both reserves lie in the Gascoyne Region of the Eremaean Botanical Province. The regional vegetation of Doolgunna is covered by the Peak Hill vegetation map sheet and Mooloogool is covered by the Glengarry vegetation map sheet (Beard 1976). The predominant landscape vegetation is characterized by Beard (1976) as vegetation type “a₁Li - Low Mulga Woodland” and “a₁Lp -Mulga, trees in groves or patches”. Doolgunna and Mooloogool lie in the Central Province of the Western Faunal Sub-Region of Kikkawa and Pearse (1969).

Avifauna sampling during 2003 was carried out in a range of vegetation types and habitats, but no time or area restrictions were followed for these surveys on either reserve. Standardized or fixed-effort sampling provides the ability to make statistically valid comparisons of samples, sites, habitats, seasons or other features influencing avian populations (Elphick 1997; Rosenstock *et al.* 2002; Watson 2003; 2004). Perma-

nent-site surveys in 2007 involved four contiguous 2 ha square plots sampled for 30 minutes for bird presences. The surveys of 2011 utilized 500 m radius plots sampled for the presence of species during a 30-minute period in each of the 90° quadrants of the plots. Each of the eight survey plots on Doolgunna and the three plots on Mooloogool were surveyed twice during the sampling periods of mid-July of 2007 and 2011, once in the morning and once in the afternoon. Plots were chosen to geographically cover the reserves and represent a range of non-wetland habitats (Table 1). Also, a number of additional sites in 2007 and 2011 provided added habitat coverage of the area. As with all sites in the 2003 survey, in each of these supplemental sites of 2007 and 2011, a list of the bird presences was made, but the time and area restrictions of the basic sampling system was not observed. It is acknowledged that different observers were used in the three survey periods; however, recent studies on sampling systems have found that variation in competence of reasonably well-trained volunteers does not generally invalidate conclusions regarding broad-scale ecological patterns (see Lindenmayer *et al.* 2009).

Turnover rates between the 2003, 2007 and 2011 reserve lists were determined as:

$$T = 100 [(d+a)/s]$$

where “d” is the number of local departures (number of species recorded on the reserves during the first survey, but missing from the second survey), “a” is the number of local arrivals (number of species not recorded on the reserves during the first survey, but present during the second survey), and “s” is the total number of species observed on the reserves during either survey period (Maron *et al.* 2005).

A frequency of occurrence value from the percentage of the eight quadrants (two time-period samples, each with four quadrants) with a species presence recorded in the surveys of the permanent plots provided a quantitative indication of the likelihood that a bird species would be encountered. The matrix of the frequency of occurrence data by sample was analysed by Detrended Correspondence Analysis (DCA) to reveal patterns of bird community structure (Jongman *et al.* 1995).

Results

During the rangeland surveys on Doolgunna and Mooloogool during 2003, 2007 and 2011, we recorded a total of 105 species, including 44 non-passerines and 61 passerines (Appendix 1). Among the non-passerines, there were twelve diurnal and three nocturnal raptors, eight parrots, four cuckoos and eleven aquatic-site and shorebirds. Among the passerines were seven species of honeyeaters. Separate station lists from the 2003 surveys had richness values of 72 and

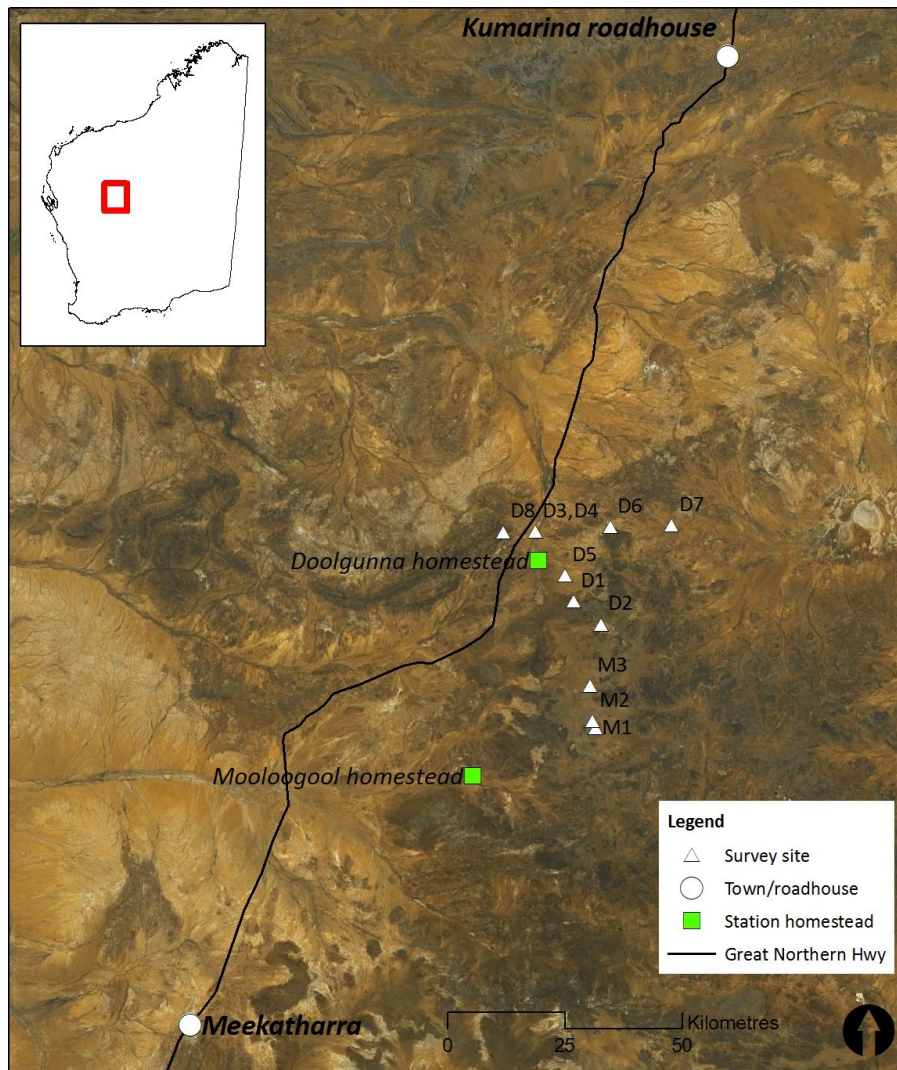


Figure 1. Location of Doolgunna and Mooloogool rangelands and permanent survey plots (Aerial photo © 2012 Google, © 2012 Cnes/Spot Image).

68 species for Doolgunna and Mooloogool, respectively (Table 2). The values for the two reserves in the drier 2007-survey period were 49 and 37 species. The separate richness total for the 2011 surveys on Doolgunna was 75 species, while on Mooloogool, the total was 53 species. Turnover rates on Doolgunna between 2003 and 2007 and 2007 and 2011 averaged 51%, while the average turnover rate on Mooloogool over this time period was 54%. Overall turnover rates for the region was 46% between samples.

In the permanent survey points surveyed in both 2007 and 2011, Zebra Finches occurred in 21 of 22 plots (Appendix 1). Singing Honeyeaters, Spiny-cheeked Honeyeaters and Willie Wagtails occurred in 20 survey points, with Yellow-throated Miners, Rufous Whistlers, Crested Bellbirds, Chestnut-rumped and Inland Thornbills and Red-capped Robins also common overall. Little Button-quails, Common Bronzewing, Western Bowerbirds and Diamond Doves were very common during 2011, but were not recorded or rarely observed during the 2007 survey.

Grey and Pied Butcherbirds and Little Corella were common in 2007, but observations were limited in 2011. Uncommon species included Black-breasted Buzzard, Rufous-crowned Emu-wren, Elegant Parrot, Grey Currawong, Ground Cuckoo-shrike and Brown Quail, mostly only observed in a single quadrant at a single site.

Individual site richness values recorded during the detailed 2007 and 2011 surveys ranged from a high of 37 species in a Riverine Woodland site on Doolgunna (D3) during 2011, 13 in a recently burnt hummock grassland site on Mooloogool (M3) during 2011, and to lows of 11 species in two Mulga-dominated sites on Doolgunna in 2007 (D2 and D6) and.

Of the 105 species recorded on the two conservation reserves, 33 were sighted in areas of the reserves other than in the permanent survey plots and a further 13 were only recorded once in the plots. Only data from the remaining 59 species were employed in the DCA analyses.

The first DCA axis explained 28% of the sample

Table 1. Location and vegetation of permanent survey plots on Doolgunna and Mooloogool.

Plot	Latitude	Longitude	Vegetation description
D1	25°45'56"S	119°18'07"E	Low Mulga Woodland
D2	25°48'32"S	119°21'39"E	Low Mulga Woodland
D3	25°37'57"S	119°13'07"E	Riparian Woodland
D4	25°37'57"S	119°13'07"E	Open Scrub near Riparian Woodland
D5	25°42'58"S	119°16'57"E	Low Mulga Woodland
D6	25°37'15"S	119°22'37"E	Low Mulga Scrub
D7	25°36'58"S	119°30'28"E	Low Mulga Woodland
D8	25°38'03"S	119°09'00"E	Low Mulga Woodland
M1	26°00'32"S	119°21'10"E	Hummock Grassland-Scrub
M2	25°59'43"S	119°20'49"E	Hummock Grassland-Scrub
M3	25°55'40"S	119°20'23"E	Hummock Grassland

variance and generally separated bird assemblages associated with vegetation type (Figure 2). Avian species with low DCA Axis 1 scores were those associated with mulga woodlands on Doolgunna and Mooloogool (Appendix 2). Species uniquely recorded in mulga woodland sites included Jacky Winter, Rufous Songlark, Chestnut-breasted Quail-thrush, Southern White-face and Yellow-rumped Thornbill. More widely distributed species generally associated with mulga woodlands were White-browed Babbler, Grey Shrike-thrush and Redthroat.

Species with high DCA Axis 1 scores included species mostly associated with hummock grassland vegetation sites on Mooloogool. These species included Australian Magpie, Brown Songlark, Crimson Chat, Magpie-lark, Galah and Torresian Crow. The central part of the first DCA axis contained the four surveys from the Riparian Woodland site (D3) and the scrub vegetation site immediately adjacent to the Riparian Woodland (D4). Species associated with these riparian margin habitats were the Red-backed Kingfisher, White-plumed Honeyeater, Tree Martin, Mistletoebird and the Pied Butcherbird, but also a number of the common and widely-distributed species, such as Spiny-cheeked Honeyeater, Galah, Yellow-throated Miner and Zebra Finch.

The second DCA site axis explained another 13% of the remaining variance in the sample data and generally separated samples from the 2007 surveys from the 2011 surveys. Species unique to the 2007 surveys, such as Grey Fantail, Little Corella and Slaty-backed Thornbill and Little Woodswallow, and species unique to the 2011 surveys, such as Jacky Winter, Hooded Robin, Chestnut-breasted Quail-thrush and Masked Woodswallow, contributed to the separation of sites on the second DCA site axis. The third and fourth DCA iterations contributed less than 10% of the remaining sample variance and were not considered further.

Discussion

Widely-varying site richness values are common in bird surveys from arid zones of Western Australia

(Burbidge *et al.* 2000, 2010). In the present study, overall total richness for all surveys on Doolgunna and Mooloogool was 105. For individual years, Doolgunna species richness ranged from 73 (2011) to 52 (2007) with a mean turnover of 48%. For Mooloogool, the species richness value ranged from 68 (2003) to 37 (2007) with a mean turnover of 56%. The highest richness value (2011) was recorded after the highest pre-sample period (May-June) of rainfall and the lowest richness value (2007) occurred after the lowest pre-sample amount of rainfall. Turnover values for both these conservation reserves were slightly higher than the mean of 45% measured for Western Australian eucalypt woodlands sampled in 2004 and then again in 2006 (Bell *et al.* 2007), but lower than the 63% turnover rate recorded in the Wimmera region of western Victoria between full-year surveys from 1994-1995 versus surveys from same areas in 2001-2002 (Maron *et al.* 2005).

On Doolgunna and Mooloogool, mean site richness for the intensive survey plots was 21 ± 7 species with a range from 37 to 11, values similar to other Western Australian arid-zone bird community samples (Burbidge *et al.* 2002, 2010). Also in common with other surveys of the arid interior of Western Australia, the intensive plot surveys included a large number of singletons (species recorded only once). Many studies have indicated that one-time surveys have a lower probability of detection of all species compared to multiple-time surveys (Wiens 1981; MacNally 1996; Maron *et al.* 2005). However, the high numbers of singletons in samples can also be caused by the high numbers of arid-zone species with wide geographic ranges, irruptive species, low natural densities or nomadic behaviours and observation difficulties due to highly cryptic colouration and effective detection avoidance mechanisms. Species with large geographic ranges noted in the Doolgunna and Mooloogool surveys included the raptors, such as Black-breasted Buzzard, Brown Goshawk, Collared Sparrowhawk and the Brown and Black Falcons. Irruptive species recorded included Little Button-quail, Crimson Chat, Budgerigar, Cockatiel and Black-faced and Masked Woodswallows. Cryptic,

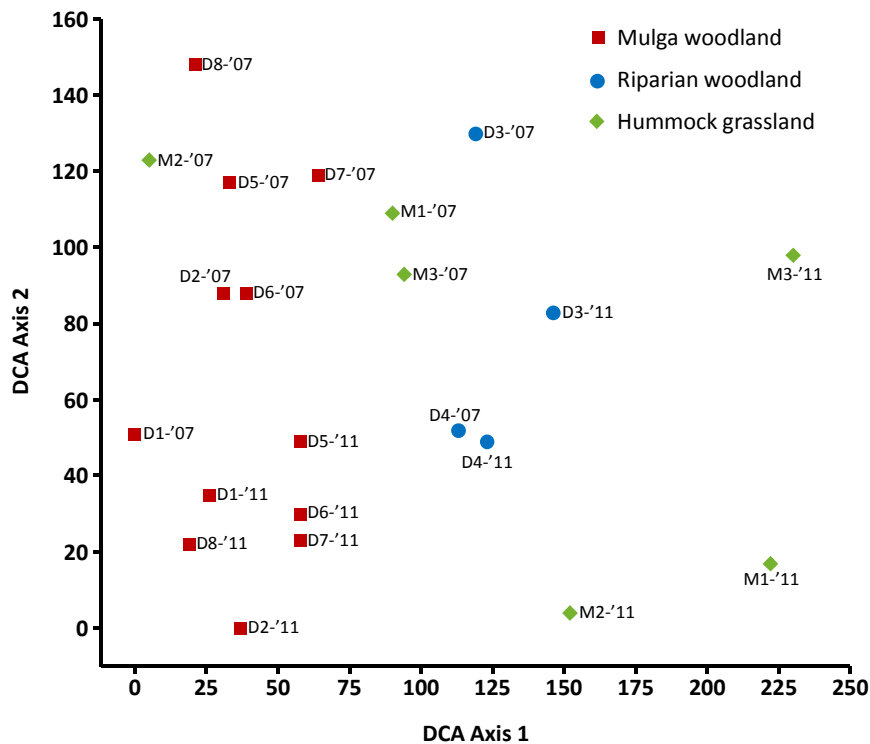


Figure 2. Site ordination of the first and second Detrended Correspondence Analysis (DCA) axes of plot frequency data from the Doolgunna and Mooloogool 2007 and 2011 BAWA rangeland surveys. The DCA position of each survey has been marked with a symbol designation associated with vegetation type. Symbol labels refer to a combination of site identifier and year. For example, D8-'07 refers to the Doolgunna site 8 survey undertaken in 2007, and M2-'11 refers to the Mooloogool site 2 survey undertaken in 2011.

well camouflaged, species, like the Brown Quail and Australasia Pipit, species of low natural densities, such as the Rufous-crowned Emu-wren, Banded Whiteface and Grey Honeyeater, and species with highly mobile behaviours, such as the Peregrine Falcon, Elegant Parrot and Australian Hobby were recorded, but other such species were undoubtedly missed in the three winter-survey periods.

The richness value of 105 species for Doolgunna and Mooloogool region is somewhat less than that recorded in the much larger regions sampled in the southern Carnarvon Basin with 126 species (Burbidge *et al.* 2000), the 132 species recorded in the Pilbara (Burbidge *et al.* 2010), the 126 species of Kachana Station in the east Kimberley (Henggeler and Phillips 2008) and the 150 species of the Jarrah forest of southwest Western Australia (Nichols and Muir 1989), but higher than the 92 species recorded for eucalypt forest and woodland sites along a 625 km gradient in the interior southwest (Bell *et al.* 2007). Richness values for remnant Wandoo woodlands (56 species - Arnold 1988; 62 species - Recher and Davis 1998; 87 species - Arnold 2003), subtropical woodlands (63 species - Farmer *et al.* 2004; 82 species - Phillips *et al.* 2008) and Salmon Gum woodland sites (63 species - Recher and Davis 2002; 77 species - Recher and Davis 2010) are generally lower, undoubtedly due to the much-

reduced size and reduced habitat diversity of the areas sampled in these individual woodland surveys.

Species common throughout the Doolgunna and Mooloogool rangelands were the Red-capped Robin, Spiny-cheeked Honeyeater, Diamond Dove, Crested Bellbird, Rufous Whistler and the Singing Honeyeater. These species were also the most common in the wider regional survey of the Pilbara reported by Burbidge *et al.* (2010).

Birds previously linked with Mulga woodland vegetation include the Singing Honeyeater, Rufous Whistler, Zebra Finch, Pied Butcherbird, Willy Wagtail, Inland Thornbill, Grey Shrike-thrush, Splendid Fairywren, Chestnut-rumped Thornbill and Crested Bellbird (Cody 1994; Burbidge and Fuller 2007; Burbidge *et al.* 2010). On Doolgunna and Mooloogool, these species were also among those associated with mulga woodlands, but the Redthroat and the Jacky Winter were also found in this vegetation type.

Riverine sites in the Pilbara (Burbidge *et al.* 2010) and other arid Australian regions (James *et al.* 1995; Kingston *et al.* 2002) are richer than Mulga woodland sites. Watercourses of the Jarrah forests (Wykes 1983) and tropical savannas (Henggeler and Phillips 2008) are also richer in bird species than upslope locations. Increased riparian avifauna richness probably relates to a greater array of foraging types, especially lerp-

Table 2. Yearly species richness and turnover values for Doolgunna and Mooloogool.

	Yearly species richness				Turnover	
	2003	2007	2011	Total	2003-2007	2007-2011
Doolgunna	72	49	75	96	49%	53%
Mooloogool	68	37	53	86	58%	54%
All sites	85	55	81	105	46%	45%

producing invertebrates (Weins 1989; Woinarski *et al.* 1997; Kitchener *et al.* 2003), drinking water for birds generally foraging in surrounding habitats (Fisher *et al.* 1972; Morton 1990), greater litter layer insectivore food supply (Wyndham 1978; Wykes 1983), an increase in hollows for parrots (Bennett *et al.* 1994) and the presence of large trees for the nests of raptors (Best and Stauffer 1980; Aumann 2001). Species of such sites on Doolgunna and Mooloogool included the Tree Martin, Australian Ringneck, Galah, Weebill, Red-backed Kingfisher and White-plumed Honeyeater.

Irruptive arid-zone species, previously reported by Burbidge and Fuller (2007), such as Little Button-quail, Budgerigar, Crimson Chat, Zebra Finch and Masked Woodswallow, were frequently observed in the 2011 surveys on Doolgunna and Mooloogool following the exceptional rainfall events of May and June 2011. These species were also those associated with the hummock grassland sites of Mooloogool in 2011.

Several species noted in these Gascoyne region conservation reserves were species thought to be expanding their previously known geographic ranges. The 2003 record of the Banded Whiteface is somewhat west of the normal range, while the presence of Grey Fantails in 2007 was at the northeastern edge of their previously documented geographic range. The covey of Brown Quail observed at Noonyereena Pool in 2011 was well south of the previously recorded range (Johnstone and Storr 1998). The Doolgunna occurrences of Jacky Winter and Grey Currawong are near the northern limits of their previously recorded ranges (Johnstone and Storr 2004), while the 2011 records of Elegant Parrots on Doolgunna further strengthens the observations of Higgins (1999) and Davis and Burbidge (2008) concerning the northern extension of this species' range.

The large turnover percentages between the survey samples on Doolgunna and Mooloogool highlight the need for periodic replicate samples of the avifauna (Woinarski and Tidemann 1991; Maron *et al.* 2005). The detection of further recovery and maintenance of biodiversity on conservation rangelands depends on multiple (Maron *et al.* 2005) and periodic surveys (Woinarski and Fisher 2003). Designation of reserves in the Important Bird Area Program also depends on the record of such uncommon species on reserves (Dutson *et al.* 2009). Detection of restricted-range and rare species can be important for management objectives (Davis and Metcalf 2008). In addition, the pres-

ently reported series of samples were all undertaken during winter. As particular summer migrants, for example, the Rainbow Bee-eater and irruptive species, such as the Black and Pied Honeyeaters are more likely summer or spring species at Doolgunna and Mooloogool, it could be important to consider surveys of the avifauna in other seasons of the year despite the difficulties of the sampling conditions.

Delegates at the Australasian Ornithological Conference (2007) rated 'conservation of threatened species', 'conservation of birds and biodiversity in general' and 'monitoring and management' as the most important research and conservation priorities for Australian birds (Miller and Weston 2009). Cooperation between BirdLife Western Australia, the Western Australian Naturalist's Club, and the Western Australian Department of Environment and Conservation to survey the bird assemblages of former pastoral leases supports government and other policies aimed at conserving and understanding Australia's birds (Morton *et al.* 1995).

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Appendix 1. Matrix for bird species recorded at Doolgunna (D) and Mooloogool (M) Conservation Reserves during surveys in 2003, 2007 and 2011.

Common name	Species name	D-'03	D-'07	D-'11	M-'03	M-'07
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>	X			X	
Australasian Pipit	<i>Anthus australis</i>	X	X	X	X	
Australian Bustard	<i>Ardeotis australis</i>	X			X	
Australian Hobby	<i>Falco longipennis</i>		X	X	X	
Australian Magpie	<i>Cracticus tibicen</i>	X		X	X	X
Australian Owlet-nightjar	<i>Aegotheles cristatus</i>			X		
Australian Ringneck	<i>Barnardius zonarius</i>	X	X	X	X	X
Australian Wood Duck	<i>Chenonetta jubata</i>	X				
Banded Lapwing	<i>Vanellus tricolor</i>	X				
Banded Whiteface	<i>Aphelocephala nigricincta</i>	X				
Black Kite	<i>Milvus migrans</i>				X	
Black Swan	<i>Cygnus atratus</i>				X	
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>	X		X	X	
Black-eared Cuckoo	<i>Chrysococcyx osculans</i>		X			
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>	X	X	X	X	X
Black-faced Woodswallow	<i>Artamus cinereus</i>	X	X	X	X	X
Black-fronted Dotterel	<i>Elseyornis melanops</i>	X			X	
Black-shouldered Kite	<i>Elanus axillaris</i>			X		
Bourke's Parrot	<i>Neopsephotus bourkii</i>	X		X	X	
Brown Falcon	<i>Falco berigora</i>	X	X		X	
Brown Goshawk	<i>Accipiter fasciatus</i>			X		
Brown Honeyeater	<i>Lichmera indistincta</i>			X		
Brown Quail	<i>Coturnix ypsilophora</i>			X		
Brown Songlark	<i>Cinclorhamphus cruralis</i>	X		X		
Budgerigar	<i>Melopsittacus undulatus</i>	X	X	X		
Chestnut-breasted Quail-thrush	<i>Cinclosoma castaneothorax</i>	X		X	X	
Chestnut-rumped Thornbill	<i>Acanthiza uropygialis</i>	X	X	X	X	X
Cockatiel	<i>Nymphicus hollandicus</i>	X	X	X	X	
Collared Sparrowhawk	<i>Accipiter cirrhocephalus</i>			X	X	
Common Bronzewing	<i>Phaps chalcoptera</i>	X		X		X
Crested Bellbird	<i>Oreoica gutturalis</i>	X	X	X	X	X
Crested Pigeon	<i>Ocyphaps lophotes</i>	X	X	X	X	X
Crimson Chat	<i>Epthianura tricolor</i>	X		X	X	
Diamond Dove	<i>Geopelia cuneta</i>	X		X	X	
Dusky Woodswallow	<i>Artamus cyanopterus</i>	X				
Elegant Parrot	<i>Neophema elegans</i>	X		X		
Emu	<i>Dromaius novaehollandiae</i>	X	X		X	
Eurasian Coot	<i>Fulica atra</i>				X	
Fan-tailed Cuckoo	<i>Cuculus flabelliformis</i>	X	X			
Galah	<i>Eolophus roseicapillus</i>	X	X	X	X	X
Grey Butcherbird	<i>Cracticus torquatus</i>	X	X		X	X
Grey Currawong	<i>Strepera versicolor</i>			X		
Grey Fantail	<i>Rhipidura fuliginosa</i>		X			X
Grey Honeyeater	<i>Conopophila whitei</i>	X				
Grey Shrike-thrush	<i>Colluricincla harmonica</i>	X	X	X	X	X
Grey Teal	<i>Anas gracilis</i>				X	
Grey-crowned Babbler	<i>Pomatostomus temoralis</i>	X	X	X	X	X
Ground Cuckoo-shrike	<i>Coracina maxima</i>				X	
Hoary-headed Grebe	<i>Poliocephalus poliocephalus</i>				X	
Hooded Robin	<i>Melanodryas cucullata</i>	X		X		
Horsfield's Bronze-Cuckoo	<i>Chalcites basalus</i>		X	X		
Inland Thornbill	<i>Acanthiza apicalis</i>	X	X	X	X	X
Jacky Winter	<i>Microeca fascinans</i>			X		
Little Button-quail	<i>Turnix velox</i>			X		
Little Corella	<i>Cacatua sanguinea</i>			X	X	

Appendix 1. Continued.

Common name	Species name	D-'03	D-'07	D-'11	M-'03	M-'07
Little Crow	<i>Corvus bennetti</i>	X	X		X	X
Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>				X	
Little Woodswallow	<i>Artamus minor</i>		X			X
Magpie-lark	<i>Grallina cyanoleuca</i>	X	X	X	X	X
Masked Woodswallow	<i>Artamus personatus</i>			X		
Mistletoebird	<i>Dicaeum hirundinaceum</i>	X		X		
Mulga Parrot	<i>Psephotus varius</i>	X		X	X	X
Nankeen Kestrel	<i>Falco cenchroides</i>	X		X	X	X
Pacific Black Duck	<i>Anas superciliosa</i>	X				
Pallid Cuckoo	<i>Cacomantis pallidus</i>	X		X	X	
Peregrine Falcon	<i>Falco peregrinus</i>			X		
Pied Butcherbird	<i>Cracticus nigrogularis</i>	X	X	X	X	X
Red-backed Kingfisher	<i>Todiramphus pyrrhopygia</i>		X	X		
Red-capped Robin	<i>Petroica goodenovii</i>	X	X	X	X	X
Redthroat	<i>Pyrrholaemus brunneus</i>	X	X	X		X
Rufous Songlark	<i>Cinclorhamphus mathewsi</i>			X		X
Rufous Whistler	<i>Pachycephala rufiventris</i>	X	X	X	X	X
Rufous-crowned Emu-wren	<i>Stipiturus ruficeps</i>			X		
Sacred Kingfisher	<i>Todiramphus sanctus</i>			X		
Singing Honeyeater	<i>Lichenostomus virescens</i>	X	X	X	X	X
Slaty-backed Thornbill	<i>Acanthiza robustirostris</i>	X	X		X	X
Southern Boobook	<i>Elanus axillaris</i>		X		X	
Southern Whiteface	<i>Aphelocephala leucopsis</i>	X	X	X	X	
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>	X	X	X	X	X
Splendid Fairy-wren	<i>Malurus splendens</i>	X	X	X	X	X
Straw-necked Ibis	<i>Threskiornis spinicollis</i>					
Striated Pardalote	<i>Pardalotus striatus</i>	X			X	
Tawny Frogmouth	<i>Podargus strigoides</i>			X		
Torresian Crow	<i>Corvus orru</i>	X	X	X	X	X
Tree Martin	<i>Petrochelidon nigricans</i>	X	X	X	X	
Varied Sittella	<i>Daphoenositta chrysoptera</i>		X	X	X	
Variegated Fairy-wren	<i>Malurus lamberti</i>	X	X	X	X	X
Wedge-tailed Eagle	<i>Aquila audax</i>	X	X	X	X	
Weebill	<i>Smicrornis brevirostris</i>	X		X		X
Welcome Swallow	<i>Hirundo neoxena</i>	X			X	
Western Bowerbird	<i>Chlamydera guttata</i>	X	X	X	X	
Western Gerygone	<i>Gerygone fusca</i>	X	X	X	X	X
Whistling Kite	<i>Haliastur sphenurus</i>	X		X	X	
White-browed Babbler	<i>Pomatostomus temporalis</i>	X	X	X	X	X
White-browed Treecreeper	<i>Climacteris affinis</i>	X				
White-faced Heron	<i>Egretta novaehollandiae</i>	X		X	X	
White-fronted Honeyeater	<i>Purnella albifrons</i>	X		X	X	
White-necked Heron	<i>Ardea pacifica</i>				X	
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>	X	X	X	X	
White-winged Fairy-wren	<i>Malurus leucopterus</i>	X				
White-winged Triller	<i>Lalage sueurii</i>	X	X	X	X	X
Willie Wagtail	<i>Rhipidura leucophrys</i>	X	X	X	X	X
Yellow-rumped Thornbill	<i>Acanthiza chrysorrhoa</i>	X	X	X	X	
Yellow-throated Miner	<i>Manorina flavigula</i>	X	X	X	X	X
Zebra Finch	<i>Taeniopygia guttata</i>	X	X	X	X	X
Total Species Richness		72	49	73	68	37

Appendix 2. Species recorded at Doolgunna and Mooloogool in 2007 and 2011 and frequency of occurrence in 2011. Doolgunna (D) and Mooloogool (M) survey points and sample species richness ordered by Detrended Correspondence Analysis (DCA) Site and Species Scores.

Species Name	Site codes																	DCA species score					
	D1-07	M2-07	D8-11	D8-07	D1-11	D2-07	D5-07	D2-11	D6-07	D5-11	D6-11	D7-11	D7-07	M1-07	M3-07	D4-07	D3-11	M2-11	M1-11	M3-11	Axis 1	Axis 2	
Grey Fantail	-	25%	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-270	299	
Little Corella	-	12.5%	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-251	363	
White-winged Fairy-wren	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jacky Winter	-	-	-	-	-	-	-	25%	-	-	12.5%	-	-	-	-	-	-	-	-	-	-188	-273	
Yellow-rumped Thornbill	-	25%	-	-	-	-	-	-	-	25%	12.5%	12.5%	-	-	-	-	-	-	-	-	-126	211	
White-browed Babbler	12.5%	-	25%	-	37.5%	12.5%	12.5%	-	-	-	37.5%	25%	-	-	-	-	12.5%	-	-	-	-93	-119	
Chestnut-breasted Quail-thrush	-	-	-	-	-	-	-	12.5%	-	-	-	25%	-	-	-	-	-	-	-	-	-91	-204	
Rufous Songlark	-	12.5%	-	-	12.5%	-	-	-	-	12.5%	-	-	-	12.5%	-	-	-	-	-	-	-91	136	
Little Woodswallow	-	12.5%	-	25%	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-81	359	
Rufous-crowned Emu-wren	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chestnut-rumped Thornbill	25%	37.5%	87.5%	12.5%	87.5%	-	12.5%	25%	25%	75%	12.5%	25%	25%	12.5%	-	12.5%	-	25%	-	-	-78	-36	
Slaty-backed Thornbill	-	-	-	12.5%	-	-	37.5%	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-76	342	
Inland Thornbill	37.5%	37.5%	37.5%	25%	50%	12.5%	25%	-	-	-	25%	25%	25%	12.5%	-	12.5%	-	37.5%	-	-	-67	100	
Splendid Fairy-wren	37.5%	12.5%	37.5%	50%	62.5%	-	12.5%	-	-	50%	25%	25%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	-63	69	
Grey Butcherbird	37.5%	-	-	12.5%	-	-	-	-	-	-	-	-	12.5%	12.5%	-	-	-	-	-	-	-41	95	
Crested Bellbird	87.5%	25%	62.5%	-	12.5%	25%	25%	25%	12.5%	12.5%	62.5%	37.5%	12.5%	12.5%	50%	37.5%	12.5%	-	-	-	-28	-22	
Rufous Whistler	62.5%	25%	12.5%	12.5%	62.5%	-	37.5%	62.5%	12.5%	62.5%	25%	25%	12.5%	12.5%	-	37.5%	62.5%	-	-	-	-28	62	
Grey Shrike-thrush	12.5%	-	12.5%	12.5%	50%	-	-	50%	12.5%	25%	62.5%	12.5%	-	12.5%	-	37.5%	37.5%	-	-	-	-13	-24	
Willie Wagtail	12.5%	62.5%	37.5%	37.5%	12.5%	50%	75%	25%	25%	37.5%	50%	12.5%	25%	12.5%	12.5%	37.5%	37.5%	12.5%	-	-	14	160	
Hooded Robin	-	-	25%	-	-	-	-	25%	-	-	-	25%	-	-	-	37.5%	-	-	-	-	31	-243	
Spiny-cheeked Honeyeater	62.5%	50%	37.5%	37.5%	50%	100%	100%	62.5%	50%	100%	62.5%	75%	25%	37.5%	62.5%	62.5%	62.5%	37.5%	-	-	33	105	
Western Gerygone	12.5%	37.5%	25%	25%	12.5%	12.5%	12.5%	-	25%	25%	12.5%	25%	25%	-	25%	-	50%	-	-	-	33	148	
Variagated Fairy-wren	12.5%	-	-	-	12.5%	-	-	25%	-	25%	-	-	25%	12.5%	12.5%	12.5%	-	-	-	-	37	23	
Red-capped Robin	12.5%	12.5%	37.5%	12.5%	25%	-	37.5%	12.5%	-	37.5%	12.5%	62.5%	25%	12.5%	25%	37.5%	37.5%	12.5%	-	-	51	105	
Redthroat	-	12.5%	-	-	12.5%	-	-	-	-	37.5%	25%	25%	12.5%	-	-	-	-	25%	-	-	55	29	
Southern Whiteface	-	-	12.5%	-	-	-	-	-	-	25%	-	12.5%	-	-	-	25%	-	-	-	-	55	139	
Singing Honeyeater	37.5%	37.5%	62.5%	12.5%	37.5%	37.5%	62.5%	75%	-	75%	75%	87.5%	-	50%	62.5%	75%	25%	12.5%	25%	12.5%	70	14	
Black-faced Cuckoo-shrike	-	12.5%	-	-	-	12.5%	-	-	-	12.5%	12.5%	-	-	-	-	37.5%	-	-	-	-	72	296	
White-winged Triller	-	-	-	25%	-	-	-	-	-	-	-	-	-	-	-	12.5%	12.5%	-	-	-	75	377	
Brown Falcon	12.5%	-	-	-	-	-	-	-	-	12.5%	-	-	12.5%	-	37.5%	-	-	-	-	-	84	-9	
Common Bronzewing	-	12.5%	12.5%	-	-	-	-	-	-	12.5%	-	25%	-	-	-	-	-	25%	-	-	95	-58	
Diamond Dove	-	-	12.5%	-	25%	-	-	37.5%	-	50%	37.5%	62.5%	-	-	-	75%	50%	-	-	-	98	-82	

Appendix 2. Continued.

Species Name	D1-07	M2-07	D8-11	D8-07	D1-11	D2-07	D5-07	D2-11	D6-07	D5-11	D6-11	D7-11	D7-07	M1-07	M3-07	D4-07	D3-07	D4-11	D3-11	M2-11	M1-11	M3-11	Axis 1	Axis 2
Zebra Finch	-	62.5%	25%	37.5%	100%	12.5%	62.5%	50%	25%	100%	100%	87.5%	87.5%	25%	75%	75%	100%	100%	87.5%	12.5%	25%	12.5%	98	121
Western Bowerbird	-	-	25%	-	25%	-	-	-	-	75%	12.5%	12.5%	-	-	-	12.5%	-	50%	37.5%	-	-	-	107	-38
Pied Butcherbird	-	25%	-	12.5%	-	-	-	12.50%	12.5%	-	12.50%	12.50%	37.5%	12.5%	12.50%	-	-	12.5%	25%	12.5%	-	-	111	255
Mulga Parrot	-	-	-	-	12.5%	-	25%	-	-	-	12.5%	25%	-	-	12.5%	12.5%	12.5%	25.00%	25.00%	-	-	-	158	-45
Grey-crowned Babbler	12.5%	-	-	-	12.5%	-	25%	-	-	-	12.5%	12.5%	-	-	12.5%	12.5%	12.5%	37.5%	25%	-	-	120	76	
Mulga Parrot	-	-	-	-	-	-	-	12.5%	-	-	12.5%	12.5%	-	-	12.5%	12.5%	12.5%	25%	25%	-	-	158	-45	
Elegant Parrot	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grey Currawong	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nankeen Kestrel	-	12.5%	-	-	-	-	-	-	-	-	25%	-	-	-	-	-	-	-	-	-	12.5%	-	160	39
Australasian Pipit	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	25%	12.5%	-	-	-	164	13	
Budgerigar	-	-	-	-	-	-	12.5%	25%	-	25%	25%	-	-	-	-	75%	62.5%	50%	12.5%	12.5%	12.5%	176	37	
Little Button-quail	-	-	12.5%	-	75%	-	-	12.5%	-	62.5%	12.5%	37.5%	-	-	-	-	-	50%	75%	50%	25%	184	-50	
Crested Pigeon	-	-	12.5%	-	-	25%	-	-	12.5%	25%	-	-	25%	12.5%	50%	12.5%	50%	50%	12.5%	100%	-	188	-20	
Galah	-	12.5%	-	37.5%	-	12.5%	25%	-	-	12.5%	-	37.5%	-	-	-	-	-	37.5%	87.5%	25%	-	201	2	
Australian Ringneck	-	-	-	-	-	-	-	12.5%	-	12.5%	12.5%	12.5%	25%	75%	75%	12.5%	25%	12.5%	50%	25%	37.5%	205	141	
Yellow-throated Miner	-	12.5%	12.5%	-	25%	-	12.5%	-	12.5%	25%	12.5%	12.5%	25%	25%	25%	12.5%	25%	12.5%	12.5%	25%	25%	213	267	
Red-backed Kingfisher	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37.5%	12.5%	12.5%	-	-	-	216	260
Cockatiel	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25%	-	-	-	-	12.5%	216	260
White-plumed Honeyeater	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	62.5%	50%	87.5%	-	-	-	221	207
Magnie-lark	-	-	-	-	-	-	12.5%	-	-	-	-	-	12.5%	12.5%	-	-	-	-	50%	-	-	12.5%	227	261
Horsfield's Bronze-Cuckoo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	12.5%	-	-	-	233	300
Black-faced Woodswallow	-	-	12.5%	-	-	-	-	12.5%	-	-	-	-	-	12.5%	-	37.5%	25%	37.5%	12.5%	25%	25%	12.5%	239	-34
Tree Martin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	62.5%	75%	-	12.5%	-	244	146
Collared Sparrowhawk	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	12.5%	12.5%	-	12.5%	-	256	-19
Mistletoebird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	12.5%	12.5%	-	261	-56	
Torresian Crow	-	-	-	-	-	-	-	-	-	-	25%	25%	-	-	12.5%	50%	-	12.5%	-	75%	37.5%	269	-101	
Australian Hobby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	12.5%	-	290	1	
Masked Woodswallow	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	12.5%	12.5%	-	290	-172
Whistling Kite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	25%	-	12.5%	307	6	
Crimson Chat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25%	12.5%	50%	25%	339	-101	
Brown Songlark	-	-	-	-	-	-	-	-	-	12.5%	12.5%	-	-	-	-	-	-	-	25%	12.5%	12.5%	344	171	
Varied Sittella	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-
Wedge-tailed Eagle	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-
White-fronted Honeyeater	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-	-
Bourke's Parrot	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-	-	-	-	-	-	-	-	-
Black-breasted Buzzard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 2. Continued.

Species Name	D1-07	M2-07	D8-11	D8-07	D1-11	D2-07	D5-07	D2-11	D6-07	D5-11	D6-11	D7-11	M1-07	M3-07	D4-07	D3-07	D4-11	D3-11	M2-11	M1-11	M3-11	Axis 1	Axis 2
Australian Magpie	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	25%	-	410	-84
Weebill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37.5%	-	-	-	-	-
Brown Goshawk	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	-	-	-
Ground Cuckoo-shrike	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	-
Little Crow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5%	-	-
DCA Axis 1 Site Score	0	5	19	21	26	31	33	37	39	58	58	58	64	90	94	113	119	123	152	222	230	-	-
DCA Axis 2 Site Score	51	123	22	148	35	88	117	0	88	49	30	23	119	109	52	130	49	83	4	17	98	-	-
Site richness value	18	23	23	17	22	11	20	22	11	28	28	29	17	14	17	23	33	37	27	17	13	-	-