

Winter bird assemblages of the Fortescue Marshes and surrounding vegetation, Pilbara Region, Western Australia

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Abstract. The Fortescue Marshes is an Important Bird Area (IBA) in the Pilbara region of northwestern Western Australia. The marshes are presently part of Roy Hill, Marillana, Hillside and Mulga Downs Stations, all presently working cattle stations. Portions of each station will be relinquished from current pastoral leases in 2015. Following an Indigenous Land Use Agreement, the land will be vested in the Conservation Commission and jointly managed by the Western Australia Department of Parks and Wildlife as a conservation estate. The birds of four open-water pools, 21 terrestrial sites from Roy Hill Station and 23 terrestrial sites from Mulga Down Station were surveyed by volunteers of BirdLife Western Australia between 10–25 July 2012. A total of 122 avian species was recorded. Thirty species of waterbirds were observed on open-water pools, with Plumed Whistling Duck, Eurasian Coot, Grey Teal and Australian Pelican, the most numerous. Ordination analyses of bird surveys from permanently marked surrounding terrestrial sites indicated primary avian differences were related to vegetation type. Average species richness of terrestrial site samples surrounding the wetlands was 24 species per site, with species richness thought to relate to vegetation structure complexity. Riparian eucalypt woodlands were the richest sites averaging 30 species per site. Samphire sites had the poorest assemblages with species richness averaging 20 species per site. Mulga woodlands and spinifex sites were intermediate in species richness. A sparse understory, attributed to grazing damage, may relate to the paucity of small insectivores, such as the Chestnut-rumped Thornbill, while increased frequencies of many other bird species reported previously in the literature could be related to the presence of the marsh providing a seasonal water source in this generally arid, inland region. Conservation, rehabilitation and continued protection of the region should be encouraged.

Keywords. Arid-zone bird assemblages, avian species/vegetation interactions, grazing impacts, species richness, waterbirds

Introduction

The Fortescue Marshes is a region of lakes and wetlands of national significance (Kendrick 2003) and one of the largest Important Bird Area (IBA) in Western Australia (Dutson *et al.* 2005). It is the largest wetland in the Pilbara region and provides an important seasonal habitat for waterbirds (Halse *et al.* 2005). The surrounding samphire salt marshes, spinifex hummock grasslands, mulga wood-

lands and eucalypt riparian woodlands provide habitat for a wide range of terrestrial birds. The Fortescue Marshes is also the most recent locality for a confirmed Western Australian sighting of the critically endangered Night Parrot (*Pezoporus occidentalis*) (Davis and Metchalf 2008). Portions of the pastoral leases of Roy Hill, Marillana, Hillside and Mulga Downs Stations will be relinquished in 2015, to put the Fortescue Marshes and some surrounding lands under the joint control

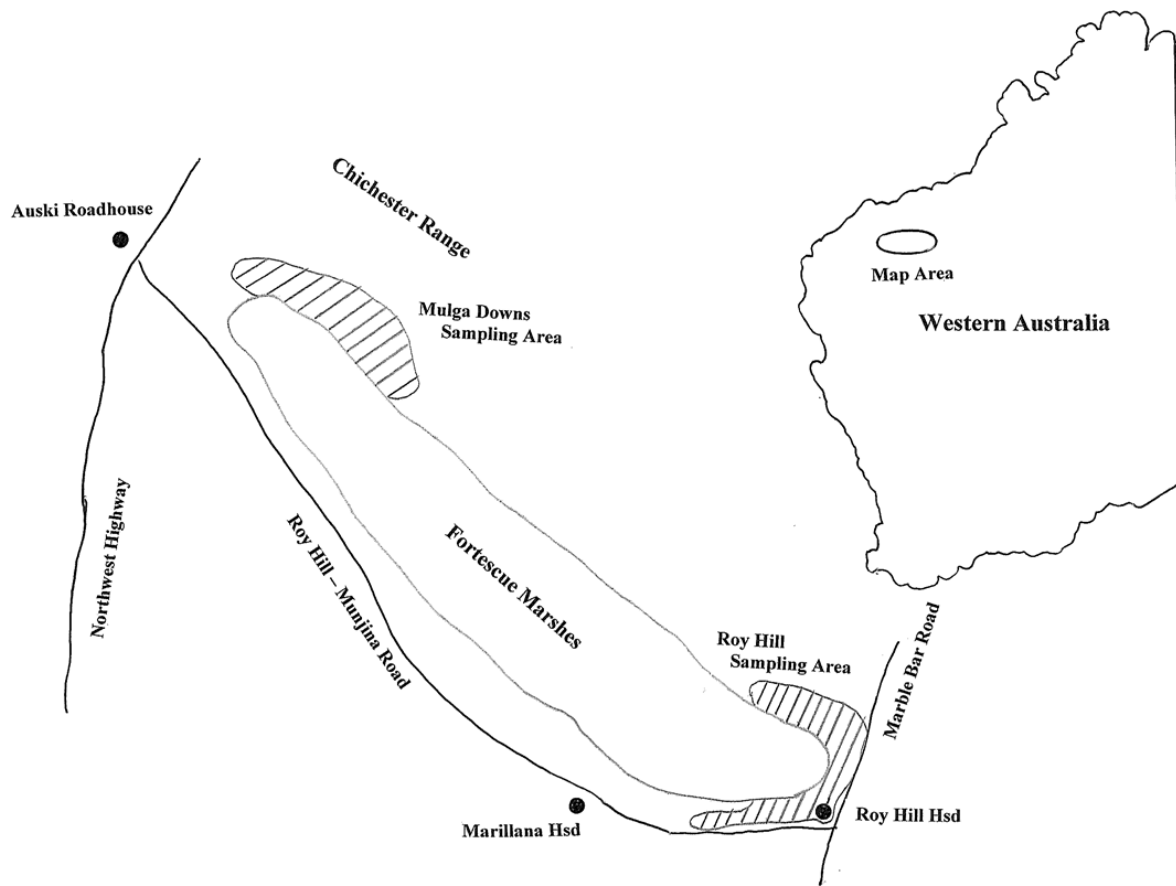


Figure 1. Map of the study area, highlighting the general location of the Fortescue Marshes and the general regions of the terrestrial survey sites on Roy Hill Station at the east end of the marshes and on Mulga Downs Station at the northwest end of the marshes.

of the Conservation Commission and the Western Australia Department of Parks and Wildlife under an Indigenous Land Use Agreement. Management priorities will then change from predominantly cattle grazing to nature conservation. The objectives of this study were: 1) to document winter waterbird populations in a number of open water pools; 2) to survey the terrestrial avifauna of a range of locations on Roy Hill and Mulga Downs Stations; and 3) to determine possible bird assemblage/habitat interaction and compare the avifauna of the two geographically-separated stations. The present study was designed to provide baseline information to determine the effects of changes in management priorities on the avifauna of this region.

Methods

The Fortescue Marshes are a large area of ephemeral pools and poorly drained sections of the upper Fortescue River, situated approximately 100 km north northwest of Newman in the Pilbara region of Western Australia (Figure 1). Bed levels of the marshes are approximately 400 m above sea level in the Hamersley Basin, situated between the Chichester and Hamersley Ranges. Rainfall in the region is primarily influenced by tropical cyclone systems of January to March, with

the long-term average rainfall at Newman of 312 mm (<http://www.bom.gov.au/climate/averages/>). Prior to the survey period, the region experienced large cyclonic rainfall events in January and February 2011 and January 2012. More than 460 mm of rain fell in January 2012, but subsequent rainfall events were scarce. Temperatures in the region are generally high with summer maxima commonly between 35 and 40°C and winter maxima typically 22–30°C. Annual evaporation greatly exceeds annual rainfall.

Four major vegetation communities are found in and around the Fortescue Marshes (Beard 1975): halophilic shrubland (samphire) dominated by *Pachycornia triandra*, *Atriplex cinerea* and *Arthrocneum halocnemoides*; hummock grassland (spinifex), typically comprised of *Triodia basedowii* and *T. pungens*; mulga woodland (mulga) with trees of *Acacia aneura* and an understory dominated by *A. victoriae* and *A. tetragonophylla*; and stream-course eucalypt woodland (riparian) dominated by *Eucalyptus microtheca* and *E. camaldulensis*. The avifauna has previously been included in Kikkawa and Pearse's (1969) Central Province of the Western Faunal Sub-Region.

Two geographic regions, one on Roy Hill Station on the eastern edge of the marshes and the second on Mulga Downs Station, some 30km to the northwest, were selected for intensive survey (Figure 1). Avifauna

Table 1. Locations and habitat type for avifauna survey sites at Roy Hill (RH) and Mulga Downs (MD) Stations. Downs Station at the northwest end of the marshes.

Site Name	Latitude	Longitude	Habitat Type
Coondiner (RH)	22°43'25.8"	119°39'22.7"	Open Water
14 Mile (RH)	22°33'11.0"	119°51'49.0"	Open Water
Native Well (RH)	22°30'43.4"	119°45'51.3"	Open Water
RH 11	22°30'30.1"	119°46'56.1"	Samphire shrubland
RH 13	22°33'39.0"	119°55'11.0"	Samphire shrubland
RH 17	22°32'08.0"	119°48'28.0"	Samphire shrubland
RH 18	22°31'04.0"	119°41'08.0"	Riparian woodland
RH 19	22°29'50.0"	119°50'13.0"	Riparian woodland
RH 20	22°39'27.5"	119°46'02.3"	Samphire shrubland
RH 61	22°32'50.0"	119°52'27.7"	Mulga woodland
RH 62	22°32'50.0"	119°52'27.8"	Mulga woodland
RH 63	22°34'06.7"	119°58'29.6"	Mulga woodland
RH 64	22°33'50.5"	119°58'06.5"	Mulga woodland
RH 65	22°32'34.9"	119°54'58.2"	Mulga woodland
RH 66	22°32'04.3"	119°52'02.5"	Samphire shrubland
RH 67	22°32'32.6"	119°52'06.9"	Mulga woodland
RH 68	22°32'49.6"	119°54'05.7"	Mulga woodland
RH 69	22°33'23.0"	119°54'40.0"	Riparian woodland
RH 70	22°32'28.0"	119°52'20.3"	Mulga woodland
RH 71	22°39'37.6"	119°55'31.3"	Spinifex grassland
RH 72	22°39'38.6"	119°53'33.1"	Spinifex grassland
RH 73	22°40'11.5"	119°52'04.5"	Spinifex grassland
RH 74	22°42'41.2"	119°42'45.0"	Mulga woodland
RH 75	22°43'25.8"	119°39'22.7"	Riparian woodland
RH 76	22°42'41.0"	119°41'26.8"	Mulga Woodland
Mulga Downs Pool	22°21'14.2"	119°12'34.8"	Open Water
MD 1	22°13'35.0"	119°02'33.1"	Mulga woodland
MD 2	22°13'35.0"	119°02'33.1"	Mulga woodland
MD 3	22°13'28.4"	119°03'00.2"	Riparian woodland
MD 4	22°13'45.6"	119°03'51.2"	Spinifex grassland
MD 5	22°16'13.9"	119°05'22.8"	Riparian woodland
MD 6	22°18'11.0"	119°06'08.4"	Riparian woodland
MD 7	22°18'26.7"	119°07'31.8"	Spinifex grassland
MD 8	22°17'59.7"	119°08'58.8"	Mulga woodland
MD 9	22°18'44.7"	119°09'00.1"	Samphire shrubland
MD 10	22°18'55.2"	119°10'18.1"	Samphire shrubland
MD 11	22°12'21.1"	119°12'21.0"	Spinifex grassland
MD 12	22°20'13.7"	119°12'34.7"	Samphire shrubland
MD 13	22°19'02.0"	119°14'59.7"	Mulga woodland
MD 14	22°18'46.4"	119°14'06.3"	Mulga woodland
MD 15	22°18'28.3"	119°12'42.0"	Mulga woodland
MD 16	22°17'32.6"	119°12'48.2"	Mulga woodland
MD 17	22°17'04.3"	119°13'01.4"	Mulga woodland
MD 18	22°17'00.6"	119°12'11.9"	Mulga woodland
MD 19	22°17'57.5"	119°08'05.8"	Mulga woodland
MD 20	22°17'16.6"	119°05'01.3"	Riparian woodland
MD 21	22°14'16.9"	119°05'40.7"	Mulga woodland
MD 22	22°18'30.3"	119°07'56.7"	Spinifex grassland
MD 24	22°20'22.1"	119°16'55.8"	Samphire shrubland

sampling of 10–25 July 2012 was carried out from four open water pools and in 44 terrestrial sites in the surrounding vegetation (Table 1). Waterbird densities were estimated on open-water pools from 1–4 visits during the survey period. Avifauna documentation of terrestrial sites employed fixed-effort sampling techniques (Elphick 1997; Rosenstock *et al.* 2002; Watson 2003, 2004). The surveys utilized 500 m-radius plots sampled for the presence of bird species during a 30-minute period in each of the 90° quadrants of the plots. All sites were monitored once in the morning and once in the afternoon of different days. Two to three experienced birdwatchers from BirdLife Western Australia were employed in each quadrant to simultaneously acquire all field data for each sample. Although the observers varied in their ability to detect and identify bird species, variation in competence among reasonably well-trained observers does not generally invalidate conclusions regarding major ecological patterns (Lindenmayer *et al.* 2009).

Total species richness for each site was the total number of species observed during the two survey periods. Species richness was also determined for each station and mean richness was also determined for each vegetation type. Frequency of species occurrence values from the percentage of the eight quadrants (each sampling point with four 90° quadrants, each sampled in a morning and an afternoon) containing a particular species provided a quantitative indication of the likelihood that a bird species would be encountered. The matrix of the species frequency of occurrence by sample site was analysed by Detrended Correspondence Analysis (DCA) ordination to reveal patterns of bird community structure (Jongman *et al.* 1995). Nomenclature of birds followed Christidis and Boles (2008).

Results

Overall avifauna assemblage

A total of 122 avian species (72 non-passerines and 50 passerines) was recorded in the Fortescue River pools and surrounding terrestrial habitats of Roy Hill and Mulga Downs Stations (Appendix 1). Of the 72 non-passerines, there were 15 diurnal raptors, three nocturnal raptors and six parrots. Of the 50 passerines, there were 12 species of the Meliphagidae (honeyeaters and chats). Surveys on the open water pools recorded 30 species. There were 64 species recorded in the 21 permanent terrestrial survey plots on Roy Hill and 71 species in the 23 survey plots on Mulga Downs. Although not used in subsequent analyses, 14 additional species were recorded outside the permanent survey plots or open pool survey periods.

Waterbirds

A total of 30 species of waterbirds was recorded from

the four accessible open water pools of the Fortescue River (Table 2). The most common waterbird species were Eurasian Coot, Hardhead and Plumed Whistling Duck, Grey Teal, and Australian Pelican, while sightings of the Freckled Duck, White-necked Heron, Little Egret, Little Pied Cormorant, Black-winged Stilt and Australasian Grebe were much more limited.

Terrestrial birds

The most commonly recorded species of the terrestrial habitats surrounding the Fortescue Marshes was the Willy Wagtail, which was found in every sampling site and in more than 60% of the individual quadrant samples. Other ubiquitous species included the Zebra Finch, Red-capped Robin, Spiny-cheeked and Singing Honeyeaters and Rufous Whistler. Several nomadic species were common during the survey period, including Diamond Dove, Budgerigar, Cockatiel, Black-faced Woodswallow, Little Button-quail, White-winged Triller and Crimson Chat. Most species were equally common on both stations, except for Cockatiels and Chestnut-rumped Thornbills. Cockatiels were much more common on Roy Hill Station, where as Chestnut-rumped Thornbills were much more common on Mulga Downs Station.

Of the terrestrial birds recorded in habitats at Roy Hill Station and Mulga Downs Station, 67 species were observed in two or more survey plots and analysed for correspondence by the DCA ordination analysis (Appendices 2 & 3). The first axis of the DCA site ordination accounted for 29% of the sample variance and separated the avian assemblages in samphire from the other vegetation communities (Figure 2). The second axis of the DCA ordination explained another 13% of the sample variance and generally separated bird assemblages of mulga woodlands from those in riparian eucalypt woodlands. Despite the Roy Hill Station sites being 30–50 km from the Mulga Downs sites, the ordination results did not reveal bird assemblage differences based on this geographic separation.

The DCA species ordination values identified those bird species associated with the particular vegetation communities (Appendices 2 & 3). Species with high DCA axis 1 scores were strongly associated with the samphire vegetation and included the Fairy Martin, Horsfield's Bushlark, Brown Songlark, Australasian Pipit, White-winged Fairy-wren and a number of raptors. Species closely associated with mulga woodlands (low scores on both DCA 1 & 2 axes) included White-browed Babbler, Chestnut-rumped and Slaty-backed Thornbills and Bourke's Parrot. Species with low DCA axis 1 scores and high DCA axis 2 scores, associated mainly with the riparian eucalypt vegetation, included Western Gerygone, Grey Shrike-thrush, White-fronted, Brown and Grey-headed Honeyeaters, Mistletoebird, Crested Bellbird, Australian Ringneck and Little Corella.

A number of uncommon species and species at the edge of their geographic range were recorded during the surveys. These were the White-bellied Sea Eagle, Whiskered Tern, Bourke's Parrot, Inland Thornbill, Red-browed Pardalote, Western Gerygone, Grey Fantail, Orange Chat and the Grey-headed and White-fronted Honeyeaters

Species richness

The species richness of the terrestrial sampling plots surrounding the Fortescue Marshes averaged 23.9 ± 5.0 species per site (Table 3). There was no overall difference between species richness of samples on Roy Hill

Station (23.9 ± 5.5) and those on Mulga Downs Station (23.0 ± 4.5). Determination of species richness of the particular vegetation types indicated that the riparian eucalypt-dominated plots (29.5 ± 3.0) were the richest assemblages. Samphire sites (20.2 ± 3.5) were the most depauperate on average. Roy Hill mulga sites (21.6 ± 3.7) were relatively low in species richness compared to Mulga Downs mulga sites (20.0 ± 3.1). Spinifex site richness on Roy Hill was high (29.3 ± 4.7) compared to similar habitat sites on Mulga Downs (23.7 ± 4.1).

Table 2. Waterbird counts at the open water sites of the Fortescue Marshes. The data presented are means of 1-4 counts from different times of day and different days.

Species	Coondiner	Native Well	9 Mile	Mulga Downs
Plumed Whistling Duck			867	1000
Freckled Duck			7	
Black Swan		49	18	120
Australian Shelduck	1	29	5	12
Australian Wood Duck			12	
Pink-eared Duck			11	30
Grey Teal	35		36	800
Pacific Black Duck			3	
Hardhead		15	6	300
Australasian Grebe				1
Hoary-headed Grebe			41	2
Australasian Darter		1	5	1
Little Pied Cormorant			1	
Little Black Cormorant	25		18	40
Australian Pelican	5		2	500
White-necked Heron		1		1
Eastern Great Egret	2	1	1	5
White-faced Heron			1	3
Little Egret		1	1	
Straw-necked Ibis	5	3	1	5
Royal Spoonbill		4	8	
Yellow-billed Spoonbill	1		3	
Black-tailed Native-hen			5	
Eurasian Coot				1500
Black-winged Stilt			5	
Red-capped Plover			3	100
Black-fronted Dotterel	5	64	19	50
Red-kneed Dotterel		1		
Caspian Tern				20
Whiskered Tern		11	14	20

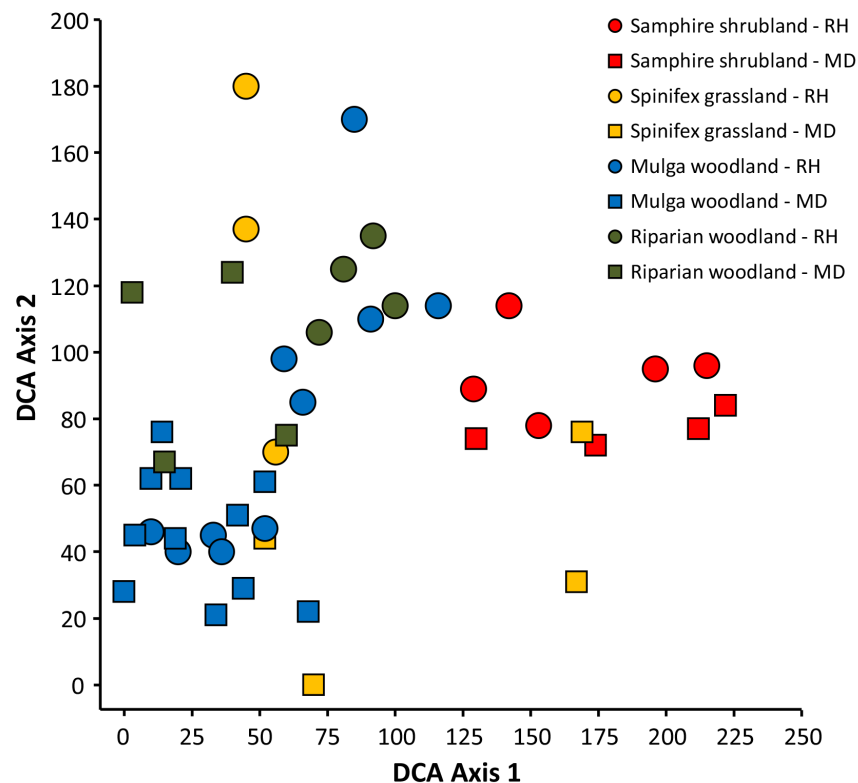


Figure 2. DCA site ordination axis 1 versus axis 2 scores of Fortescue Marsh terrestrial plot frequency data. Symbols include numbered Roy Hill sites (diamonds) and Mulga Downs (squares) with red for samphire, yellow for spinifex, blue for mulga and green for riparian vegetation types Station at the northwest end of the marshes.

Discussion

Birds of open water pools

There is a growing awareness of the importance of arid zone wetlands as important breeding habitats and drought-period refuges for waterbirds (Olsen and Weston 2004). The Fortescue Marshes, Lake Gregory and Mandora Marsh in northern Western Australia support over a million waterbirds during the dry season in some years and, as such, are considered important breeding sites (Halse *et al.* 2005). Although many of the open water pools of the Fortescue Marshes are inaccessible, those surveyed in our study indicated some species could be extremely numerous. Plumed Whistling Duck, Eurasian Coot, Grey Teal and the Australian Pelican were the most common species, each with hundreds of individuals. Studies by van Leeuwen (2004) between 1999 and 2003 reported 47 species of waterbirds utilising the pools of the Fortescue Marsh region compared to the 30 species recorded in this study in July 2012.

Changes in the frequency and extent of flooding have been shown to affect breeding opportunities for Australian waterbirds (Roshier *et al.* 2002). Water extraction, water storage, sedimentation and climate change can have impacts on the distribution of refugia

during dry periods. Wetland conservation is essential for breeding and maintenance of populations of waterbirds between flood events (Maher and Braithwaite 1992; Halse *et al.* 2005; Kingford *et al.* 2010). Opportunities to manage waterfowl numbers at particular locations are limited because processes influencing the population dynamics of waterfowl occur at broad scales in response to a stochastic, variable climate and corresponding resource availability (Roshier *et al.* 2002).

In the Fortescue Marshes, the regions surrounding the marshlands are subjected to cattle grazing, populations of feral animals, iron ore mining and water extraction, all of which could have significant direct and indirect impacts on the avifauna (Barber and Jackson 2011). The planned 2015 Department of Parks and Wildlife acquisition of portions of Marillana, Roy Hill, Hillside and Mulga Downs Stations surrounding the marshes is essential to the continued maintenance of the habitat and the long-term survival of populations of birds in this region of the Pilbara (Shepherd and van Leeuwen 2011).

Terrestrial bird assemblages

Terrestrial bird assemblages in arid, northwestern Western Australia vary in relation to environmental

Table 3. Mean avian species richness (\pm sd) values for terrestrial survey sites on Roy Hill and Mulga Down Stations along the margins of the Fortescue Marshes.

Habitat Type	Roy Hill	Mulga Downs	All Sites
Riparian	29.5 \pm 3.0	31.3 \pm 2.1	29.5 \pm 3.0
Samphire	20.6 \pm 4.3	20.0 \pm 3.1	20.2 \pm 3.5
Mulga	21.6 \pm 3.7	26.0 \pm 3.0	23.2 \pm 4.1
Spinifex	29.3 \pm 4.7	23.7 \pm 4.1	25.7 \pm 5.0

parameters (Burbidge *et al.* 2000), dominant vegetation community structure (Burbidge *et al.* 2010) and temporal conditions (Bell *et al.* 2013). Avifaunal assemblages of the Carnarvon Basin appear to be determined primarily by climatic factors, particularly diurnal temperature range and precipitation, with substrate and vegetation characteristics operating at a more local scale (Burbidge *et al.* 2000). Avian biogeographic patterns in the Pilbara in general, however, appear more related to vegetation structure with substrate variables and environmental parameters of lesser importance (Burbidge *et al.* 2010). Annual variation in precipitation has also been shown to influence the composition of avifaunal associations of inland regions of the Gascoyne (Bell *et al.* 2013). Annual variation in the flowering intensity of eucalypts may also influence the avian assemblages of Western Australian habitats (Bell *et al.* 2007).

The primary influence on the composition of avifaunal assemblages in the Fortescue Marshes related to vegetation community structure with little difference due to the geographic separation of the two stations. Generally, the avian assemblage samples of Roy Hill were comparable to those of Mulga Downs with both regions showing strong influences of the vegetation types on avifaunal assemblage composition.

Ubiquitous species

The most widely spread and common species of the terrestrial habitats of the Fortescue Marshes were Willy Wagtail, Black-faced Woodswallow, Singing Honeyeater, Zebra Finch and Diamond Dove. These species were also the most common species in the regional study of the Pilbara reported by Burbidge *et al.* (2010). Also, a number of the commonly recorded species in our study included species that are considered to be highly nomadic, including the Budgerigar, Cockatiel, Diamond Dove, Black-faced Woodswallow, White-winged Triller, Little Button-quail and Crimson Chat. The Cockatiel was found much more commonly on Roy Hill Station, but none of these nomadic species appeared to favour any particular vegetation type.

Birds of specific habitats

Avian species more commonly recorded in the salt-affected samphire habitats of the Fortescue Marshes

included the Brown Songlark, White-winged Fairy-wren, Horsfield's Bush-lark, Australasian Pipit and Fairy Martin. The White-winged Fairy-wren and Australasian Pipit were species also found commonly in samphire vegetation near Olympic Dam in South Australia (Reid *et al.* 2000). Although the Fortescue Marshes Night Parrot sighting of Davis and Metcalf (2008) was noted to be from samphire vegetation, we were not successful in sighting this most enigmatic of Australian species.

Several species identified as occurring regularly in samphire habitats also occurred in spinifex-dominated sites. These included the White-winged Fairy-wren and Australasian Pipit. The Spinifexbird, however, was especially confined to sites with a dense covering of spinifex. Bird species associated with spinifex grasslands in our study have previously been reported to be wide-spread species, such as Singing Honeyeater, Zebra Finch, Willie Wagtail and Diamond Dove, and other species which frequent open areas or areas with only scattered trees, such as Torresian Crow, Brown Falcon, Australasian Pipit, Little Button-quail and Horsfield's Bushlark (Burbidge *et al.* 2010). Species common on grasslands of the Gascoyne to the south of the present study area included Australian Magpie, Brown Songlark, Crimson Chat, Magpie-lark, Galah and Torresian Crow (Bell *et al.* 2013). Several species of Fairy-wrens were also conspicuous in spinifex grasslands of the central Tanami Desert (Paltridge and Southgate 2001). Burbidge *et al.* (2010) noted Spinifex Pigeon was also common in the Pilbara; however, this species was uncommon in our study.

Species strongly associated with mulga woodlands of the regions surrounding the Fortescue Marshes included the White-browed Babbler, Chestnut-rumped and Slaty-backed Thornbills and Bourke's Parrot. Many of the species highlighted in our study as species of mulga woodlands have been noted previously (Cody 1994; Recher and Davis 1997; Burbidge *et al.* 2000; 2010). In the large scale Burbidge *et al.* (2010) study of the Pilbara, species common to the mulga included Singing Honeyeater, Rufous Whistler, Zebra Finch, Pied Butcherbird, Willie Wagtail and Crested Bellbird, Spiny-cheeked Honeyeater and Chestnut-rumped and Inland Thornbills.

In our study, the Chestnut-rumped Thornbill was less common in the Roy Hill sites compared to those

from the Mulga Downs sites. Chestnut-rumped Thornbill was one of the most common species in other Pilbara region reports (Burbidge *et al.* 2010; Bell *et al.* 2013). Severe cattle grazing impacts on the shrub-layer density on Roy Hill Station is suspected, as bird species reliant on dense understory are vulnerable to the negative impacts of grazing (Reid *et al.* 2000; Martin and Possingham 2005; Martin and McIntyre 2007). Thornbills and Robins have previously been recorded as favouring the shrub vegetation and ground layers (Bell *et al.* 2010). Cousin (2004) reports that small insectivorous species, such as Western Yellow Robin, tend to occupy sites with higher loads of leaf and logs and recommend exclusion of grazing stock as a conservation measure.

Species associated with eucalypt-dominated riparian woodlands of the Fortescue Marshes margins included the White-plumed Honeyeater, Weebill, Striated and Red-browed Pardalotes, Australian Ringneck and Little Corella. In arid inland Australia, species such as Peaceful Dove, Little Corella, Blue-winged Kookaburra, Black-tailed Treecreeper, Yellow-throated Miner, Pied Butcherbird, Magpie-lark and White-plumed Honeyeater are considered common species of riparian habitats (Pavey and Nano 2009; Burbidge *et al.* 2010). Species associated with stream courses of Doolgunna and Mooloogool Stations near Meekatherra also included Red-backed Kingfisher, White-plumed Honeyeater, Tree Martin, Mistletoebird and Pied Butcherbird and a number of the common and widely-distributed species, such as Spiny-cheeked Honeyeater, Galah, Yellow-throated Miner and Zebra Finch (Bell *et al.* 2013).

Species richness

Species richness values for terrestrial sites of the Fortescue Marshes were comparable or slightly higher than site richness values recorded for other regions of the Pilbara (Burbidge *et al.* 2010; Bell *et al.* 2013). Richness values for riverine eucalypt sites in this study averaged 30 species, which was similar to richness values of sites in the Pilbara ($n = 28$) (Burbidge *et al.* (2010) and the Doolgunna and Mooloogool rangelands of the Murchison ($n = 28$) (Bell *et al.* 2013). Vegetation structural heterogeneity and habitat heterogeneity have been correlated with avian species richness in other arid environments of Australia (Pavey and Nano 2009; Schneider and Greisser 2009) and elsewhere (Blendinger 2005). In the vicinity of the Fortescue Marshes, gradually decreasing site species richness may have been related to decreasing structural heterogeneity. The riparian sites included a eucalypt overstory, an understory tree and shrub strata and a grassy ground layer. However, mulga-dominated woodland sites generally had only limited shrub and ground-layer vegetation and the spinifex and samphire-dominated sites had only a single vegetation stratum.

The riparian habitats were the habitats with the greatest species richness among the vegetation types we sampled. Stream-margin sites in other regions of the arid zone of Australia have proven to be species-rich habitats (James *et al.* 1995; Kingston *et al.* 2002; Bell *et al.* 2013). Streamside habitats provide a broad range of feeding substrates (Kitchener *et al.* 2003), drinking water sources for seed-eating birds (Schneider and Griesser 2009), large trees for nest sites and perching locations of raptors (Storr 1984; Aumann 2001) and nesting hollows for parrots (Bennett *et al.* 1994).

Avian richness has also been correlated to high rainfall seasons (Burbidge and Fuller 2007; Bell *et al.* 2013) and the availability of water and nutrients in arid landscapes (James *et al.* 1995). The Fortescue Marshes region could be marginally richer than other Pilbara locations because of the proximity of the sites to the water of the marshes. Both proximity to open water and the influences of higher than normal rainfall in the previous two years may be causative for the slightly increased species richness values of the Fortescue Marshes survey sites.

Long-term data sets provide information and understanding to support evidence-based policy, decision making and conservation management of conservation reserves (Sutherland *et al.* 2004; Fortescue Metals Group 2009; Lindenmayer *et al.* 2012). This study provides baseline data for the avifaunal assemblages of terrestrial habitats surrounding the Fortescue Marshes. The specific GPS locations of the centre points for each survey site and a standardized methodology will allow for future repetitions of the surveys.

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References

- Aumann, T. (2001). The structure of raptor assemblages in riparian environments in the south-west of the Northern Territory, Australia. *Emu* **101**, 293–304.
- Barber, M., and Jackson, S. (2011). 'Water and indigenous people in the Pilbara, Western Australia. A Preliminary Study'. (CSIRO: Water for a Healthy Country Flagship, Canberra.)
- Beard, J. S. (1975). 'Vegetation Survey of Western Australia 1 000 000 Vegetation Series Explanatory Notes to Sheet 5 The Vegetation of the Pilbara Area.' (University of Western Australia Press, Nedlands).
- Bell, D. T., Bell, R. C., and Cousin, J. A. (2010). Winter foraging patterns in the avifauna from south-west Western Australia with special reference to niche differentiation in

- the Acanthizidae and Meliphagidae. *Amytornis* **2**, 1–14.
- Bell, D. T., Bell, R. C., and Loneragan, W. A. (2007). Winter bird assemblages across an aridity gradient in south-west Western Australia. *Journal of the Royal Society of Western Australia* **90**, 219–227.
- Bell, D. T., Luyer, J. R., and Agar, P. K. (2013). Birds of the Doolgunna and Mooloogool Rangelands, northeast Gascoyne Region, Western Australia. *Amytornis* **5**, 1–13.
- Bennett, A. F., Lumsden, L. F., and Nicholls, A. O. (1994). Tree hollows as a resource for wildlife in remnant woodlands: spatial and temporal patterns across the northern plains of Victoria, Australia. *Pacific Conservation Biology* **1**, 222–235.
- Blendinger, P. G. (2005). Foraging behaviour of birds in an arid sand-dune scrubland in Argentina. *Emu* **105**, 67–79.
- Burbidge, A. A., and Fuller, P. J. (2007). Gibson Desert birds: responses to drought and plenty. *Emu* **107**, 126–134.
- Burbidge, A. H., Johnstone, R. E., Fuller, P. J., and Stone, P. (2000). Terrestrial birds of the southern Carnarvon Basin, Western Australia: contemporary patterns of occurrence. *Records of the Western Australian Museum*, Supplement **61**, 449–464.
- Burbidge, A. H., Johnstone, R. H., and Pearson, D. J. 2010. Birds in a vast arid upland: Avian biogeographical patterns in the Pilbara region of Western Australia. *Records of the Western Australian Museum*, Supplement **78**, 247–270.
- Christidis L, and Boles, L (2008). ‘Systematics and Taxonomy of Australian Birds’. (CSIRO Publishing, Canberra.)
- Cody, M. L. (1994). Mulga bird communities, 1, species composition and predictability across Australia. *Australian Journal of Ecology* **19**, 206–219.
- Cousin, J. A. (2004). Habitat selection of the western yellow robin (*Eopsaltria griseogularis*) in a wandoo woodland, Western Australia. *Emu* **104**, 229–234.
- Davis, R. A., and Metcalf, B. M. (2008). The Night Parrot (*Pezoporus occidentalis*) in northern Western Australia: a recent sighting from the Pilbara Region. *Emu* **108**, 233–236.
- Dutson G., Garnett, S., and Gole, C. (2009). ‘Australia’s Important Bird Areas – Key Sites for Bird Conservation. Birds Australia RAOU Conservation Statement No. 15.’ (Birds Australia, Carlton, Victoria.)
- Elphick, C. S. (1997). Correcting avian richness estimates for unequal sampling effort in atlas studies. *Ibis* **139**, 189–190.
- Fortescue Metals Group Ltd. (2009). ‘Fortescue Marshes Management Plan’. (Pilbara Iron Ore and Infrastructure Project, Fortescue Metals Group Ltd. Report 45-PI-En-009, Perth.)
- Halse, S. A., G. B. Pearson, G. B., Hassell, C., Collins, P., Scanlon, M. D., and Minton, C. D. T. (2005). Mandora Marsh, north-western Australia, an arid-zone wetland maintaining continental populations of waterbirds. *Emu* **105**, 115–125.
- James, C. D., Landsberg, J., and Morton, S. R. (1995). Ecological functioning in arid Australia and research to assist conservation of biodiversity. *Pacific Conservation Biology* **2**, 126–142.
- Jongman, R. H. G., ter Braak, D. J. R., and Tongeren, O. F. R. (Eds.) (1995). ‘Data Analysis in Community and Landscapes’. (Cambridge University Press, Cambridge.)
- Kendrick, P. (2003). Pilbara 2 (PIL2 Fortescue Plains subregion). In ‘A Biodiversity Audit of Western Australia’s 53 Biogeographical Subregion in 2002’. (Eds. J. E. May and N. L. McKenzie). pp. 559–567. (Department of Conservation and Land Management, Perth.)
- Kingford, R. T., Roshier, D. A., and Porter, J. L. (2010). Australian waterbirds – time and space travellers in dynamic desert landscapes. *Marine and Freshwater Research* **81**, 875–884.
- Kikkawa, J., and Pearse, K. (1969). Geographic distribution of land birds in Australia – a numerical analysis. *Australian Journal of Zoology* **17**, 821–840.
- Kingston, M. B., Catterall, C. P., and Kordas, G. S. (2002). Use of riparian areas by terrestrial birds of the mulga lands – southwest Queensland. *Sunbird* **32**, 1–14.
- Kitchener, D. J., Dell, J., Muir, B. G., and Palmer, M. (2003). Birds in Western Australian wheatbelt reserves – implications for conservation. *Biological Conservation* **22**, 127–163.
- Lindenmayer, D. B., Wood, J. T., and MacGregor, C. (2009). Do observer differences in bird detection affect inferences from large-scale ecological studies? *Emu* **109**, 100–106.
- Lindenmayer, D. B., Likens, G. E., Andersen, A., Bowman, D., Bull, C. M., Burns, E., Dickmann, C. R., Hoffman, A. A., Keith, D. A., Liddell, M. J., Lowe, A. J., Metcalfe, D. J., Phinn, S. R., Russell-Smith, J., Thurgate, N., and Wardle, G. M. (2012). Value of long-term ecological studies. *Austral Ecology* **37**, 745–757.
- Maher, M. T., and Braithwaite, L. W. (1992). Patterns of waterbird use in wetlands of the Paroo, a river system of inland Australia. *The Rangeland Journal* **14**, 128–142.
- Martin, T. G., and McIntyre, S. (2007). Impacts of livestock grazing and tree clearing on birds of woodland and riparian habitats. *Conservation Biology* **21**, 504–514.
- Martin, T. G., and Possingham, H. P. (2005). Predicting the impact of livestock grazing on birds using foraging height data. *Journal of Applied Ecology* **42**, 400–408.
- Olsen, P., and Weston, M. (2004). ‘The State of Australia’s Birds 2004 Water, Wetlands and Birds’. (Birds Australia, Hawthorne East, Victoria.)
- Paltridge, R., and Southgate, R. (2001). The effect of habitat type and seasonal conditions on fauna in two areas of the Tanami Desert. *Wildlife Research* **28**, 247–260
- Pavey, C. R., and Nano, C. E. M. (2009). Bird assemblages of arid Australia: vegetation patterns have a greater effect than disturbance and resource pulses. *Journal of Arid Environments* **73**, 634–642.
- Read, J. L., Reid, N., and Venables, W. N. (2000). Environmental auditing: Which birds are useful bioindicators of mining and grazing impacts in arid South Australia? *Environmental Management* **26**, 215–232.
- Recher, H. F., and Davis, W. E. (1997). Foraging ecology of a mulga bird community. *Wildlife Research* **24**, 27–43.
- Rosenstock, S. S., Anderson, D. R., Giesen, K. M., Leukering, T., and Carter, M. F. (2002). Landbird counting techniques: current practices and an alternative. *Auk* **119**, 46–53.
- Roshier, D. A., Robertson, A. I., and Kingsford, R. T. (2002). Responses of waterbirds to flooding in an arid region of Australia and implications for conservation.

- Biological Conservation* **106**, 399–411.
- Schneider, N. A., and Griesser, M. (2009). Influence and value of different water regimes on avian species richness in arid inland Australia. *Biodiversity and Conservation* **18**, 457–471.
- Shepherd, K. A., and van Leeuwen, S. J. (2011). *Tecticornia globulifera* and *T. medusa* (subfamily Salicornioideae; Chenopodiaceae), two new priority samphires from the Fortescue Marsh in the Pilbara region of Western Australia. *Telopea* **13**, 349–358.
- Storr, G. M. (1984). Birds of the Pilbara Region, Western Australia. *Records of the Western Australian Museum*, Supplement **16**: 1–63.
- Sutherland, W.L., Pullin, A. S., Dolman, P. M., and Knight, T. M. (2004). The need for evidence-based conservation. *Trends in Ecology and Evolution* **19**, 305–308.
- van Leeuwen, S. J. (2004). Background documentation: Fortescue Marsh visit: Conservation Commission, Western Australia, Friday 1 July 2005. (Unpublished report by the Department of Conservation and Land Management, Karratha, Australia.)
- Watson, D. M. (2003). The ‘standardized search’: An improved way to conduct bird surveys. *Austral Ecology* **28**, 515–525.
- Watson, D. M. (2004). Comparative evaluation of new approaches to survey birds. *Wildlife Research* **31**, 1–11.

Appendix 1. Fortescue Marshes pools and surrounding terrestrial species list for sightings during the July 2012 survey period.

Common name	Species name	Fortescue Pools	Roy Hill	Mulga Downs	Misc. Sightings
Stubble Quail	<i>Coturnix pectoralis</i>			X	
Brown Quail	<i>Coturnix ypsilophora</i>		X		
Plumed Whistling Duck	<i>Dendrocygna eytoni</i>	X			
Freckled Duck	<i>Stictonetta naevosa</i>	X			
Black Swan	<i>Cygnus atratus</i>	X			
Australian Shelduck	<i>Tadorna tadornoides</i>	X			
Australian Wood Duck	<i>Chenonetta jubata</i>	X			
Pink-eared Duck	<i>Malacorhynchus membranaceus</i>	X			
Grey Teal	<i>Anas gracilis</i>	X			
Pacific Black Duck	<i>Anas superciliosa</i>	X			
Hardhead	<i>Aythya australis</i>	X			
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>	X			
Hoary-headed Grebe	<i>Poliocephalus poliocephalus</i>	X			
Common Bronzewing	<i>Phaps chalcoptera</i>		X	X	
Flock Bronzewing	<i>Phaps histrionica</i>				X
Crested Pigeon	<i>Ocyphaps lophotes</i>		X	X	
Spinifex Pigeon	<i>Geophaps plumifera</i>		X		
Diamond Dove	<i>Geopelia cuneata</i>		X	X	
Peaceful Dove	<i>Geopelia striata</i>		X		
Tawny Frogmouth	<i>Podargus strigoides</i>			X	
Spotted Nightjar	<i>Eurostopodus argus</i>		X	X	
Australian Owlet-nightjar	<i>Aegotheles cristatus</i>			X	
Australasian Darter	<i>Anhinga novaehollandiae</i>	X			
Little Pied Cormorant	<i>Microcarbo melanoleucos</i>	X			
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>	X			
Australian Pelican	<i>Pelecanus conspicillatus</i>	X			
Eastern Great Egret	<i>Ardea modesta</i>	X			
White-necked Heron	<i>Ardea pacifica</i>	X			
Little Egret	<i>Egretta garzetta</i>	X			
White-faced Heron	<i>Egretta novaehollandiae</i>	X			
Straw-necked Ibis	<i>Threskiornis spinicollis</i>	X			
Yellow-billed Spoonbill	<i>Platalea flavipes</i>	X			
Royal Spoonbill	<i>Platalea regia</i>	X			
Black-shouldered Kite	<i>Elanus axillaris</i>		X	X	
Square-tailed Kite	<i>Lophoictinia isura</i>				X
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>				X
White-bellied Sea Eagle	<i>Haliaeetus leucogaster</i>				X
Whistling Kite	<i>Haliastur sphenurus</i>		X	X	
Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>			X	
Brown Goshawk	<i>Accipiter fasciatus</i>		X	X	
Swamp Harrier	<i>Circus approximans</i>				X
Spotted Harrier	<i>Circus assimilis</i>		X	X	
Wedge-tailed Eagle	<i>Aquila audax</i>		X	X	
Little Eagle	<i>Hieraaetus morphnoides</i>			X	
Brown Falcon	<i>Falco berigora</i>		X	X	
Nankeen Kestrel	<i>Falco cenchroides</i>		X	X	
Australian Hobby	<i>Falco longipennis</i>		X	X	
Peregrine Falcon	<i>Falco peregrinus</i>				X
Australian Spotted Crake	<i>Porzana fluminea</i>				X
Black-tailed Native Hen	<i>Tribonyx ventralis</i>	X			
Eurasian Coot	<i>Fulica atra</i>	X			
Australian Bustard	<i>Ardeotis australis</i>		X	X	
Black-necked Stilt	<i>Himantopus himantopus</i>	X			
Red-capped Plover	<i>Charadrius ruficapillus</i>	X			
Black-fronted Dotterel	<i>Elsyornis melanops</i>	X			
Red-kneed Dotterel	<i>Erythronyx cinctus</i>	X			

Appendix 1. Continued

Common name	Species name	Fortescue Pools	Roy Hill	Mulga Downs	Misc. Sightings
Little Button-quail	<i>Turnix velox</i>		X	X	
Caspian Tern	<i>Hydroprogne caspia</i>	X			
Whiskered Tern	<i>Chlidonias hybrida</i>	X			
Galah	<i>Eolophus roseicapillus</i>		X	X	
Little Corella	<i>Cacatua sanguinea</i>		X	X	
Cockatiel	<i>Nymphicus hollandicus</i>		X	X	
Australian Ringneck	<i>Barnardius zonarius</i>		X	X	
Mulga Parrot	<i>Psephotus varius</i>				X
Budgerigar	<i>Melopsittacus undulatus</i>		X	X	
Bourke's Parrot	<i>Neopsephotus bourkii</i>		X	X	
Pallid Cuckoo	<i>Cacomantis pallidus</i>		X	X	
Southern Boobook	<i>Ninox novaeseelandiae</i>			X	
Blue-winged Kookaburra	<i>Dacelo leachii</i>				X
Red-backed Kingfisher	<i>Todiramphus pyrrhopygius</i>		X	X	
Sacred Kingfisher	<i>Todiramphus sanctus</i>		X		
Rainbow Bee-eater	<i>Merops ornatus</i>		X	X	
Splendid Fairy-wren	<i>Malurus cyaneus</i>				X
Variegated Fairy-wren	<i>Malurus lamberti</i>		X	X	
White-winged Fairy-wren	<i>Malurus leucopterus</i>		X	X	
Weebill	<i>Smicrornis brevirostris</i>		X	X	
Western Gerygone	<i>Gerygone fusca</i>			X	
Inland Thornbill	<i>Acanthiza apicalis</i>			X	
Slaty-backed Thornbill	<i>Acanthiza robustirostris</i>		X	X	
Chestnut-rumped Thornbill	<i>Acanthiza uropygialis</i>		X	X	
Red-browed Pardalote	<i>Pardalotus rubricatus</i>		X	X	
Striated Pardalote	<i>Pardalotus striatus</i>				X
Pied Honeyeater	<i>Certhionyx variegatus</i>		X	X	
Grey-headed Honeyeater	<i>Lichenostomus keartlandi</i>		X		
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>		X	X	
Singing Honeyeater	<i>Lichenostomus virescens</i>		X	X	
White-fronted Honeyeater	<i>Purnella albifrons</i>		X	X	
Yellow-throated Miner	<i>Manorina flavigula</i>		X	X	
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>		X	X	
Grey Honeyeater	<i>Conopophila whitei</i>				X
Orange Chat	<i>Epthianura aurifrons</i>		X		
Crimson Chat	<i>Epthianura tricolor</i>		X	X	
Black Honeyeater	<i>Sugomel niger</i>		X	X	
Brown Honeyeater	<i>Lichmera indistincta</i>		X	X	
White-browed Babbler	<i>Pomatostomus superciliosus</i>			X	
Grey-crowned Babbler	<i>Pomatostomus temporalis</i>		X	X	
Varied Sittella	<i>Daphoenositta chrysoptera</i>			X	
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>		X	X	
White-winged Triller	<i>Lalage sueurii</i>		X	X	
Rufous Whistler	<i>Pachycephala rufiventris</i>		X	X	
Grey Shrike-thrush	<i>Colluricincla harmonica</i>		X	X	
Crested Bellbird	<i>Oreoica gutturalis</i>		X	X	
Black-faced Woodswallow	<i>Artamus cinereus</i>		X	X	
Little Woodswallow	<i>Artamus minor</i>		X		
Pied Butcherbird	<i>Cracticus nigrogularis</i>		X	X	
Grey Butcherbird	<i>Cracticus torquatus</i>			X	
Australian Magpie	<i>Cracticus tibicen</i>				X
Grey Fantail	<i>Rhipidura albiscapa</i>			X	
Willie Wagtail	<i>Rhipidura leucophrys</i>		X	X	
Torresian Crow	<i>Corvus orru</i>		X	X	
Magpie-lark	<i>Grallina cyanoleuca</i>		X	X	
Red-capped Robin	<i>Petroica goodenovii</i>		X	X	

Appendix 1. Continued.

Common name	Species name	Fortescue Pools	Roy Hill	Mulga Downs	Misc. Sightings
Hooded Robin	<i>Melanodryas cucullata</i>		X	X	
Horsfield's Bushlark	<i>Mirafrja javanica</i>			X	
Brown Songlark	<i>Cincloramphus cruralis</i>		X	X	
Rufous Songlark	<i>Cincloramphus mathewsi</i>		X	X	
Spinifexbird	<i>Eremiornis carteri</i>			X	
Fairy Martin	<i>Petrochelidon ariel</i>		X	X	
Tree Martin	<i>Petrochelidon nigricans</i>				X
Mistletoebird	<i>Dicaeum hirundinaceum</i>		X	X	
Zebra Finch	<i>Taeniopygia guttata</i>		X	X	
Australasian Pipit	<i>Anthus novaeseelandiae</i>		X	X	
Total		30	64	71	14

Appendix 2. Roy Hill terrestrial survey plots data on frequency of occurrence with DCA ordination site and species values.

Site DCA	Axis 1	215	129	153	100	81	196	66	85	36	20	33	142	116	59	72	91	45	45	56	10	52	Axis 2	Axis 3			
Axis 2		96	89	78	114	125	95	85	170	40	40	45	114	114	98	106	110	180	137	70	46	47					
Axis 3		66	80	94	70	79	67	129	110	86	63	97	87	123	103	58	85	53	26	10	67	86	DCA Species				
Common Name		RH11	RH13	RH17	RH18	RH19	RH20	RH61	RH62	RH63	RH64	RH65	RH66	RH67	RH68	RH69	RH70	RH71	RH72	RH73	RH74	RH76	Axis 1	Axis 2	Axis 3		
Brown Quail													12.5%														
Common Bronzewing						12.5%				12.5%					25.0%	12.5%		12.5%						-66	-13	133	
Crested Pigeon		25.0%				12.5%		50.0%	62.5%								12.5%	75.0%	12.5%		12.5%	12.5%		-19	196	303	
Spinifex Pigeon									37.5%									50.0%						34	490	72	
Diamond Dove		37.5%		25.0%	75.0%	50.0%	37.5%	62.5%	75.0%	87.5%	87.5%	87.5%	25.0%	62.5%	75.0%	87.5%	75.0%	100.0%	100.0%	25.0%	87.5%	75.0%		41	94	96	
Peaceful Dove																		25.0%									
Spotted Nighthjar													12.5%												-59	-98	121
Black-shouldered Kite																				12.5%				225	110	-210	
Wedge-tailed Eagle		12.5%			12.5%	12.5%	25.0%					25.0%						12.5%	12.5%					147	134	0	
Whistling Kite				12.5%			12.5%	12.5%	25.0%	25.0%	12.5%		50.0%	12.5%	25.0%			25.0%				12.5%		189	172	222	
Brown Goshawk					12.5%	12.5%			12.5%			12.5%									12.5%			29	201	270	
Spotted Harrier																								280	29	195	
Brown Falcon		12.5%	12.5%		12.5%	37.5%	37.5%		12.5%		12.5%		25.0%	12.5%		12.5%								241	63	55	
Nankeen Kestrel		12.5%	37.5%			25.0%	37.5%				12.5%		12.5%			12.5%					12.5%			233	43	-40	
Australian Hobby			25.0%				12.5%								25.0%									146	115	314	
Australian Bustard			12.5%	12.5%								25.0%				25.0%								142	-56	9	
Little Button-quail		12.5%			37.5%	37.5%			12.5%	25.0%	12.5%					25.0%	12.5%	25.0%	50.0%	25.0%				200	74	-48	
Galah			12.5%		12.5%	50.0%	12.5%	12.5%				12.5%	12.5%	25.0%	12.5%	25.0%								83	124	277	
Little Corella																								-9	260	285	
Cockatoo		62.5%	37.5%	25.0%	62.5%	87.5%	37.5%	37.5%	75.0%	12.5%	12.5%	12.5%	75.0%	87.5%	12.5%	25.0%	87.5%	12.5%	25.0%				62.5%	176	169	166	
Australian Ringneck			12.5%			37.5%			25.0%							37.5%	12.5%	75.0%	62.5%					43	284	-7	
Budgerigar			37.5%	50.0%	100.0%	100.0%	12.5%	25.0%		75.0%	75.0%	37.5%	25.0%		50.0%	62.5%	12.5%	62.5%	12.5%	75.0%	37.5%	87.5%	76	29	70		
Bourke's Parrot											25.0%					12.5%								-66	-168	-14	
Pallid Cuckoo																				12.5%				-12	243	-144	
Red-backed Kingfisher			12.5%	12.5%	12.5%				12.5%			12.5%	37.5%		37.5%	62.5%			12.5%	25.0%				94	7	65	
Sacred Kingfisher																12.5%											
Rainbow Bee-eater					12.5%		12.5%		12.5%		12.5%					50.0%		25.0%			12.5%			3	206	-167	
Variegated Fairy-wren					12.5%			12.5%	12.5%		12.5%				12.5%	62.5%	25.0%				50.0%			-9	37	80	
White-winged Fairy-wren		75.0%	87.5%	25.0%	12.5%		37.5%		12.5%				100%		25.0%	50.0%		12.5%	25.0%	25.0%	25.0%			269	103	13	
Weebill					25.0%	25.0%												25.0%			12.5%			-38	217	0	
Slaty-backed Thornbill																								-118	-42	-207	

Appendix 2. Continued.

Common Name	RH11	RH13	RH17	RH18	RH19	RH20	RH61	RH62	RH63	RH64	RH65	RH66	RH67	RH68	RH69	RH70	RH71	RH72	RH73	RH74	RH76	Axis 1	Axis 2	Axis 3
Chestnut-rumped Thornbill	-----	-----	-----	-----	-----	-----	-----	-----	50.0%	37.5%	25.0%	-----	-----	25.0%	12.5%	-----	-----	-----	-----	37.5%	-----	-122	-17	162
Red-browed Pardalote	-----	-----	-----	37.5%	37.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	25.0%	-----	-----	-----	-----	12	223	-228
Pied Honeyeater	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-129	-24	217
Grey-headed Honeyeater	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-105	272	-466
White-plumed Honeyeater	-----	25.0%	-----	75.0%	87.5%	-----	50.0%	100.0%	12.5%	12.5%	25.0%	62.5%	25.0%	62.5%	100.0%	75.0%	100.0%	100.0%	12.5%	-----	-----	51	243	108
Singing Honeyeater	12.5%	37.5%	-----	-----	50.0%	-----	25.0%	-----	75.0%	100.0%	62.5%	12.5%	-----	-----	-----	25.0%	12.5%	50.0%	100.0%	87.5%	75.0%	-25	-56	-29
White-fronted Honeyeater	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-142	218	-93
Yellow-throated Miner	-----	12.5%	-----	25.0%	100.0%	-----	-----	25.0%	-----	12.5%	-----	12.5%	-----	12.5%	75.0%	25.0%	75.0%	25.0%	12.5%	12.5%	12.5%	7	208	14
Spiny-cheeked Honeyeater	-----	-----	-----	-----	12.5%	-----	-----	-----	12.5%	62.5%	12.5%	-----	-----	-----	-----	12.5%	50.0%	50.0%	37.5%	62.5%	25.0%	-72	75	-37
Crimson Chat	12.5%	12.5%	12.5%	12.5%	-----	37.5%	12.5%	-----	12.5%	25.0%	12.5%	-----	12.5%	12.5%	-----	25.0%	-----	-----	-----	25.0%	25.0%	135	-50	66
Black Honeyeater	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.0%	50.0%	-----	-----	-----	-62	386	-280
Brown Honeyeater	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	12.5%	12.5%	-----	-----	12.5%	-133	216	-46
Grey-crowned Babbler	-----	-----	-----	25.0%	12.5%	-----	-----	25.0%	12.5%	12.5%	-----	-----	12.5%	25.0%	25.0%	12.5%	12.5%	-----	-----	12.5%	-----	1	224	172
Black-faced Cuckoo-shrike	12.5%	50.0%	-----	25.0%	25.0%	12.5%	-----	12.5%	-----	-----	25.0%	-----	-----	-----	37.5%	12.5%	-----	-----	-----	37.5%	-----	150	12	173
White-winged Triller	12.5%	-----	-----	12.5%	12.5%	-----	12.5%	-----	25.0%	25.0%	-----	-----	-----	12.5%	12.5%	-----	-----	-----	-----	-----	-----	86	-91	-9
Rufous Whistler	-----	12.5%	-----	37.5%	25.0%	-----	25.0%	12.5%	25.0%	100%	62.5%	12.5%	-----	12.5%	50.0%	-----	12.5%	25.0%	12.5%	75.0%	37.5%	-76	33	133
Grey Shrike-thrush	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-151	176	-239
Crested Bellbird	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	12.5%	-----	-----	-----	-----	-----	-----	25.0%	25.0%	25.0%	50.0%	-----	-108	121	-53
Black-faced Woodswallow	62.5%	37.5%	12.5%	50.0%	12.5%	50.0%	25.0%	12.5%	12.5%	12.5%	-----	37.5%	-----	25.0%	37.5%	-----	12.5%	87.5%	25.0%	25.0%	185	88	-18	-18
Little Woodswallow	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	12.5%	-----	-83	-35	166
Pied Butcherbird	12.5%	-----	-----	12.5%	12.5%	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	12.5%	199	222	0
Willie Wagtail	62.5%	25.0%	25.0%	62.5%	25.0%	25.0%	12.5%	37.5%	12.5%	25.0%	12.5%	50.0%	12.5%	50.0%	50.0%	50.0%	-----	25.0%	37.5%	62.5%	121	42	84	84
Torresian Crow	-----	12.5%	-----	-----	25.0%	-----	-----	25.0%	25.0%	25.0%	-----	25.0%	50.0%	25.0%	25.0%	25.0%	50.0%	37.5%	37.5%	-----	43	223	35	35
Magpie-lark	-----	-----	12.5%	25.0%	12.5%	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	12.5%	-----	25.0%	25.0%	-----	-----	-----	99	247	213
Red-capped Robin	12.5%	-----	25.0%	-----	12.5%	-----	50.0%	-----	37.5%	37.5%	62.5%	-----	25.0%	37.5%	12.5%	25.0%	-----	25.0%	-----	75.0%	62.5%	-34	-49	216
Hooded Robin	-----	-----	12.5%	-----	-----	-----	12.5%	-----	25.0%	25.0%	-----	12.5%	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	19	-131	167
Brown Songlark	87.5%	12.5%	75.0%	50.0%	25.0%	50.0%	-----	25.0%	-----	-----	12.5%	12.5%	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	309	141	59
Rufous Songlark	-----	37.5%	12.5%	25.0%	12.5%	-----	12.5%	-----	-----	-----	25.0%	25.0%	12.5%	50.0%	50.0%	-----	12.5%	12.5%	-----	-----	-----	142	150	29
Fairy Martin	25.0%	-----	-----	-----	-----	37.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	419	152	-38
Mistletoebird	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	25.0%	-----	-----	12.5%	-----	12.5%	-----	-109	245	-86
Zebra Finch	12.5%	100.0%	50.0%	87.5%	87.5%	37.5%	75.0%	50.0%	50.0%	75.0%	100.0%	37.5%	25.0%	62.5%	100.0%	50.0%	62.5%	100.0%	37.5%	50.0%	12.5%	94	74	90
Australasian Pipit	62.5%	12.5%	12.5%	12.5%	12.5%	37.5%	25.0%	12.5%	-----	-----	-----	-----	50.0%	12.5%	-----	12.5%	-----	-----	-----	-----	-----	3	1	2

Appendix 3. Continued.

Species	MD1	MD2	MD3	MD4	MD5	MD6	MD7	MD8	MD9	MD10	MD11	MD12	MD13	MD14	MD15	MD16	MD17	MD18	MD19	MD20	MD21	MD22	MD24	Axis 1	Axis 2	Axis 3	
White-winged Fairy-wren	-----	-----	-----	-----	-----	25.0%	37.5%	12.5%	-----	62.5%	50.0%	50.0%	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	37.5%	87.5%	269	103	13	
Weebill	-----	-----	-----	25.0%	62.5%	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	12.5%	-----	-----	-38	217	0	
Western Gerygone	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-159	222	-54	
Inland Thornbill	-----	25.0%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	-----	-----	-----	-----	-180	106	600	
Slaty-backed Thornbill	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-118	-42	-207	
Chestnut-rumped Thornbill	12.5%	25.0%	37.5%	25.0%	37.5%	12.5%	-----	12.5%	-----	-----	-----	-----	12.5%	62.5%	25.0%	50.0%	75.0%	37.5%	12.5%	37.5%	37.5%	-----	12.5%	-122	-17	162	
Red-browed Pardalote	25.0%	12.5%	12.5%	12.5%	12.5%	25.0%	12.5%	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12	223	-228	
Pied Honeyeater	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.0%	-----	12.5%	-----	-----	-----	-----	-129	-24	217	
Grey-headed Honeyeater	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-105	272	-466	
White-plumed Honeyeater	-----	-----	12.5%	-----	62.5%	87.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	25.0%	12.5%	87.5%	12.5%	-----	-----	51	243	108	
Singing Honeyeater	75.0%	75.0%	100.0%	75.0%	62.5%	50.0%	75.0%	87.5%	-----	-----	12.5%	-----	62.5%	50.0%	62.5%	12.5%	37.5%	62.5%	37.5%	25.0%	62.5%	25.0%	50.0%	-25	-56	-29	
White-fronted Honeyeater	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-142	218	-93	
Yellow-throated Miner	37.5%	50.0%	25.0%	12.5%	62.5%	50.0%	12.5%	12.5%	-----	-----	-----	-----	12.5%	12.5%	-----	12.5%	25.0%	50.0%	-----	37.5%	-----	-----	-----	7	208	14	
Spiny-cheeked Honeyeater	-----	25.0%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.0%	12.5%	50.0%	-----	25.0%	50.0%	12.5%	12.5%	12.5%	-----	-----	-72	75	-37	
Crimson Chat	12.5%	37.5%	50.0%	12.5%	-----	37.5%	50.0%	12.5%	50.0%	-----	12.5%	-----	-----	12.5%	37.5%	-----	12.5%	-----	25.0%	25.0%	-----	-----	-----	135	-50	66	
Black Honeyeater	-----	37.5%	12.5%	25.0%	75.0%	12.5%	75.0%	12.5%	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-62	386	-280	
Brown Honeyeater	12.5%	37.5%	50.0%	-----	62.5%	12.5%	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	12.5%	12.5%	-----	-----	-----	-133	216	-46	
White-browed Babbler	12.5%	12.5%	12.5%	-----	12.5%	-----	12.5%	25.0%	-----	-----	-----	-----	12.5%	37.5%	12.5%	50.0%	25.0%	-----	-----	-----	25.0%	-----	-----	-145	-121	259	
Grey-crowned Babbler	-----	-----	-----	-----	50.0%	-----	-----	-----	-----	-----	12.5%	-----	12.5%	-----	-----	25.0%	12.5%	-----	-----	25.0%	-----	-----	-----	1	224	172	
Vared Sittella	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-4	-62	190	
Black-faced Cuckoo-shrike	62.5%	25.0%	-----	12.5%	12.5%	25.0%	12.5%	-----	37.5%	25.0%	-----	-----	25.0%	12.5%	25.0%	25.0%	12.5%	-----	-----	12.5%	37.5%	25.0%	50.0%	150	12	173	
White-winged Triller	25.0%	-----	37.5%	25.0%	-----	-----	50.0%	12.5%	25.0%	12.5%	-----	-----	-----	12.5%	12.5%	-----	-----	12.5%	-----	-----	-----	-----	-----	86	-91	-9	
Rufous Whistler	25.0%	37.5%	25.0%	12.5%	87.5%	37.5%	12.5%	12.5%	-----	-----	-----	62.5%	50.0%	37.5%	62.5%	62.5%	75.0%	25.0%	25.0%	50.0%	50.0%	12.5%	-----	-76	33	133	
Grey Shrike-thrush	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-151	176	-239	
Crested Ballbird	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	12.5%	12.5%	25.0%	12.5%	12.5%	-----	-----	-----	12.5%	-----	-----	-108	121	-53	
Black-faced Woodswallow	50.0%	25.0%	37.5%	50.0%	-----	12.5%	12.5%	12.5%	62.5%	12.5%	25.0%	50.0%	-----	-----	50.0%	-----	-----	-----	12.5%	12.5%	37.5%	-----	25.0%	185	88	-18	
Little Woodswallow	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-83	-35	166	
Grey Butcherbird	-----	-----	-----	-----	12.5%	-----	-----	12.5%	-----	-----	-----	-----	12.5%	-----	37.5%	-----	-----	12.5%	-----	-----	12.5%	-----	-----	-150	-26	131	
Pied Butcherbird	-----	-----	12.5%	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	199	222	0	
Australian Magpie	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	43	284	-7	
Grey Fantail	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Willie Wagtail	50.0%	25.0%	37.5%	50.0%	100.0%	25.0%	50.0%	50.0%	75.0%	25.0%	25.0%	75.0%	87.5%	87.5%	62.5%	100.0%	75.0%	50.0%	62.5%	62.5%	25.0%	50.0%	62.5%	121	42	84	

Appendix 3. Continued.

Species	MD1	MD2	MD3	MD4	MD5	MD6	MD7	MD8	MD9	MD10	MD11	MD12	MD13	MD14	MD15	MD16	MD17	MD18	MD19	MD20	MD21	MD22	MD24	Axis 1	Axis 2	Axis 3	
Torresian Crow	-----	-----	-----	-----	25.0%	-----	-----	25.0%	12.5%	-----	-----	-----	-----	37.5%	37.5%	-----	-----	-----	-----	50.0%	-----	-----	-----	43	223	35	
Magpie-lark	-----	25.0%	-----	-----	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	50.0%	-----	-----	-----	99	247	213	
Red-capped Robin	37.5%	37.5%	12.5%	-----	-----	-----	12.5%	12.5%	12.5%	12.5%	12.5%	-----	25.0%	75.0%	62.5%	62.5%	62.5%	25.0%	-----	-----	37.5%	-----	-----	-34	-49	216	
Hooded Robin	-----	-----	-----	-----	-----	-----	12.5%	12.5%	12.5%	37.5%	37.5%	-----	12.5%	25.0%	25.0%	-----	-----	-----	25.0%	12.5%	-----	-----	-----	19	-131	167	
Horsfield's Bushlark	-----	-----	-----	-----	-----	25.0%	-----	50.0%	-----	75.0%	-----	-----	-----	-----	12.5%	-----	-----	-----	-----	-----	-----	37.5%	-----	-----	374	42	217
Brown Songlark	-----	12.5%	-----	-----	-----	12.5%	50.0%	-----	12.5%	50.0%	-----	-----	-----	-----	-----	-----	-----	12.5%	-----	12.5%	12.5%	37.5%	37.5%	309	141	59	
Rufous Songlark	-----	12.5%	12.5%	-----	12.5%	25.0%	12.5%	-----	25.0%	12.5%	-----	12.5%	-----	-----	-----	-----	-----	12.5%	12.5%	25.0%	12.5%	-----	-----	142	150	29	
Spinfexbird	-----	-----	-----	12.5%	12.5%	-----	-----	-----	75.0%	-----	12.5%	87.5%	-----	-----	-----	-----	-----	-----	25.0%	-----	-----	50.0%	-----	-----	159	-300	165
Fairy Martin	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	12.5%	12.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	419	152	-38
Mistletoebird	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.0%	-----	-----	-----	-----	-----	-----	-109	245	-86
Zebra Finch	87.5%	75.0%	62.5%	25.0%	25.0%	87.5%	75.0%	25.0%	62.5%	-----	87.5%	-----	37.5%	37.5%	37.5%	50.0%	50.0%	25.0%	50.0%	62.5%	62.5%	87.5%	62.5%	94	74	90	
Australasian Pipit	-----	12.5%	-----	-----	-----	-----	-----	-----	-----	12.5%	12.5%	37.5%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.5%	277	140	190