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A survey of the birds of the Darwin Stringybark *Eucalyptus tetrodonta* forest: When is a survey 'complete'?

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Abstract. The 2-ha 20-minute bird survey method was used to survey bird assemblages in the Darwin Stringybark *Eucalyptus tetrodonta* forest of the Weipa bauxite plateau, Cape York Peninsula, Queensland. A standardised method was preferred so that bird data could be compared with bird data collected in post-mining rehabilitation sites. Thirty-six native forest survey sites were selected using stratification (8 vegetation types) and replication. Over 16 months, eight surveys were conducted at each site, amounting to a total of 160 minutes of survey effort per site. No single site had the full complement of native-forest bird species. A minimum of 14 sites, including seven of the eight site types, was required for all 79 species to be recorded at least once. Sufficient bird data were obtained to conduct statistical analyses, but the species list remained incomplete compared with an estimate of asymptotic species richness.

Introduction

The 2-ha 20-minute bird survey method, originally devised for forest-ecology studies (Loyn 1986) and then adapted for use in the Australian Bird Count (Hewish & Loyn 1989) and the Atlas of Australian Birds, is the preferred survey method for BirdData, the continental database of Australian birds maintained by BirdLife Australia. It is a standardised survey method that emphasises inputs, i.e. fixed search area and fixed search effort (Loyn 1986; Barrett *et al.* 2003). This contrasts with standardised surveys that emphasise outputs, i.e. proportion of the bird community detected (Watson 2003). Standardising surveys by output aims to ensure that estimates of species richness are of equal accuracy across sites. This is achieved by using results-based stopping rules.

Bird survey methods that standardise effort have been criticised on the grounds that standardisation may come at the cost of survey completeness (Watson 2003, 2004). Methods that standardise effort can introduce systematic error (bias) because of differences in survey efficiency between vegetation types (Harden *et al.* 1986). Pyke & Recher (1984) reviewed census methods and found none that provided unbiased density estimates. However, the advantage of survey methods that standardise effort is that they can provide metrics that enable comparison across space and time (Recher 1988). By conducting repeat surveys, survey completeness can be maximised (Thompson 2002). Repeat surveys also reduce bias in the data from temporal effects (Field *et al.* 2002). Slater (1994) found that the total time spent on site was more important than the survey duration or the number of repetitions and concluded that to obtain a complete species list for sites with a sparse understorey a minimum survey time of 100 minutes would be required.

I wanted to know the extent to which post-mining rehabilitation on the Weipa bauxite plateau, Cape York, Queensland, had restored the bird habitat values of the Darwin Stringybark *Eucalyptus tetrodonta* open forest. This was broken down into four questions:

1. How do bird assemblages in mine rehabilitation compare with those in native forest?
2. What is the temporal pattern of bird succession in mine rehabilitation?
3. What environmental factors determine bird occupancy in mine rehabilitation and native forest?, and
4. Is post-mining rehabilitation likely to restore habitat similar to that of pre-mining native forest?

Given my need to compare bird assemblages between pre-mining native-forest sites and post-mining rehabilitation sites, and to examine associations between birds and site vegetation attributes, I decided to use a standardised bird survey method.

Temporal variation in bird assemblages is a general phenomenon that also occurs in tropical eucalypt woodlands (Franklin & Noske 1999; Woinarski *et al.* 2000; Maron *et al.* 2005). To reduce error because of temporal variance and known sources of bias, I used repeat surveys and a set of survey protocols. I assumed that I should be able to obtain reliable estimates of variance of vegetation data and bird data through a combination of vegetation stratification, replication of site 'types', and repeat surveys at each site adding up to a total of 160 minutes survey time at each site. Analysis and results relating to my first two research questions are reported in Gould (2011), to the third question in Gould & Mackey (2015) and to the fourth question in Gould (2012). Here I report on the bird assemblages of the Weipa bauxite plateau Darwin Stringybark native forest and reflect on the meaning of completeness in bird surveys.

Methods

To ensure that the bird data represented the target vegetation, all study sites were on the bauxite plateau, within the bauxite mining lease, and had been mapped as Darwin Stringybark open forest/tall woodland. To capture spatial variation within the target vegetation, 36 study sites were selected through a process of *a priori* stratification and 'replication'. The stratification process identified eight *a priori* vegetation types (Table 1). These included six types that are structural and floristic variants of the pre-mining native forest that occurs on red earth on the bauxite plateau. Two additional vegetation types that are mapped as Darwin Stringybark open forest but are not mined were included. One of these occurs on yellow earth on the bauxite plateau where drainage is impeded, and the other occurs on the rocky edges of the bauxite plateau. These two variants of the Darwin Stringybark open forest are considered to be potential analogues for the post-mining landscape. All sites were at least 1 km apart to ensure that bird observations were independent. Different vegetation types were interspersed and 'replicates' of each vegetation type were selected from different geographical areas as far as possible.

The bird survey method used was a modification of the 2-ha 20-minute area search used for the Atlas of Australian Birds (Loyn 1986; Barrett *et al.* 2003). Each site was divided into two 1-ha plots, the boundaries of which were identified in the field using a mapping GPS (Garmin 60CX). All birds seen or heard within 1 ha were identified and numbers of individuals of each species were counted for 10 minutes. This was repeated in the second hectare for 10 minutes avoiding counting individuals already counted in the first hectare. Dividing the survey effort in this way was intended to improve site coverage and the reliability of count data. Birds flying over the site were not counted, but birds using the air space, such as raptors or aerial insectivores flying low over the canopy that appeared to be searching for prey within the site, were included.

Eight surveys were conducted at each site over 16 months (September 2006–December 2007) adding up to a total survey time at each site of 160 minutes. Once each round of surveys commenced, 3–5 surveys were conducted daily until all sites had been visited, unless circumstances dictated otherwise. The order in which sites were visited was changed with each round of surveys.

Bias because of environmental conditions was reduced by conducting all surveys between 0630 and 1000 h and not surveying when it was raining or windy. Bias because of differences in vegetation density between sites was reduced by actively searching each plot (Loyn 1986) rather than doing point counts from the centre of each 1-ha plot. I conducted all surveys, so bias from differences between observers was not an issue (Kavanagh & Recher 1983; Cunningham *et al.* 1999). I was able to identify most species by call from the outset of the study.

Analysis

All bird observations were entered into an MS Access database which was used to generate summary data and conduct calculations. Data were exported to MS Excel and put into the appropriate formats for use in statistical packages. Summary values were calculated for each species using pooled data from all sites and all surveys. The mean reporting rate was calculated by: (1) site reporting rates were calculated for each species as the number of times that species was detected at that site out of eight site visits, and (2) mean species reporting rates were calculated using only the data for the sites where that species was detected. Additional analyses and results are reported in Gould (2011, 2012) and Gould & Mackey (2015). The minimum asymptotic species richness was estimated using the Chao 2 estimator in the freeware package EstimateS (Version 9.1.0) (Colwell 2018). The estimate was based on the pooled individual-based abundance data from all 36 sites and all site visits.

Results

Using pooled data for all native forest sites (36 sites) and all site visits (8 surveys per site), the total native forest survey (96 hours) yielded 79 bird species from 8906 individual records. This compares with an estimated asymptotic species richness of 90 ± 7 species using the Chao 2 estimator. One species, White-throated Honeyeater *Melithreptus albogularis*, occurred in every native forest site during every survey (Appendix 1). A further seven species were ubiquitous in that they were detected in every native forest site at least once and another 16 species were widespread (occurred in more than half of all sites). Of the 79 species recorded, 46 were recorded in ≥5 sites (14% of sites).

Three species, White-throated Honeyeater, Rainbow Lorikeet *Trichoglossus moluccanus* and Little Friarbird *Philemon citreogularis* were abundant (count ≥500), accounting for 23.5% of all individuals recorded. Another 15 species were common (count 125–499); five were locally common (count 20–124 and species reporting rate ≥0.3); and 13 were moderately common (count 20–124 and species reporting rate <0.3) (Appendix 1). Ten species were recorded only once. The 33 species (41.7%) that occurred in <5 sites accounted for <2% of all individuals counted. No single site had the full complement of native-forest bird species. Combining data from all sites and all site visits, a minimum of 14 sites, including seven of the eight site types, was required for all 79 species to be recorded at least once. Bird summary statistics differed between site types but differences were not significant (Table 1).

Discussion

The 2-ha 20-minute bird survey method was efficient in characterising the bird assemblages of the Weipa plateau Darwin Stringybark open forest. For the eight ubiquitous bird species, the survey method was guaranteed to detect them even with low rates of spatial and temporal replication. This may reflect a systematic bias in the survey method towards species that are highly detectable. Detection of the remaining species required differing levels of both spatial and temporal replication. This reflects variation between bird species in their spatial distribution, movement and detectability in Darwin Stringybark open forest.

Interspecific differences in reporting rates found in this study reflect the varying degrees to which the spatial and temporal grain of the research design matched multiple species that differ in their needs, and a varying environment. Bird species' distributions vary individualistically depending on their behavioural ecology, their specific resource needs and spatial and temporal variation in the availability of those resources. The distribution of individual bird species has been related to a range of vegetation attributes, including canopy height (Woinarski *et al*. 1988), structural

Table 1. Characteristics of the eight vegetation types surveyed and summary of bird data by vegetation type in Darwin Stringybark forest across the Weipa bauxite plateau, Cape York Peninsula, Queensland. Land unit 2B is cleared and mined for bauxite; land units 2C and 5K are not mined and are considered to be analogues for the post-mining landscape; bird survey data have coefficients of variation in parentheses.

Land unit	*Soil type*	*Structural variation*	*Floristic variation (& no. of sites)*	*Mean site bird species richness (all visits)*	*Mean site bird species richness/survey*	*Mean site bird abundance/survey (all species)*
2B (*n* = 28)	Red earth	Darwin Stringybark open forest–tall woodland	1. Sparse shrub layer, grassy (6)	27 (15%)	12 (24%)	31 (30%)
			2. Melville Island Bloodwood *Corymbia nesophila* co-dominant (2)			
			3. Subcanopy layer of Cooktown Ironwood *Erythrophleum chlorostachys* (5)			
	Red/yellow earth	Darwin Stringybark open forest–tall woodland	4. Subcanopy layer of Dwarf Fan Palm *Livistona muelleri* (1)			
		Darwin Stringybark tall, layered woodland	5. Well-developed shrub layer (10)			
			6. High density of small stems of Darwin Stringybark (4)			
2C (*n* = 4)	Yellow/grey earth with impeded drainage	Darwin Stringybark tall, layered woodland	7. Subcanopy layer of Dwarf Fan Palm and Swamp Mahogany *Lophostemon suaveolens* (4)	29 (8%)	14 (23%)	34 (33%)
5K (*n* = 4)	Yellow/red earth with outcropping ironstone	Darwin Stringybark tall woodland–open woodland	8. Woodland (4)	29 (16%)	13 (26%)	28 (32%)

complexity (Kikkawa 1982), bark attributes, tree-hollows (Loyn 1985) and presence of mistletoe (Woinarski *et al.* 1988). Vegetation productivity has also been shown to be an important factor determining bird species richness and abundance generally in Australian eucalypt formations (Loyn 1985; Milledge & Recher 1985; Recher 1985; Braithwaite *et al.* 1989; Neave *et al.* 1996; Recher *et al.* 1996). Temporal variation in bird assemblages in tropical Australia has also been demonstrated over multiple temporal scales (Maron *et al*. 2005; Kutt *et al*. 2012). Thus, interspecific differences in reporting rates are expected.

Although there appears to be a bias towards highly detectable species, the amount of spatial and temporal replication in this study provided sufficient data for a range of comparative analyses (Gould 2011; Gould & Mackey 2015). The fact that 14 of the 36 study sites, including seven of the eight site types, were required for each of the 79 native-forest bird species to be detected at least once emphasises the importance of vegetation stratification and site replication to obtain more complete species information. Long-term monitoring of the survey sites would improve the accuracy of density estimates for species that were detected in only very low numbers, or that were only intermittently present or whose detectability changes through the seasons. However, the additional survey effort required to obtain density estimates for species that may be only transitory may not be justified, depending on the aims of the study.

Even with vegetation stratification, replication of site types and eight repeat visits to each site over a period of 16 months, the species count fell short of the statistically estimated asymptotic species richness. Thus, more bird species are expected in the Darwin Stringybark open forest. More spatial replication and/or temporal replication, or the addition of different survey methods, including nocturnal surveys, would provide more complete species lists for the Weipa plateau Darwin Stringybark open forest.

I conclude that the 2-ha 20-min survey was a suitable method for my research questions but only with large amounts of stratification, and spatial and temporal replication. An advantage of having used this method is that the data were suitable for addition to BirdData, the continental database of Australian birds maintained by BirdLife Australia. The fact that the final species count fell short of the estimated asymptotic species richness raises two questions. First, what does survey completeness mean in the context of ecosystems that are open and dynamic? Second, what does a site represent and how long can it be deemed to be the same site? Given that multiple species-specific factors affect a bird's use of any vegetation and that these factors change independently over multiple temporal scales, a site species list is only true for a specific time and is always open to new additions. The corollary of this is that failure to detect a species during surveys should not be interpreted to mean that it never uses that site, only that it was not detected during surveys. Without large-scale and long-term datasets to quantify species distribution and abundance, and to interpret change, we are just peeking at wildlife through a narrow window.

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Appendix 1. Birds of the Darwin Stringybark native forest of the Weipa bauxite plateau, Cape York Peninsula, Queensland, using pooled data from all sites. Mean species reporting rate is a mean of the species reporting rate only for the sites in which the species was detected. Ubiquitous (U) = species that occurred in all sites; widespread (W) = species that were not ubiquitous but occurred in >50% of sites; abundant (A) = species with ≥500 individuals; common (C) = species with 125–499 individuals; locally common (LC) = species with 20–124 individuals and mean site reporting rate ≥0.3; moderately common (MC) = species with 20–124 individuals and mean site reporting rate <0.3. Bird names follow BirdLife Australia Working List v. 3.

Common name	*Scientific name*	*Description*	*Count of individuals*	*% of sites*	*Mean species reporting rate*
White-throated Honeyeater	*Melithreptus albogularis*	U, A	1603	100	1.00
Rainbow Lorikeet	*Trichoglossus moluccanus*	U, A	1213	100	0.77
Little Friarbird	*Philemon citreogularis*	U, A	883	100	0.92
Lemon-bellied Flycatcher	*Microeca flavigaster*	W, C	481	97.2	0.78
Banded Honeyeater	*Cissomela pectoralis*	W, C	390	75.0	0.30
White-bellied Cuckoo-shrike	*Coracina papuensis*	U, C	362	100	0.71
Rufous Whistler	*Pachycephala rufiventris*	W, C	335	86.1	0.80
Leaden Flycatcher	*Myiagra rubecula*	W, C	306	97.2	0.66
Black-backed Butcherbird	*Cracticus mentalis*	U, C	289	100	0.61
Noisy Friarbird	*Philemon corniculatus*	U, C	289	100	0.55
Mistletoebird	*Dicaeum hirundinaceum*	U, C	283	100	0.67
Yellow Honeyeater	*Stomiopera flava*	U, C	280	100	0.61
Varied Sittella	*Daphoenositta chrysoptera*	W, C	228	58.3	0.27
Laughing Kookaburra	*Dacelo novaeguineae*	W, C	176	80.6	0.39
Forest Kingfisher	*Todiramphus macleayii*	W, C	149	83.3	0.46
Red-winged Parrot	*Aprosmictus erythropterus*	W, C	148	80.6	0.29
Grey Shrike-thrush	*Colluricincla harmonica*	W, C	144	83.3	0.49
Striated Pardalote	*Pardalotus striatus*	W, C	132	75.0	0.41
Yellow-tinted Honeyeater	*Ptilotula flavescens*	LC	103	30.6	0.30
Red-backed Fairy-wren	*Malurus melanocephalus*	W, LC	99	61.1	0.31
Sulphur-crested Cockatoo	*Cacatua galerita*	W, MC	95	63.9	0.28
Brown Treecreeper	*Climacteris picumnus*	LC	88	41.7	0.43
Bar-shouldered Dove	*Geopelia humeralis*	W, MC	76	66.7	0.26
Pale-headed Rosella	*Platycercus adscitus*	W, MC	72	58.3	0.21
Peaceful Dove	*Geopelia placida*	W, MC	60	55.6	0.29
Rainbow Bee-eater	*Merops ornatus*	MC	58	38.9	0.23
Northern Common Cicadabird	*Edilosoma tenuirostre melvillensis*	W, MC	57	75.0	0.21
Blue-winged Kookaburra	*Dacelo leachii*	MC	37	38.9	0.20
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	MC	35	44.4	0.18
White-breasted Woodswallow	*Artamus leucorynchus*	MC	32	13.9	0.13
Weebill	*Smicrornis brevirostris*	LC	29	11.1	0.41
Brush Cuckoo	*Cacomantis variolosus*	MC	27	36.1	0.22
Torresian Crow	*Corvus orru*	MC	26	38.9	0.14
Graceful Honeyeater	*Meliphaga gracilis*	LC	25	11.1	0.41
Spangled Drongo	*Dicrurus bracteatus*	MC	23	38.9	0.20
Olive-backed Oriole	*Oriolus sagittatus*	MC	20	38.9	0.16
Great Bowerbird	*Chlamydera nuchalis*		17	13.9	0.43
Grey-crowned Babbler	*Pomatostomus temporalis*		17	13.9	0.18

Appendix 1 continued

Common name	*Scientific name*	*Description*	*Count of individuals*	*% of sites*	*Mean species reporting rate*
Eastern Koel	*Eudynamys orientalis*		15	22.2	0.17
Pheasant Coucal	*Centropus phasianinus*		14	25.0	0.17
Pied Butcherbird	*Cracticus nigrogularis*		13	13.9	0.23
Whistling Kite	*Haliastur sphenurus*		12	27.8	0.13
Collared Sparrowhawk	*Accipiter cirrocephalus*		12	25.0	0.17
Brown-backed Honeyeater	*Ramsayornis modestus*		11	19.4	0.16
White-winged Triller	*Lalage tricolor*		11	19.4	0.14
Pied Imperial-Pigeon	*Ducula bicolor*		11	16.7	0.15
Green Oriole	*Oriolus flavocinctus*		11	11.1	0.25
Yellow-spotted Honeyeater	*Meliphaga notata*		9	5.6	0.38
Dusky Honeyeater	*Myzomela obscura*		8	16.7	0.15
Australasian Figbird	*Sphecotheres vieilloti*		8	2.8	0.63
Olive-backed Sunbird	*Cinnyris jugularis*		7	11.1	0.16
Blue-faced Honeyeater	*Entomyzon cyanotis*		7	8.3	0.13
Brown Goshawk	*Accipiter fasciatus*		6	13.9	0.15
Red-browed Pardalote	*Pardalotus rubricatus*		6	2.8	0.25
Tawny Frogmouth	*Podargus strigoides*		5	11.1	0.13
White-throated Needletail	*Hirundapus caudacutus*		4	8.3	0.13
Peregrine Falcon	*Falco peregrinus*		4	5.6	0.19
Emu	*Dromaius novaehollandiae*		4	5.6	0.13
Wedge-tailed Eagle	*Aquila audax*		4	2.8	0.25
Little Bronze-Cuckoo	*Chalcites minutillus*		4	2.8	0.13
Bush Stone-curlew	*Burhinus grallarius*		3	5.6	0.13
Pacific Baza	*Aviceda subcristata*		3	5.6	0.13
Northern Fantail	*Rhipidura isura*		3	2.8	0.13
Brahminy Kite	*Haliastur indus*		2	5.6	0.13
Brown Falcon	*Falco berigora*		2	5.6	0.13
Grey Fantail	*Rhipidura albiscapa*		2	5.6	0.13
Brown Whistler	*Pachycephala simplex*		2	2.8	0.25
Little Woodswallow	*Artamus minor*		2	2.8	0.13
Papuan Frogmouth	*Podargus papuensis*		2	2.8	0.13
Orange-footed Scrubfowl	*Megapodius reinwardt*		1	2.8	0.13
Oriental Cuckoo	*Cuculus saturatus*		1	2.8	0.13
Southern Boobook	*Ninox boobook*		1	2.8	0.13
Grey Goshawk	*Accipiter novaehollandiae*		1	2.8	0.13
Black Kite	*Milvus migrans*		1	2.8	0.13
Dollarbird	*Eurystomus orientalis*		1	2.8	0.13
Palm Cockatoo	*Probosciger aterrimus*		1	2.8	0.13
Helmeted Friarbird	*Philemon buceroides*		1	2.8	0.13
Varied Triller	*Lalage leucomela*		1	2.8	0.13
Magpie-lark	*Grallina cyanoleuca*		1	2.8	0.13