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Dry-Season Bird Diversity in Tropical Rainforest and Surrounding Habitats in North-east Australia

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Summary: A quantitative analysis of bird species richness and abundance in habitats in and adjacent to rainforest in north-east Queensland, Australia, is presented. Bird assemblages in five habitats surrounding tropical rainforest were compared using line transects over a six-week period in the winter dry-season, between July and September 1995. Data were analysed using the Shannon–Weaver index of biodiversity and by a rarefaction method. Avian biodiversity was more variable between sites than between habitat types. While no habitat stood out at either extreme, diversity was highest in an area of riverine rainforest. Rainforest interior proved one of the poorest habitats for bird diversity. However, species assemblages were different among habitats, with 38% of species being found in only one habitat type.

While it is clear that habitat destruction endangers biodiversity (Wilson 1992; Balmford & Long 1994), in the current economic and political climate the emphasis on ecological aims is to accept change as inevitable, but then fight for the lesser of the many evil options (Caldecott et al. 1997). Diversity studies remain as important subjects for research for three reasons: (1) global biodiversity proves hard to assess (Gaston & Blackburn 1995; Williams et al. 1997) and consequently it is still a fundamental priority (see Gaston 1996); (2) mechanisms underlying biodiversity are still not understood (eg. Stevens 1989; Blackburn & Gaston 1996); and (3) methods to mitigate habitat destruction and conserve maximum biodiversity are vague, as a consequence of a paucity of information about (1) and (2).

Australian rainforests contain 2500 species of flowering plants, 70% of which are endemic to Australia (Collins 1990) and 23 species of endemic birds (Long et al. 1996), as well as some species which are considered ‘endangered’ or which have other threatened status (Baker-Gabb 1994; Collar et al. 1994). Little ornithological work has been conducted in the tropical rainforests of north-east Australia. Several authors have studied foraging ecology of birds in Queensland in both lowland (Crome 1975, 1978) and upland rainforest (Frith 1984) and also in lowland rainforest in New Guinea (Bell 1982a, b; Beehler 1981). But quantitative studies detailing bird diversities in different habitat types are few and baseline data with which to compare future studies have recently been called for (Mac Nally 1997). This study is also pertinent to contemporary conservation biology because transient rainforest edge habitats have been claimed to be very diverse, and because with increasing human impact on rainforest there is a need for studies of species diversity in disturbed habitats (Madden & Mair 1996; Danielsen 1997). Crome (1990) stated that at that time there were no studies at all of vertebrates in Australian successional rainforest vegetation.

Across the globe, mass deforestation and disturbance of rainforests continues (Whitmore 1997) but the reasons why particular species suffer extinction are still not well understood (see Sieving & Karr 1997 and references therein). It has been shown that smaller habitats support less avian diversity (e.g. Cieslak & Dombrowski 1993; McCollin 1993; Woinarski 1993) and Warburton (1997) found a highly significant correlation between species richness and forest fragment size on the Atherton Tablelands, Queensland, near our study site. Nest success and fledgling mass may be compromised in small habitats (Lens & Dhondt 1994; Paton 1994) and parasitism and predation have been reported to be higher in more fragmented forest plots (Opdam et al. 1985; Robinson & Wilcove 1994). Small, isolated metapopulations may suffer inbreeding depression (e.g. Wildt et al. 1987; Caughley 1994) and have a higher probability of extinction (see Wright & Hubbell 1983). The species most susceptible to habitat fragmentation are large, predatory and with habitat specific home ranges (Redpath 1995); hence, many large forest raptors are particularly vulnerable to habitat destruction (e.g. Queensland’s Red Goshawk *Accipiter radiatus*, Baker-

Gabb 1994). While small species are more able to persist, it remains vital to investigate the effects of disturbance and secondary vegetation on biodiversity and to provide base-line data against which future changes may be identified. This study is a contribution to those aims.

Methods and site description

The study was conducted within a 7900 km^2 area of rainforest in north-east Queensland, which lies in an almost continuous block from Townsville to Cooktown. The study site is located to the west of Weary Bay, 45 km south of Cooktown at 15°51′S, 145°20′E (Fig. 1). Mean annual rainfall is 1784 mm, with *c.* 50 mm in each of the dry season months July, August and September. Mean temperatures for these months are 22°C, 23°C and 25°C, respectively (meteorological data are for Cooktown).

The area was once continuous rainforest (tropical closed-forest, Specht 1981) but has altered considerably with climate change, mining activity and the end of traditional Aboriginal land-use which used to maintain the separation of dry and wet vegetation. Data from the Rossville area (Unwin et al. 1988), which lies < 15 km from our study sites, indicate that rainforest has spread in this area for two reasons. First, the cessation of Aboriginal burning practices allowed the spread of fire sensitive rainforest into eucalypt woodland, which would formerly have undergone periodic re-burning. Second, rainforest spread into other areas where natural fires were controlled during mining activity over the last 100 years, and into disused mining areas that remain protected from fire (Unwin et al. 1988). Later, rainforest was cleared in some areas for sugar cane production and cattle (Collins 1990; Madden & Mair 1996). Cattle ranching may also have enhanced the spread of rainforest by reducing the grass crop, which acts as fuel in bush fires. The existing rainforest forms a belt limited on one side by the Coral Sea and on the other by drier climate to the west of the Great Dividing Range.

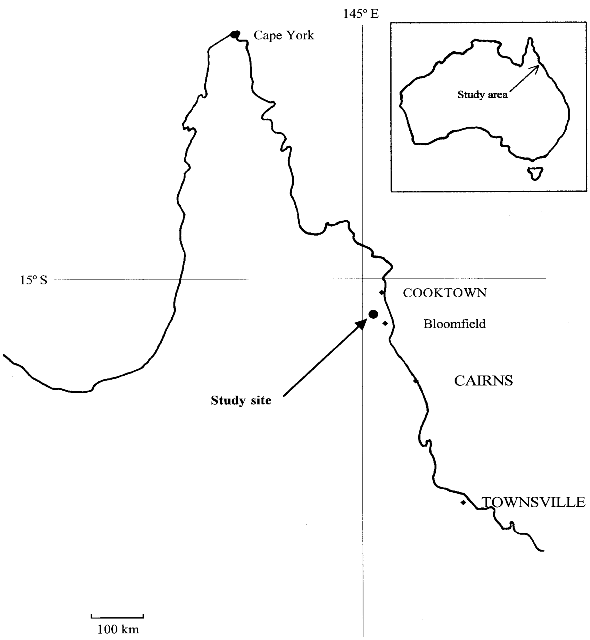

Figure 1 Map of the location of the study area (scale, 1:6 400 000).

A series of line transects were conducted (Bibby et al. 1992) by three observers, between 0700–1000 h and 1600–1800 h over a six week period, from late July to early September 1995. Dawn was at *c.* 0600 h and dusk at *c.* 1930 h. At eight different transect sites, which were classified into five habitat types, we carried out 115 counts in all (totalling 72 hours of observation). Transects were predetermined routes, 500 m long and 40 m wide (or 20 m wide in riverine and forest edge habitats when observations were made from a habitat boundary; this was corrected for in later analyses). All birds observed or heard in the transect area were identified and recorded to species level. Only birds actually using the habitat were included; those flying over the habitat were not (Pomeroy 1991). The three observers were experienced bird watchers. All spent time familiarising themselves with the local birds before transects started. JM had visited the region for a reconnaissance the previous year (at the same time of year); DJ arrived ahead of the rest of the expedition and spent two weeks with a local bird guide. Both authors have had considerable experience studying birds overseas. Of course, it is noted that this remains a possible source of bias.

We studied five different habitats: 1, Rainforest; 2, Rainforest Edge; 3, Wet Sclerophyll; 4, Dry Sclerophyll; and 5, Riverine Rainforest. Table 1 gives habitat descriptions following Specht (1981). Wet sclerophyll is a transitional habitat, forming a border where rainforest has been cleared or is re-establishing itself. The riverine rainforest ran between two large areas of rainforest.

To avoid diurnal variation in bird activity, transects were conducted only in the morning or evening (between the times stated above), between which we found

Table 1 Habitat descriptions of sites.

Habitat Type	Description (after Specht 1981)
(1) Rainforest	Tall, Tropical Closed-Forest, with a canopy height of 30 m and sparse emergents up to 50 m. Strangling Figs (*Ficus* spp.) and buttress roots prominent. Canopy foliage cover of > 70%. Ground layer of herbaceous plants < 2 m tall. Hanging lianes and epiphytic ferns, lichens and mosses.
(2) Rainforest Edge	Edge of closed-forest, maintained by fire, cyclones, roads etc. Vegetation as (1) above, but old edges have secondary growth forming a thick wall in front of the forest edges
(3) Riverine Rainforest (3 sites)	In thin belts along water courses. Vegetation as (1) above, but with some riparian species present, and colonising species from adjacent disturbed areas.
(4) Wet Sclerophyll (2 sites)	Tall Open-forest. Transition zone between habitats (1) and (5) (the 'Closed-Open Forest Interface'). *Eucalyptus* species dominant but with some rainforest species.
(5) Dry Sclerophyll	Open Forest. Lower rainfall, *Eucalyptus* dominated overstorey with an understorey of grasses (savannah) and shrubs.

no significant difference in counts of species or individuals, i.e. birds appeared to be equally active at these times. Other bias may still have occurred due to varying observer competence or variation in weather and therefore observation conditions, and fluctuations in bird activity over the study period. In the dry season particularly, many bird species are prone to move between patchy food sources. In order to reduce possible methodological bias (see Harden et al. 1986) as far as possible, we used four methods of measuring bird 'diversity', in order to cross-check the congruence of results.

1. Birds per hour

Line transect census methods normally allow a calculation of birds per unit area. However, with differential ease of sightings and movement between habitats, and the difficulty of seeing birds in tall rainforest trees (therefore requiring more identification time), abundance is represented in terms of birds per hour. For comparative purposes this is more suitable; it can remove some bias due to varying area covered and time spent in habitats (Harden et al. 1986). It is not intended to represent 'biodiversity'.

2. Bird Species Diversity

A measure of biodiversity was calculated using the Shannon–Weaver Index of Biodiversity (Shannon 1948) obtainable by multiplying the proportion of the *i*th species with its logarithm and summing, given by the equation:

$$\text{Bird Species Diversity} = \text{BSD} = -\sum_{i=1}^{n} \text{p}i \ln \text{p}i \qquad (1)$$

3. Equally Common Species

Equally Common Species, a measure of the number of species with similar densities, is derived from (1) as follows:

$$\text{Equally Common Species} = \text{ECS} = e^{\text{BSD}} \qquad (2)$$

4. Monte Carlo Sampled Species Richness (rarefaction method)

This is calculated by taking random runs of 100 consecutive individuals across transects and determining the number of different species of which these were comprised (C. Bibby pers. com.). Five runs were performed for each habitat, and the mean is given.

Results

During the study period we recorded 150 species, including two from the Near Threatened species list (Collar et al. 1994): Bower's Shrike-thrush and Bridled Honeyeater. Table 2 shows a summary of the results, including the totals for all transects in each habitat and component sites. An appendix lists all species recorded in each site of all habitat types.

There was no significant difference in bird activity (abundance) between morning and afternoon transects in any particular transect site or across all transects (latter: Mann–Whitney *U*-test, two tailed: $U = 729.5$, $z = -2.09$, $P = 0.074$ n.s.), or using a corrected figure of abundance recorded per unit time, per transect ($U = 754.5$, $z = -1.91$, $P = 1.12$ n.s.), or between species across all transects ($U = 835.5$, $z = -1.33$, $P = 0.37$ n.s.).

There was no large difference between any measure of biodiversity between any of the habitats (BSD range 2.49-3.36; see Table 2). The highest biodiversity was measured in the Riverine site 2 (BSD = 3.36). The next highest was the Wet Sclerophyll site (3.06), followed by Rainforest Edge (2.94), Riverine site 3 (2.88), Rain-

Table 2 Results and biodiversity indices for all habitats and the component study sites.

Habitat	Component sites	Total distance covered/km	Birds per hour	Birds per km	BSD[1]	Species richness (rarefaction index)	ECS [2]
Riverine	Total:	25.0	81.50	1.88	—	18.8	—
Rainforest	Site 1	*8.5*	*91.47*	*4.77*	*2.49*	*13.6*	*12.06*
	Site 2	*9.5*	*61.56*	*3.11*	*3.36*	*22.2*	*28.79*
	Site 3	*7.0*	*109.78*	*5.11*	*2.88*	*20.6*	*17.81*
Rainforest		9.0	59.20	4.67	2.66	17.2	14.30
Rainforest Edge		8.5	92.57	4.53	2.94	18.2	18.92
Wet Sclerophyll	Total	10.5	136.37	3.23	—	16.0	—
	Site 1	*4.0*	*76.05*	*6.20*	*2.60*	*21.4*	*13.46*
	Site 2	*6.5*	*170.59*	*4.24*	*3.06*	*10.6*	*21.33*
Dry Sclerophyll		4.5	65.60	5.95	2.60	20.4	13.46

[1] Bird Species Diversity (see Methods); [2] Equally Common Species (see Methods).

forest (2.66) and Dry Sclerophyll forest and Wet Sclerophyll site 1 jointly (2.60). The lowest biodiversity was found in Riverine site 1 (2.49).

The two different measures of biodiversity, BSD and the rarefaction method, generally agreed with each other across each of the habitats and sites (but not significantly, $r = 0.12$, $P > 0.05$, although sample size is small, $n = 8$). Riverine site 2 was ranked top by both measures. This gave some indication that they gave reliable results despite differences in methodology and the sample sizes they are calculated with.

Even though species diversity indices were broadly similar, a more important question is the level of specificity of the birds within each habitat: a measure of specialisation of species within a habitat. Therefore, we analysed which species were common or unique to particular study sites and habitats, using the data detailed in the appendix. The results are summarised in Table 3. A total of 29 species were specific to a particular site (regardless of habitat), and 36 species were specific to one habitat type only.

Table 3 Numbers of specific species in different sites and habitats, not occurring elsewhere, compared to total species numbers.

Site	Species total	Specific species
Riverine Site 1	41	3
Site 2	50	9
Site 3	46	2
Riverine summed	67	19
Rainforest	35	6
Rainforest Edge	41	2
Wet Sclerophyll Site 1	41	6
Site 2	32	1
Wet Sclerophyll summed	52	7
Dry Sclerophyll	38	1

Discussion

There was no obvious relationship between habitat and species diversity (Table 2). In fact, both the highest and lowest Bird Species Diversity Indices were found within the same habitat, Riverine Rainforest, and the two sites in Wet Sclerophyll had very different diversities. Thus, habitat type *per se* did not help to explain differences in bird diversities.

While very little information is available on bird species diversity in sclerophyll, forest edge and riverine habitats, some studies exist for rainforest elsewhere in the region, although they vary widely in effort and method of data collection. Crome (1978) found 74 bird species in lowland rainforest, near Mission Beach, Innisfail, and refers in that paper to 83 species identified in 1972 on Mt Lewis (at an altitude of 1000 m). Frith (1984) recorded 52 species along transects of upland rainforest 80 km north of Townsville during two years 1978–79. In the same area, Griffin (1974) found 109 species in rainforest and fringing habitat of Mt Spec. Beehler (1981) records 150 species from one rainforest area of New Guinea (but estimated there would be 165-170 elsewhere). Pearson (1977) reviews bird diversities (excluding raptors and nocturnal birds) found in tropical lowland rainforest from six study sites in the New and Old World, not including Australia. He reports 150 species from Limoncocha, Ecuador, 131 from Yorinacocha, Peru, 124 from Tumi Chucua, Bolivia, 108 from Kutai, Borneo (Indonesia), 83 from Muprik, New Guinea and 112 species from Makokou, Gabon. These studies were not controlled for effort but cumulative species regressions showed asymptotic curves for all sites. While it is interesting to compare species lists, direct comparisons should not be drawn between our results and any of the studies above because of varying methodology, effort and other variables (e.g. season, year and altitude).

In contrast to our results, Kikkawa (1968) found species richness to be much higher in rainforest than either wet or dry sclerophyll habitats, using data from a variety of different sites in Queensland, from the Herbert River, in the south, to the Daintree River, in the north. Kikkawa (1968) suggested that species diversity was influenced most by habitat complexity and structure, and Beehler (1981) drew the same conclusion for birds in New Guinean rainforest. Gilmore (1985) found that the number of (insectivorous) bird species in Australian woodland correlated with vegetation biomass and canopy height but not plant species richness.

Wet Sclerophyll

Wet Sclerophyll site 2 was the second most diverse site. This may be partly attributable to: (i) both rainforest species and dryer country birds occurred together in this habitat. Since transitional habitats form a buffer zone between other habitats, species from the adjacent habitats can exploit it, in addition to its normal residents (Crome 1990); and (ii) at the time of the study there were several flowering paperbark trees (*Melaleuca* sp.) in the transect area. Numerous nectivorous honeyeaters (genera: *Philemon*, *Melithreptus*, *Myzomela*, *Certhionyx* and *Ramsayornis*) were exploiting these flowering trees. Rainbow Lorikeets and Scaly-breasted Lorikeets were also feeding on these trees in flocks exceeding 100 birds. Such large congregations may have biased the sampling in this habitat. Keast (1968) deduced the flowering of nectar-bearing plants to be the most important factor affecting the seasonal movements of honeyeaters across Australia and a study by Ford (1983) showed a correlation between the distribution of honeyeaters and the intensity of flowering trees in a study site near Adelaide. Inter-year variation in bird species can be large. Mac Nally (1997) discusses the great increase in density of some species due to flowering trees and, in the same study site, he recorded a 66% difference in density of birds between years (Mac Nally 1996), which included nectivorous species coinciding with flowering plants. Our data, from only one year, may therefore not be representative.

Currently, with less burning in the region and the spread of closed-forest, transitional habitats like Wet Sclerophyll with their endemic and diverse communities are endangered (Harrington & Sanderson 1994; Madden & Mair 1996). Moreau (1966) suggested that a quarter of all lowland forest bird species in Africa were species of secondary vegetation and forest edges. Slud (1960) noted that of 72 species in secondary forest vegetation in La Selva, Costa Rica, 42 were confined to it. No data are available from Australia but in New Guinea, Bell (1982b) records 26 species that were confined to secondary vegetation around forest with a 46% overlap between birds netted in that habitat and those netted in forest. Bell also noted 11 species 'pairs', one of which had a niche in forest, the other in secondary vegetation. In Australia, as well as being an important feeding habitat for many species in adjacent ones, Wet Sclerophyll offers nesting sites (in hollow logs) that are not available in rainforest because dead wood rots quickly there. Our results show that Wet Sclerophyll in our study area can sustain diverse bird assemblages. The fact that rainforest is encroaching into Wet Sclerophyll with the cessation of traditional fire regimens (Unwin et al. 1988) is an important conservation consideration.

The Riverine Rainforest

The second riverine site had the greatest BSD of all sites. This high diversity may reflect a diverse assemblage of species that are specialised to the riverine habitat itself. Indeed, in support of this, we recorded 19 species (28%) which were not recorded in any of the other habitats (Table 3). This habitat thus had the greatest number of habitat specific birds (the next ranked being rainforest with 17%).

Some birds, however, were observed which seemed to be moving along the riverine habitat between the rainforest blocks, with which it formed a connecting corridor. While we have no direct evidence, and our data *per se* are no support, this site could have been high in diversity as a result of great numbers and species of birds funnelling through it.

With global fragmentation of rainforest it is of particular interest whether or not habitat 'corridors' could sustain faunal communities across a network of connected fragments (Wiens 1994; Opdam et al. 1994). For birds, the problem is somewhat reduced on account of their mobility, yet bird populations are known to decline in isolated rainforest patches (Bierregaard & Stouffer 1997). Fragmentation and isolation appears to affect different species in different ways; while some species will fly easily to islands of rainforest over open vegetation, habitat corridors may be vital for others (Wiens 1994; Opdam et al. 1985). Certainly, some species we observed, such as Sulphur-crested Cockatoos, Leaden Flycatchers and Mistletoebirds flew by any route between the forests. However, these species are found in diverse habitats anyway and corridors are conceivably more necessary for specialised rainforest species such as Orange-footed Scrubfowl and Noisy Pittas (both were recorded in this habitat but do not usually venture outside dense vegetation). Such a corridor may be a vital conservation priority for these few species. Further studies are required to provide evidence.

Rainforest

One might expect the highest biodiversity to be in the rainforest habitat, because species-area relationships predict greater diversity in larger habitat blocks (reviews in Begon et al. 1990; Wilson 1992). However, such relationships were based on island biogeographical studies, and applying these to mainland ecology has been questioned (Margules et al. 1982; Opdam et al. 1985; Wiens 1994; but see also Warburton 1997).

In fact, rainforest was very low in bird diversity compared to the other habitats studied here. It was, at 2.66, the second lowest BSD, and lower than in bushed (3.09) and wooded grassland (2.95) in East Africa (Krüger & Johnson 1996). However, it must be emphasised that the present study is limited to (a) one season, and (b) one year, and may be an underestimate. With regard to (b), the dry season in the tropical north of Australia varies widely in climate between years (see Frith & Frith 1985), and to (a), diversity may be particularly low in the dry season compared to other times of the year. Crome (1978) noted that during the dry season food is generally more scarce, some trees are deciduous and lose their leaves at this time, and that the dry ground is unsuitable for ground foragers. Bell (1982a) found that 19 of 96 rainforest species in New Guinea showed significant periodical changes in abundance. Also, Frith & Frith (1985) showed how rainforest insect numbers and biomass — an important food source for many birds — decreased during the dry season in Queensland rainforest. Recher & Holmes (1985) were able to demonstrate that the number and abundance of bird species coincided with peak insect and other food resources in woodland in New South Wales.

Bearing these caveats in mind, why might bird diversity in rainforest be so low compared to its surrounding habitats? Some bias may exist because at this time of year many species are less vocal and therefore less obvious. Recent rain (unusual for the season) may also have contributed to the low numbers. Keast (1994) showed that some birds call less in rainy weather. The peak time of the year for flowering is variable in rainforest (Frith & Frith 1985) and, finally, rainforest species are more visually inconspicuous in comparison with other habitats.

In this study, surrounding habitats proved to be more diverse, at least in the dry season, than rainforest itself. Further studies assessing biodiversity during the wet season are needed.

Between habitat variation in species

Given that a total of 95 species were recorded over all transects, from Table 3 it can be deduced that 38% of the total bird diversity is accredited to diversity between habitats. Species-area and island biogeographical effects do not account for habitat heterogeneity; a small area with a mosaic of different habitats can be richer in species than a single large habitat. A diversity of habitats influences both 'gamma' diversity (landscape diversity, Pomeroy 1993) and 'beta' diversity (between habitat diversity, Krüger & Johnson 1996). Ecological heterogeneity has been identified as a key determinant of landscape diversity in Africa (Pomeroy 1993) and in the Amazon (Tuomisto & Ruokolainen 1997). This study supports the idea that habitat heterogeneity (including transitional habitats, such as Wet Sclerophyll, which can contain their own endemics, e.g. Harrington & Sanderson 1994) could be more important for maximising biodiversity, than conserving just one large habitat. Krüger & Johnson (1996) arrived at a similar conclusion after a study of two habitats in Uganda, which although similar, had very different bird diversities. Our results would suggest that to conserve avian biodiversity in this area, one should not concentrate solely on primary rainforest habitat. Böhning-Gaese (1997) has shown measurements of species diversity to depend on the spatial scale of the study, so studies at finer and coarser resolutions are needed.

A major consideration is that of the 'value' of the species that a conservation effort aims to assist. There is a trade off between conservation for maximum biodiversity and conservation of particular species which are deemed important. A large biodiversity may best be achieved in a heterogeneous habitat containing many species (including those common elsewhere), whereas the conservation of a single rarity may require an enormous area of one habitat type.

Conclusions

Bias can still exist in comparing habitats, if there is variation in conspicuousness, seasonal effects, effort per habitat or familiarity with certain species. Although a regression of cumulative species richness in the rainforest transects was reaching a plateau, further sites within that habitat may have revealed new species, if the habitat and bird distributions were not uniform. Some bias, however, is inevitable in such studies and Pomeroy (1991) suggested that the transect method itself underestimates presence by 15%. Although such error should be roughly constant and every effort can be made to reduce other biases, they should not be ignored when interpreting results.

In summary, the empirical results presented here found that disturbed and transitional habitats supported comparatively diverse bird assemblages and that a large block of continuous 'primary' rainforest habitat supported a low diversity. Local habitat heterogeneity increased species diversity over the landscape because many species were confined to certain habitats. Fragmented rainforest may in fact serve to increase diversity on a landscape scale, by creating a mosaic of heterogeneous habitats, all of which can hold similarly diverse bird assemblages (Table 2), but of only partly overlapping species (Table 3). It is important to note, however, that rare, habitat specific and endemic species are certainly not advantaged from conservation of habitat heterogeneity *per se*. They may instead require protection and maximisation of their specific habitat. For example, Warburton (1977) found that while small rainforest remnants of less than 20 ha supported a 'significant fraction' of the local avifauna, areas well over 600 ha would be required to conserve all the species of that habitat found in his study area.

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Appendix 1 Species list per site and per habitat in taxonomic order (after Christidis & Boles 1994).

Species	Riverine (all sites)	Riverine sites (site 1)	(site 2)	(site 3)	Rain forest	Rain-forest Edge	Wet sclerophyll (both sites)	Wet sclerophyll sites (site 1)	(site 2)	Dry sclerophyll
Alectura lathami Australian Brush-turkey	●			●		●				
Megapodius reinwardt Orange-footed Scrubfowl		●	●	●	●	●	●	●	●	●
Anas superciliosa Pacific Black Duck		●	●	●						
Egretta garzetta Little Egret	●		●							
Ardea pacifica White-necked Heron	●	●	●							

Appendix 1 Continued.

Species	Riverine (all sites)	Riverine sites (site 1)	Riverine sites (site 2)	Riverine sites (site 3)	Rain forest	Rain-forest Edge	Wet sclerophyll (both sites)	Wet sclerophyll sites (site 1)	Wet sclerophyll sites (site 2)	Dry sclerophyll
Ardea alba Great Egret	●	●								
Ardea intermedia Intermediate Egret	●		●							
Threskiornis molucca Australian White Ibis	●		●							
Threskiornis spinicollis Straw-necked Ibis	●	●	●	●						
Aviceda subcristata Pacific Baza							●		●	
Milvus migrans Black Kite	●		●							
Haliastur sphenurus Whistling Kite	●		●	●		●				
Circus assimilis Spotted Harrier		●		●						
Accipiter fasciatus Brown Goshawk	●		●	●		●	●		●	
Accipiter novaehollandiae Grey Goshawk							●		●	
Macropygia amboinensis Brown Cuckoo-Dove	●		●			●				
Chalcophaps indica Emerald Dove	●		●		●					
Geopelia humeralis Bar-shouldered Dove	●	●	●	●		●	●	●	●	
Ptilinopus magnificus Wompoo Fruit-Dove	●	●		●	●	●				●
Ptilinopus superbus Superb Fruit-Dove	●		●							●
Ptilinopus regina Rose-crowned Fruit-Dove	●		●							
Ducula bicolor Pied Imperial-Pigeon							●			
Lopholaimus antarcticus Topknot Pigeon	●	●	●				●		●	
Unidentified Dove					●					
Cacatua galerita Sulphur-crested Cockatoo	●	●	●	●	●	●	●	●	●	●
Trichoglossus haematodus Rainbow Lorikeet	●	●	●	●	●	●	●	●	●	●
Trichoglossus chlorolepidotus Scaly-breasted Lorikeet	●	●					●		●	●
Glossopsitta pusilla Little Lorikeet							●		●	
Cyclopsitta diophthalma Double-eyed Fig-parrot	●		●	●	●	●	●	●		

Appendix 1 Continued.

Species	Riverine (all sites)	Riverine sites (site 1)	(site 2)	(site 3)	Rain forest	Rain-forest Edge	Wet sclerophyll (both sites)	Wet sclerophyll sites (site 1)	(site 2)	Dry sclerophyll
Aprosmictus erythropterus Red-winged Parrot							●		●	●
Chrysococcyx minutillus Little Bronze-Cuckoo	●			●	●					
Eudynamys scolopacea Common Koel	●			●						
Collocalia spodiopygius White-rumped Swiftlet	●	●	●	●	●	●	●	●		
Alcedo azurea Azure Kingfisher	●	●	●			●				
Dacelo novaeguineae Laughing Kookaburra	●	●	●	●			●	●	●	●
Dacelo leachii Blue-winged Kookaburra							●		●	●
Todiramphus macleayii Forest Kingfisher	●	●	●	●		●	●	●		●
Merops ornatus Rainbow Bee-eater	●	●	●	●	●	●	●	●	●	●
Pitta versicolor Noisy Pitta	●	●	●			●				
Malurus amabilis Lovely Fairy-wren	●	●		●	●	●	●	●		
Gerygone magnirostris Large-billed Gerygone	●	●	●	●	●	●	●	●		●
Gerygone palpebrosa Fairy Gerygone	●	●		●		●	●	●	●	●
Philemon buceroides Helmeted Friarbird	●	●	●	●	●	●	●		●	●
Philemon argenticeps Silver-crowned Friarbird							●		●	●
Entomyzon cyanotis Blue-faced Honeyeater							●		●	
Manorina melanocephala Noisy Miner	●	●	●							
Xanthotis macleayana Macleay's Honeyeater					●	●				
Meliphaga lewinii Lewin's Honeyeater	●			●	●					
Meliphaga notata Yellow-spotted Honeyeater	●	●	●	●	●	●	●	●	●	●
Meliphaga gracilis Graceful Honeyeater	●	●	●	●	●	●	●	●	●	●
Lichenostomus frenatus Bridled Honeyeater						●				
Lichenostomus flavus Yellow Honeyeater						●		●	●	

Appendix 1 Continued.

Species	Riverine (all sites)	Riverine sites (site 1)	(site 2)	(site 3)	Rain forest	Rain-forest Edge	Wet sclerophyll (both sites)	Wet sclerophyll sites (site 1)	(site 2)	Dry sclerophyll
Lichenostomus flavicollis White-throated Honeyeater							•		•	•
Ramsayornis modestus Brown-backed Honeyeater							•	•	•	•
Certhionyx pectoralis Banded Honeyeater						•		•	•	
Myzomela obscura Dusky Honeyeater	•	•	•	•	•	•	•	•	•	•
Myzomela sanguinolenta Scarlet Honeyeater							•		•	•
Microeca flavigaster Lemon-bellied Flycatcher	•			•	•		•	•		•
Tregellasia capito Pale-yellow Robin					•					
Unidentified Flycatcher					•					
Psophodes olivaceus Eastern Whipbird					•					
Pachycephala pectoralis Golden Whistler	•			•		•				•
Pachycephala rufiventris Rufous Whistler										•
Colluricincla megarhyncha Little Shrike-thrush							•	•	•	
Colluricincla boweri Bower's Shrike-thrush	•	•	•	•	•	•	•	•		
Colluricincla harmonica Grey Shrike-thrush							•		•	•
Machaerirhyncus flaviventer Yellow-breasted Boatbill							•		•	
Monarcha trivirgatus Spectacled Monarch	•		•	•	•	•	•	•	•	
Monarcha leucotis White-eared Monarch					•					
Monarcha melanopsis Black-faced Monarch	•		•							
Arses kaupi Pied Monarch	•			•	•		•	•		
Myiagra rubecula Leaden Flycatcher	•		•	•		•	•		•	•
Myiagra cyanoleuca Satin Flycatcher	•	•	•	•		•				
Myiagra alecto Shining Flycatcher	•		•							
Rhipidura rufifrons Rufous Fantail	•		•	•	•		•	•	•	•
Rhipidura fuliginosa Grey Fantail	•	•	•	•	•		•	•	•	

Appendix 1 Continued.

Species	Riverine (all sites)	Riverine sites (site 1)	(site 2)	(site 3)	Rain forest	Rain-forest Edge	Wet sclerophyll (both sites)	Wet sclerophyll sites (site 1)	(site 2)	Dry sclerophyll
Rhipidura rufiventris Northern Fantail	●			●		●	●	●	●	●
Dicrurus bracteatus Spangled Drongo	●	●	●	●		●	●	●		●
Coracina papuensis White-bellied Cuckoo-shrike	●	●	●	●		●				●
Lalage sueurii White-winged Triller	●	●		●						
Lalage leucomela Varied Triller	●	●	●	●	●	●	●	●	●	●
Oriolus flavocinctus Yellow Oriole	●	●	●	●	●	●	●	●	●	●
Oriolus sagittatus Olive-backed Oriole	●		●	●			●		●	●
Sphecotheres viridis Figbird	●	●	●	●		●	●	●	●	●
Cracticus quoyi Black Butcherbird							●		●	
Ptiloris victoriae Victoria's Riflebird							●	●		
Ailuroedus melanotis Spotted Catbird					●	●				
Neochmia modesta Plum-headed Finch	●	●								
Lonchura punctulata Nutmeg Mannikin	●		●							
Lonchura castaneothorax Chestnut-breasted Mannikin	●	●								
Nectarinia jugularis Yellow-bellied Sunbird	●	●	●	●	●	●	●	●		●
Dicaeum hirundinaceum Mistletoebird	●	●	●	●	●	●	●	●	●	●
Zosterops lateralis Silvereye	●	●	●	●	●	●	●	●	●	●
Aplonis metallica Metallic Starling	●	●	●	●		●				
An unidentified species						●				
Total species	67	41	50	46	35	41	52	41	32	38
Specific species	19	3	9	1	6	2	8	6	1	1