

The avifauna of Kimberley rainforests

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Patches of rainforest were visited in the Kimberley, Western Australia, in June 1987, May and June 1988, and January and March 1989. A total of 96 patches were surveyed and 141 species of bird were recorded. Twenty-two species were found to be confined to or largely dependent on rainforests and for these we give details on distribution, relative abundance and habitat preferences. Rainforest patches were divided into six groups on the basis of bird species composition. Bird species were classified into one group containing most specialists and other species frequently found in rainforest patches and several smaller groups comprised mostly of woodland species. Bird distributions were influenced mainly by rainfall, floristic richness and to a lesser extent substrate. Patch area was also important, especially for rainforest specialists.

INTRODUCTION

THE Kimberley region lies within the Timorian zoogeographic subregion (Heatwole 1987 and references therein). Apart from its southern desert fringe, the Kimberley has an avifauna similar to that of the "Top End" of the Northern Territory and far northwestern Queensland (e.g., Kikkawa and Pearse 1969; Holloway and Jardine 1968). Most of the Kimberley is vegetated with open savannah woodland (Beard 1979) but scattered throughout the region, particularly in the north-west, are patches of rainforest (including communities previously called monsoon forest, complex or semi-evergreen mesophyll vine forest, semi-deciduous vine forest and deciduous vine thicket) (McKenzie, this publ.; Kenneally *et al.*, this publ.). These rainforest patches, along with mangal, provide the major closed forest habitats in the Kimberley (Beard 1979; Kenneally and Beard 1987). The unique and relatively rich bird fauna of the Kimberley mangroves has been described by Johnstone (1990) but until recent times little was known of the distribution and status of rainforest birds in this region. G. F. Hill (1911) observed and collected some rainforest birds at Napier Broome Bay from August 1909 to July 1910. More recently considerable information was gained during biological surveys of the Prince Regent Nature Reserve (Storr *et al.* 1975), Drysdale River National Park (Johnstone *et al.* 1977), Bonaparte Archipelago (Smith *et al.* 1978), Mitchell Plateau (Johnstone and Smith 1981) and Dampier Peninsula (Johnstone 1983). These and other observations on birds in the Kimberley Division are summarized by Storr (1980) who suggested that bird distributions were influenced largely by rainfall. He recognized three broad bioclimatic zones — a sub-humid zone (mean annual rainfall 1 000–1 500 mm), semi-arid zone (500–1 000 mm) and arid zone (less than 500 mm). Those bird species more or less confined to rainforest patches were mostly restricted to near coastal areas of the subhumid zone between Napier Broome Bay and Walcott Inlet, with a few species extending beyond this area.

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In wet tropical rainforest in northeastern Queensland, Crome (1975, 1978), Frith (1984) and Kikkawa and others (Kikkawa 1984 and references therein) have examined bird community composition and structure.

Kikkawa *et al.* (1981) showed a major dichotomy between Cape York Peninsula and the Kakadu area (Northern Territory) in terms of bird species presence at individual patches of seasonally dry rainforest. Furthermore, analysis of sites within Kakadu National Park also revealed a strong dichotomy between species-poor escarpment sites and species-rich plains sites. In general, these authors interpreted the biotic and structural diversity of Australian (monsoon) rainforests as responding to gradients in soil fertility, fire frequency and seasonality and amount of rainfall. Specifically, they noted that the Carpentarian Gap (Keast 1961; Ford 1982) has been an effective barrier to westward dispersal of wet-adapted forms from Cape York Peninsula. More recently there has also been some detailed work done on the composition and structure of avian communities in semi-deciduous and semi-evergreen monsoon vine forest (rainforest) in Kakadu National Park (Brooker and Parker 1985; Brooker *et al.* 1985; Woinarski 1988). These authors found that, while the bird species composition of monsoon forests is distinct from that of the surrounding woodland, very few bird species foraged exclusively in monsoon forest and many were also common inhabitants of open forest and woodland. Monsoon forests had fewer large ground or aerial feeding raptors, fewer granivores and tree-gleaners and more frugivores than nearby open forests and woodlands. Compared with rainforests in Queensland and New Guinea, the Kakadu monsoon forests have few frugivores and relatively high numbers of nectar and invertebrate-feeding honey-eaters. These differences were attributed to differences in floristic composition, seasonality of rainfall and the degree of fragmentation of the monsoon forests. The isolated Kimberley rainforest patches might be expected also to show these trends.

In a comparison of small, poorly isolated rainforest remnants in New South Wales, Howe *et al.* (1981) found that area was by far the best simple predictor of species richness but isolation, disturbance by domestic cattle and distance from water all tended to reduce the number of resident species. In evaluating their data, they pointed out that species which have invaded Australia from south-east Asian rainforests would, most probably, be those with above average capabilities for dispersal. Conversely, few sedentary tropical species could be expected to have expanded their range across a discontinuous chain of rainforest areas. These conclusions are particularly pertinent to any consideration of rainforest avifauna in the Top End and Kimberley, where rainforest patches are relatively small and isolated.

The major aim of the present study was to document the avifaunal composition of 96 isolated rainforest patches growing on a range of substrates in the north-west and east Kimberley (see also McKenzie, this publ.) in order to determine broad scale patterns in species composition. A further aim was to study 16 patches in greater detail in order to characterize avian community structure.

METHODS

This paper is based mainly on data gathered during a survey of 96 patches of rainforest in Kimberley, Western Australia (Fig. 1), in June 1987, May and June 1988 and January and March 1989. Patches are described fully and a map showing their position and reference codes are given in McKenzie (this publ.), as is the rationale for patch selection. Johnstone was responsible for gathering information from 83 patches in the north-west Kimberley (4/1–30/2) in June 1987 and 16 patches in March 1989. Burbidge obtained data from five "detailed" patches in June 1987, 11 patches in the east Kimberley in May 1988 and four "detailed" patches in June 1988. We are indebted to Andrew A. Burbidge, P. J. Fuller, N. L. McKenzie, G. Wardell-Johnson, G. R. Friend and K. D. Morris for data on the birds at 12 patches in June 1988 and to N. L. McKenzie for wet season observations in late January and early March 1989. All "detailed" patches examined were a subset of those examined by Johnstone in 1987. In patches visited late in the day, a more concerted effort was made to flush birds as less were calling. For further detail see McKenzie (this publ.).

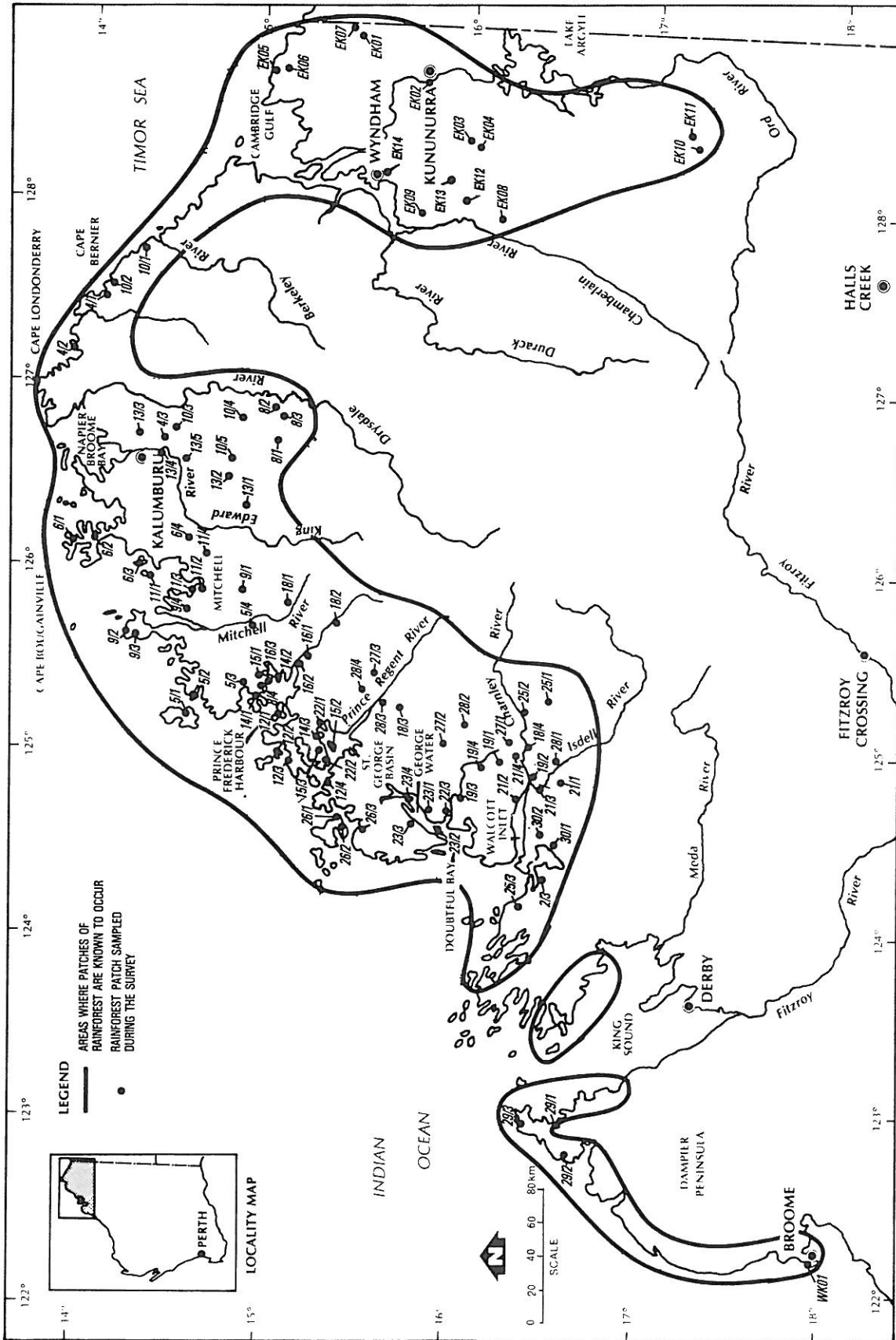


Fig. 1. The 95 patches of Kimberley rainforests sampled for birds.

Notes from R. E. Johnstone's and L. A. Smith's visits to rainforest patches on the Mitchell Plateau in January–February 1973, June 1975 and October 1976 are also included in the data.

Statistical relationships between species richness and biophysical attributes of the patches were calculated using the computer package SAS/STAT[™] (SAS Institute Inc. 1987) as outlined by McKenzie (this publ.). The Spearman rank correlation procedure was used for continuous variables and Kruskal-Wallis tests for attributes which were categorized (e.g., geological substrate type). Biophysical data were obtained from Stoneman *et al.* (this publ.) and McKenzie *et al.* (this publ.).

Using the computer package PATN, rainforest patches were classified on the basis of the bird species present, and bird species were classified on the basis of the patches at which they occurred. The rationale and procedures for the classification analyses used are outlined in McKenzie (this publ.). Bird analyses were initially carried out using all observations. Subsequent analyses were carried out excluding edge (including aquatic edge) observations and excluding species observed at only one patch (singletons) (irrespective of the number of individuals observed) as all these records appeared to represent vagrants from other habitats. As such, they contributed little to the observed patterns and the analyses were easier to interpret without them. Using dry season data only, patches were ordinated using the KYST option of PATN (see McKenzie, this publ., for details of methods).

Specimens collected during June 1987 and March 1989 are lodged in the Western Australian Museum under registration numbers A21500–21604, 21693–21707, 22313–22357. Nomenclature follows that used at the Western Australian Museum. Crop and stomach contents were retained to be analyzed at a later date by REJ. Opportunistic observations were made of foraging behaviour and identity of food items.

RESULTS

General

A total of 141 species was recorded in Kimberley rainforests (Table 1); this included 128 species in the dry season and 101 species in the wet season (but note that sampling was less extensive in the wet season). About 20 species were recorded per patch, with the drier areas (e.g., east Kimberley) supporting less. The number of species per patch ranged from five at EK03 to 48 at 19/2 (including eight edge species, averaging three per patch). A total of 21 "rainforest birds" (defined below) were recorded during the survey, but only four of these were found in the east Kimberley (Table 1). Edge and aquatic species and singletons (i.e., species occurring at a single patch) (Attachment 1) were removed before running the multivariate analyses. Of the 112 non-edge species, 58% were passerines.

Table 1. Mean number of bird species (\pm standard deviation) recorded in rainforest patches in the Kimberley. Notes: 1, defined in text; 2, all dry season records for NW, E and W Kimberley, including records from "detailed" teams; 3, north-west Kimberley only, but including Dampier Land, "helicopter" team only; 4, same as 3 but excluding Dampier Land; 5, NW Kimberley, excluding Dampier Land but including "detailed" data from 1987 and 1988; 6, "helicopter team", 19 "detailed" patches only; 7, January and March; 8, March only. See text for further details; see McKenzie (this publ.) for details of patches.

	No. of patches	Total species	Species/patch (mean \pm SD)	Rainforest species ¹	R.for. spp./patch (mean \pm SD)	Non-edge species	Non-edge spp./patch (mean \pm SD)	Singletons
All records (wet and dry)	96	141	21.4 \pm 8.3	21	6.0 \pm 4.3	112	17.9 \pm 7.2	29
Dry season ²	95	128	21.3 \pm 8.9	19	5.5 \pm 4.0	101	17.8 \pm 7.8	29
Dry season ³	83	112	19.4 \pm 5.5	18	5.6 \pm 3.3	86	16.3 \pm 4.7	29
Dry season ⁴	80	112	19.5 \pm 5.5	18	5.8 \pm 3.3	85	16.4 \pm 4.7	28
Dry season ⁵	80	124	22.6 \pm 8.8	18	6.4 \pm 3.8	96	19.1 \pm 7.6	28
Dry season ⁶	19	77	21.8 \pm 6.4	17	7.1 \pm 3.4	57	18.6 \pm 5.7	21
"Detailed" teams	19	95	29.5 \pm 8.2	16	8.8 \pm 3.9	82	25.2 \pm 7.3	25
East Kimb. dry	11	53	13.8 \pm 6.9	4	0.8 \pm 0.9	42	10.9 \pm 6.1	24
Wet season ⁷	23	101	22.2 \pm 11.1	21	6.3 \pm 4.2	86	19.4 \pm 9.8	32
Wet season ⁸	16	101	25.1 \pm 9.5	21	6.0 \pm 4.3	84	21.1 \pm 8.9	35

Patch Group		1												2												3												4												5												6											
		.000120010001001222211212111100110112222222311212111112.												0021102110011232E2.011212EEEE.11.222WE.1EEEE.												.445136929564656238712642455869218626633215019785968998.												4950088388833101K8.503107KKKK.35.999KK.OKKKKK.												.122321223132431313323312313224114342134123144132324124.												311241131231212372.4544328126.52.12315.193401.											
Species Group												
1	Broad-billed Flycatcher	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Orange-footed Scrubfowl	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Red-crowned Pigeon	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Little Shrike-thrush	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Spangled Drongo	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Varied Triller	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Torres Strait Pigeon	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Green-winged Pigeon	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Rainbow Pitta	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Figbird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Olive-backed Oriole	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Pheasant Coucal	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Sacred Kingfisher	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Shining Flycatcher	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Wood (Rufous) Fantail	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Mangrove Golden Whistler	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Yellow White-eye	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Red-headed Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Brown Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-gaped Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Northern Fantail	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Bar-shouldered Dove	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Great Bowerbird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Green-backed Flyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Mistletoebird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Leaden Flycatcher	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Silver-crowned Friarbird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Yellow Oriole	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-throated Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Red-collared Lorikeet	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Sulphur-crested Cockatoo	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Grey Butcherbird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-bellied Cuckoo-shrike	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Rufous Whistler	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Red-winged Parrot	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Double-barred Finch	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Black-faced Cuckoo-shrike	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Rainbow Bee-eater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Striated Pardalote	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Torresian Crow	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Weebill	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Blue-winged Kookaburra	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Restless Flycatcher	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Peaceful Dove	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Willie Wagtail	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Southern Boobook	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Banded Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-quilled Rock Pigeon	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Barking Owl	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Collared Sparrowhawk	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Whistling Kite	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-browed Robin	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Rufous Night Heron	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Rufous Owl	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Variegated Fairy-wren	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Brown Goshawk	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Rufous-throated Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-lined Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Northern Rosella	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Little Woodswallow	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Square-tailed Kite	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Golden-headed Cisticola	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Red-backed Fairy-wren	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Tawny Frogmouth	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Pied Butcherbird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Varied Lorikeet	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Yellow-throated Miner	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Bar-breasted Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Singing Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Peregrine Falcon	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Sandstone Shrike-thrush	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Brown Falcon	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-bellied Sea Eagle	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-breasted Woodswallow	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Brahminy Kite	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Grey Shrike-thrush	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Grey-crowned Babbler	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Little Friarbird	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Red-tailed Black Cockatoo	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Grey Fantail	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Yellow-tinted Honeyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	White-throated Flyeater	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Masked Owl	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											
	Little Corella	* * * *												* * * *												* * * *												* * * *												* * * *												* * * *											

Fig. 2. Two-way table of bird species by patch for the 95 dry season patches, excluding edge and aquatic species and singletons. Patch codes are printed vertically.

Frequency of recording varied tremendously, with some species being recorded at more than 60 patches (e.g., Brown Honeyeater was recorded at 88%, White-gaped Honeyeater at 85%; Table 2, Fig. 2) and with 29 species being recorded at one patch only (Attachment 1).

Table 2. The most frequently recorded bird species in Kimberley rainforest patches.

Species	Number of patches	
	Dry season	All data
Brown Honeyeater	84	85
White-gaped Honeyeater	81	82
Bar-shouldered Dove	75	76
Great Bowerbird	74	78
Northern Fantail	74	76
Green-backed Flyeater	72	75
Mistletoebird	70	75
Leaden Flycatcher	65	66

On the basis of earlier data (Storr *et al.* 1975; Johnstone *et al.* 1977; Smith *et al.* 1978; Johnstone and Smith 1981; Johnstone 1983) and the present survey, 22 species are regarded as being largely confined to rainforest or showing strong preferences for rainforest in the Kimberley. These species are listed as "rainforest species" in Table 1 and in other parts of the text. Of these 22, thirteen species were found to be largely confined to rainforest, namely Orange-footed Scrub-fowl (*Megapodius reinwardt*), Red-crowned Pigeon (*Ptilinopus regina*), Torres Strait Pigeon (*Ducula bicolor*), Green-winged Pigeon (Emerald Dove) (*Chalcophaps indica*), Rufous Owl (*Ninox rufa*), Rainbow Pitta (*Pitta iris*), Cicadabird (*Coracina tenuirostris*), Varied Triller (*Lalage leucomela*), Little Shrike-thrush (*Colluricincla megarhyncha*), Green-backed Flyeater (*Gerygone*) (*Gerygone chloronata*), Yellow Oriole (*Oriolus flavocinctus*), Figbird (*Specotheres viridis*) and Spangled Drongo (*Dicrurus megarhynchus*). Four species were mainly confined to closed waterside forest and rainforest, namely Oriental Cuckoo (*Cuculus saturatus*), Brush Cuckoo (*C. variolosus*), Koel (*Eudynamys scolopacea*) and White-browed Robin (*Poecilodryas superciliosa*). Another five species, Little Bronze-Cuckoo (*Chrysococcyx minutillus*), Mangrove Golden Whistler (*Pachycephala melanura*), Wood Fantail (*Rhipidura dryas*), Broad-billed Flycatcher (*Myiagra ruficollis*) and Shining Flycatcher (*M. alecto*) were mainly mangrove inhabitants but frequently visited near-coastal patches of rainforest. The above 22 species are dealt with in the annotated list (below).

Adequacy of Sampling

Based on comparisons for the four patches examined in detail in June 1987 (Tables 1,3), the helicopter team recorded 72% of all species recorded at these patches while the "detailed" team recorded 86%. The result for the rainforest specialist species (defined above) was better, as the helicopter team recorded 83% and the detailed team recorded 94% of these species known from the four patches. For those species classified in Group 1 of the species classification (the major rainforest bird assemblage; see below) the two teams recorded 77% and 86% respectively of the non-edge species from this group known from these four rainforest patches. Table 1 provides further information concerning the numbers of species recorded per patch. Higher numbers of species were recorded at the "detailed" patches for two reasons — they were sampled over several days rather than for about an hour, and they were patches of above average species richness (compare Table 1 with Table 3). Comparisons of numbers of species recorded at the 19 "detailed" patches should be made with caution because some patches were visited by "detailed" teams in 1987 and some in 1988; year to year variation could account for some of the observed differences. Some species turnover between years is apparent (see below) but is difficult to quantify; the number of species present in any one year may be related to the amount of flowering and fruiting in the patch in that year.

Not surprisingly, the species most likely to be missed were inconspicuous ones. Observations from this survey suggest that inexperienced observers were most likely to miss small species in the canopy (e.g., Green-backed Flyeater, Mistletoebird). Even experienced observers

Table 3. Number of species recorded for the four patches which were visited by both teams in 1987. See text for details.

	Mean no. of species/patch \pm S.D.				
	Total species	Non-edge species	Rainforest species	Group 1 spp. (All)	Group 1 spp. (Non-edge only)
Combined data	36.3 \pm 1.0	31.0 \pm 2.7	11.5 \pm 1.3	28.3 \pm 2.6	26.3 \pm 1.7
"Detailed" team	31.3 \pm 1.7	26.5 \pm 3.0	10.8 \pm 1.5	26.0 \pm 0.8	23.3 \pm 1.0
"Helicopter" team	26.0 \pm 3.9	22.8 \pm 2.9	9.5 \pm 0.6	21.5 \pm 1.3	20.3 \pm 1.7

could miss unobtrusive species (e.g., Green-winged Pigeon, Rainbow Pitta, Figbird, Green-backed Flyeater) during a brief visit to a rainforest patch if they were not calling. Rarer species such as the Rufous Owl are easily overlooked, but it is difficult to know to what extent this occurred.

Species richness was not significantly influenced by time of day of sampling by the helicopter team (Table 4).

Species Richness

Numerous statistically significant correlations between bird species richness and biophysical attributes were evident (Table 4), with the major ones being perennial plant species richness, area of patch, various climatic attributes (particularly amount and variability of rainfall) and geological substrate (10 class). It should be noted, however, that many attributes are inter-correlated. Measures of soil nutrients were not as good predictors of species richness as any of the above attributes. Temperature range variables showed higher correlation coefficients and higher levels of significance for rainforest specialists than for all species combined.

Rainforest patches on dolerite and sandstones over volcanics tended to be richest in rainforest specialist species, with Quaternary sands being poorest (Table 5). Care is needed in interpretation, however, as annual rainfall varies significantly with 10 class geology (patches on Quaternary sands receive less rainfall than patches on any other geological class and almost all these differences are significant).

Patch Site Classification

Dry Season

The two-way table resulting from the classifications of patches and species on the basis of dry season bird data is shown in Figure 2 and the resulting dendrogram for the patch classification in Figure 3.

Six groups of patches could be distinguished from the classification analysis (Figs 2, 3). Cutting the dendrogram at a higher number of groups resulted in difficulties of interpretation with respect to some groups. The major dichotomy in the dendrogram is between Group 1 (high rainfall, species rich patches of the north-west Kimberley) and Groups 2–6.

Group 1 consisted of 54 coastal and subcoastal patches confined to the north-west Kimberley (Fig. 4). These patches contained, on average, more species than any other group and were patches with high annual rainfall, high plant species richness and large area (Table 6, Fig. 5). Most patches in this group (70%) were on sandstones but some were on laterites (15%), volcanics (11%) or alluvial soils (4%) (Table 7). Those on alluvial soils (16/2, 18/4 and 19/2) were on or immediately adjacent to massive sandstone. None were on sands. Both ubiquitous rainforest patch species (e.g., Green-backed Flyeater and Yellow Oriole) and those which could be described as rainforest patch specialists (e.g., Orange-footed Scrubfowl and Red-crowned Pigeon) or mangrove specialists (e.g., Broad-billed Flycatcher) were frequently recorded in Group 1 patches.

The 18 Group 2 patches show slightly lower mean species richness and on average receive a lower mean annual rainfall than Group 1 patches (Table 6) but show a very similar relationship to substrate as Group 1 (72% on sandstones, 15% on laterites, 11% on volcanics and none

Table 4. Statistical relationships between bird species richness and biophysical attributes for 93 rainforest patches. The relationship between observed species richness and time of day of sampling is also shown for the 1987 "helicopter team" data from 83 patches in the north-west Kimberley.

¹Data from Kenneally *et al.* (this publ.).

²Data are coefficient followed by level of significance: * = 0.05 > P > 0.01, ** = 0.01 > P > 0.001, *** = P < 0.001, n.s. = not significant.

³ values are r² followed by level of significance as above.

Attribute	Species richness			
	Perennial plants ¹	Total	Group 1	Specialists
Spearman correlation coefficients ² (continuous variables)				
Perennial plant richness	1.000	0.66 ***	0.64 ***	0.75 ***
Canopy height	n.s.	0.27 **	0.25 *	0.22 *
Distance to coast	-0.36 ***	-0.32 **	-0.45 ***	-0.58 ***
Area of patch	0.56 ***	0.50 ***	0.49 ***	0.61 ***
Steepness of slope	0.35 ***	n.s.	n.s.	0.21 *
Soil pH	n.s.	-0.23 *	n.s.	-0.27 **
Phosphorous	0.21 *	n.s.	n.s.	0.29 **
Exchangeable calcium	n.s.	n.s.	-0.21 *	n.s.
Organic carbon	n.s.	n.s.	-0.26 *	n.s.
Annual temperature	n.s.	0.28 **	0.22 *	0.30 **
Temperature range	-0.32 **	-0.32 **	-0.45 ***	-0.57 ***
Temp., min. cold mth	0.28 **	0.33 **	0.41 ***	0.54 ***
Temp., max. warm mth	-0.39 ***	-0.22 *	-0.49 ***	-0.54 ***
Temp., coolest quarter	0.21 *	0.32 **	0.35 ***	0.49 ***
Temp., warmest quarter	-0.24 *	n.s.	n.s.	n.s.
Temp., wettest quarter	-0.28 **	n.s.	n.s.	n.s.
Temp., driest quarter	n.s.	0.29 **	0.25 *	0.35 ***
Annual rainfall	0.44 ***	0.29 **	0.51 ***	0.57 ***
Rainfall variability	0.47 ***	0.52 ***	0.65 ***	0.67 ***
Rain in wettest mth	0.51 ***	0.40 ***	0.64 ***	0.73 ***
Rain in driest mth	n.s.	-0.25 *	-0.21 *	-0.33 **
Rain in wettest quarter	0.46 ***	0.33 **	0.56 ***	0.64 ***
Rain in driest quarter	0.27 **	n.s.	0.28 **	0.39 ***
Rain in coolest quarter	0.27 **	0.31 **	0.49 ***	0.45 ***
Rain in warmest quarter	0.32 **	n.s.	0.37 ***	0.30 **
Non-parametric ANOVA (Kruskal-Wallis) ³ (categorized attributes)				
Geology (10 classes)	0.37 ***	0.26 **	0.26 **	0.23 **
Geology (6 classes)	0.22 ***	0.12 *	0.14 *	n.s.
Topography	0.22 ***	0.10 *	0.11 *	0.11 *
Aspect	0.21 ***	n.s.	n.s.	n.s.
Dominant terrain	0.22 ***	n.s.	0.09 *	0.07 *
Time of day (5 classes)	—	n.s.	n.s.	n.s.

on alluvial soils or sands for the area encompassed by the Group 1 patches, i.e., the area receiving greater than 850 mm rainfall (Fig. 5). Bird species composition is similar to that for Group 1 patches except that the rainforest patch and mangrove specialists are rather less frequent.

All except two of the ten Group 3 patches are swamp or riverine situations on alluvial soils. The exceptions are EK08 which is the wettest sandstone gorge sampled in the east Kimberley and 5/4 which is on laterite. At this latter patch, which is in a high rainfall area (estimated at about 1 300 mm annually), only six bird species were recorded. It is almost certainly significantly undersampled and therefore misclassified.

Group 4 consists of two patches (13/5 and 15/2) which are on volcanic substrates. These patches contained only eight and seven species respectively and are probably undersampled and thus misclassified. This is almost certain in the case of St Andrew Island (15/2) from which the Rainbow Pitta, White-bellied Cuckoo-shrike, Little Shrike-thrush, Northern Fantail and Leaden Flycatcher were recorded during an earlier survey (Smith *et al.* 1978; REJ unpublished) but not during the present survey.

Table 5. Matrix of significant differences (determined by Kruskal-Wallis anova) in bird species richness between 93 rainforest patches categorized according to the substrate parent material. Figures for richness are mean species richness (to the nearest integer) for all bird species, group 1 species (see text) and for rainforest "specialists", followed by the number of patches (in parentheses). In the matrix, A = all bird species, G = group 1 species and R = rainforest "specialists"; an entry occurs only if $P < 0.05$ for that combination. Geological codes are explained in Appendix 4.

Richness	Geology	Significance
21,16.8 (18)	Dolerite (Pdh) 1	
19,18.7 (3)	Sandstone over Pdh 2	—
15,14.6 (2)	Duricrust over Pdh 3	— —
13,11.5 (7)	Volcanics (Pkc) 4	AG- -G- —
21,15.7 (20)	Sandstone over Pkc 5	— — — AG-
18,14.7 (8)	Duricrust over Pkc 6	— — — —
6, 4.1 (1)	Sandstone 7	AG- -G- — — AG- —
13,11.4 (18)	Duricrusted sandstone 8	AGR -G- — — AGR — —
20,12.4 (11)	Quaternary alluvials 9	-GR -G- — — A- -G- — — A-
12, 9.1 (5)	Quaternary sands 10	AGR AGR — — AGR AGR — —R A-
		1 2 3 4 5 6 7 8 9 10

Group 5 (five patches) are all on coastal sands in the relatively low rainfall east and west Kimberley. This group is clearly separated from all other groups in receiving less rainfall in the driest quarter. The group can be subdivided into two, with the east Kimberley patch (EK05) separating from the three western patches. The eastern patch receives a higher mean annual rainfall than the western patches but had a relatively depauperate bird fauna at the time of our visit. The vegetation at this patch is also lower (Table 6) and includes less fruiting trees.

Of the six Group 6 patches, five are small isolated rainforest patches in the dry east Kimberley and the remaining patch is a relatively dry coastal patch to the north-west of here (Fig. 4). All are floristically depauperate patches (Table 6) in sandstone gullies or gorges except EK10 which is on a small spring at the base of a sandstone escarpment. On the basis of the Bioclim data, these patches experience high temperatures and an expanded temperature range compared with groups 1–5.

Correspondence between biophysical attributes and UPGMA patch groups was variable, with no Cramer values (a measure of "goodness of fit": between sample variance/total variance) greater than 0.79 (Table 8).

The ordination analysis confirmed the associations between patches revealed in the classification analysis, but a three-dimensional plot provided little extra insight as to which biophysical attributes might be influencing the observed patterns. Vector 1 in this plot appeared to be (poorly) correlated with moisture availability, and variation on vector 2 may be influenced by substrate and topography but the pattern is not clear.

Wet Season

Classification of 24 rainforest patches (including patch 2/3) based on data from the two wet season sampling sessions produced a result in broad agreement with that for the dry season data. However, it was clear that most patches visited only during the first wet season sampling session were inadequately sampled due to lack of time. Classification of 16 patches sampled in March resulted in these patches being grouped in the same combinations as for the dry season, except that 29/2 and EK05 became separated as singletons (Figs 6,7).

Species Classification

The dry season species classification revealed the presence of three broad groups — one (Group 1) containing common and more or less ubiquitous rainforest patch species as well as "rainforest patch specialists" and mangrove specialists, one (Groups 2 and 3) containing predominantly woodland species which were common overall and one (Groups 4–7) containing woodland species which were infrequently recorded in rainforest patches (Figs 2, 8).

KIMBERLEY RAINFORESTS

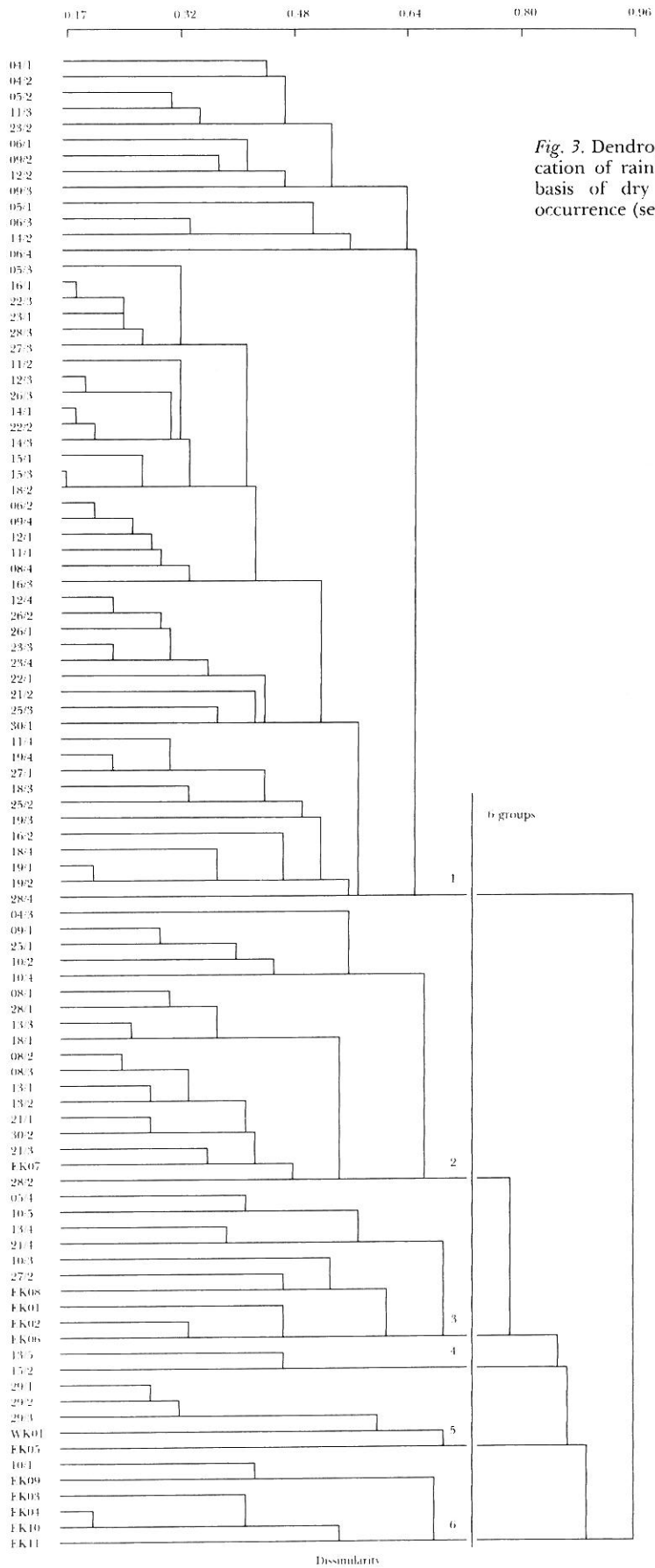
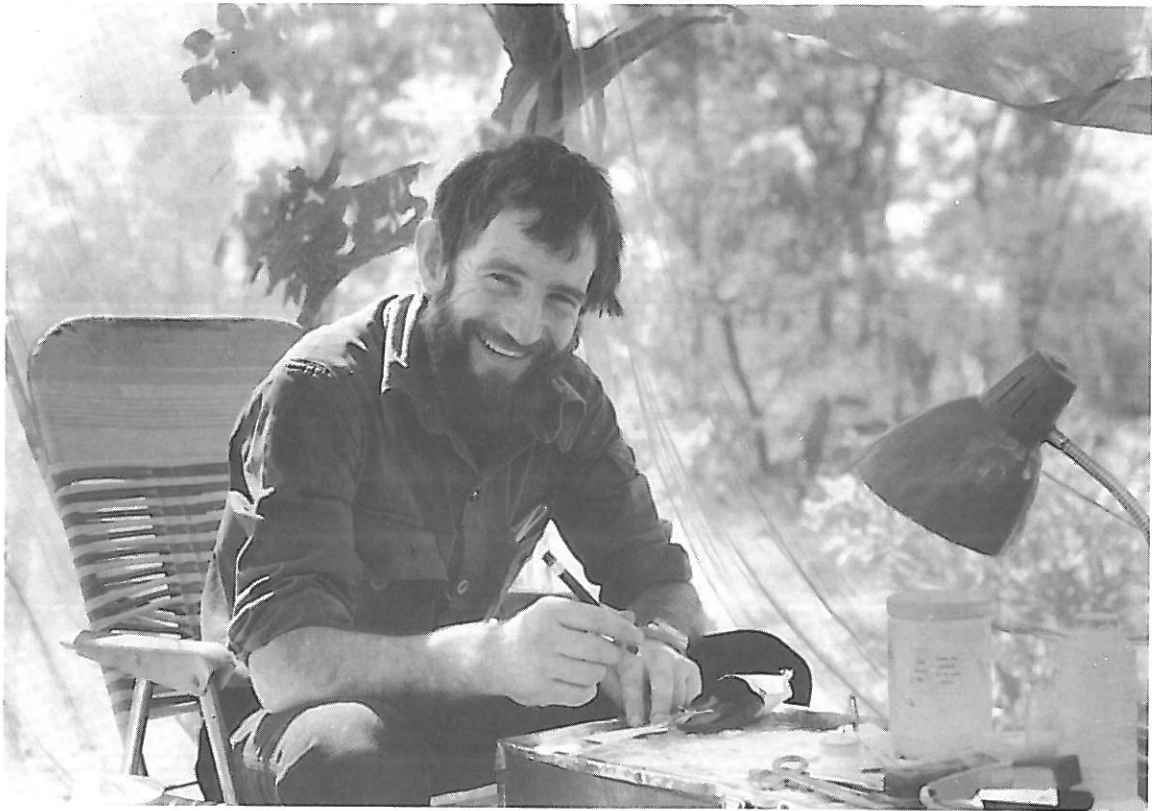


Fig. 3. Dendrogram from the classification of rainforest patches on the basis of dry season bird species occurrence (see text for details).



Ornithologist Ron Johnstone preparing bird skins at the King Edward River base camp in June 1987. (Photo K. F. Kenneally).



The Torresian Imperial Pigeon (*Ducula bicolor*) eats the fruit of many rainforest plants. It is an important dispersal vector for rainforest seeds. (Photo R. E. Johnstone).

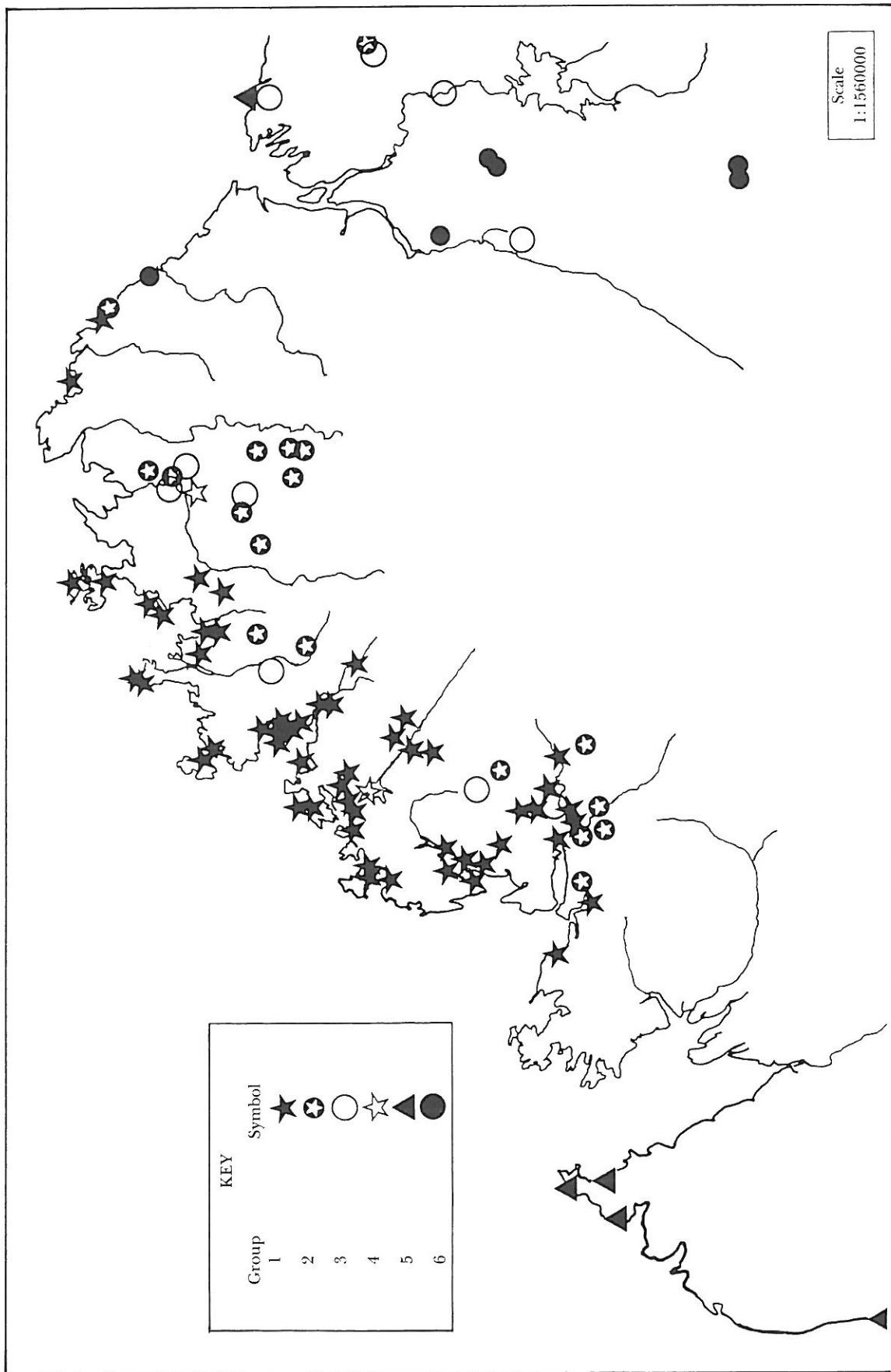


Fig. 4. Geographical distribution of the six groups of rainforest patches recognized in the classification of patches according to dry season bird species composition.

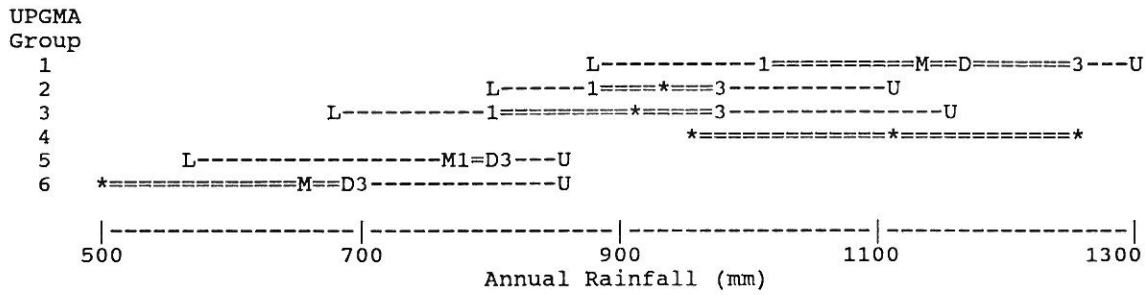


Fig. 5. Relationship between UPGMA patch groups and rainfall. (L = lower limit, U = upper limit, 1 = first quartile, 3 = third quartile, M = mean, D = median. An asterisk is shown where two or more of these overlap.

Within Group 1 of the species classification, two distinct subgroups could be recognized. Group 1a included 18 species which are predominantly mangrove or rainforest patch specialists and are largely confined to the wetter patches from Group 1 of the patch classification. Group 1b, on the other hand, included 18 species which are largely ubiquitous amongst the rainforest patches from all groups of patches. Many of these are also found in a wide range of other habitats.

Classification of species based on the patches in which they occurred in the wet season gave a result similar to that for the dry season data (Figs 6,9) in that all rainforest specialists and those species ubiquitous in rainforests were grouped together while woodland species visiting rainforest were dispersed among four smaller groups. Species in these latter groups tended to be associated with only a small number of patches per group, suggesting that they are simply a reflection of the particular woodland avifaunas surrounding those patches.

One obvious difference between the wet and dry season data was that species with strong preferences for mangroves were more commonly observed in rainforest patches in the dry season (Table 9) (but note that dry season sampling was more intensive). The most likely explanation for the difference is that these species concentrate in mangroves in the wet season for breeding. It is not known why the Little Bronze-Cuckoo shows a reverse trend.

Annotated List of Rainforest Specialists

The 22 species listed above are dealt with here where we present the following information: (1) the general nature of the patches from which each species was recorded, (2) their distribution in Kimberley from this survey and any extensions of range to that in Storr (1980), (3) relative abundance, (4) habitat preferences, (5) foraging behaviour and (6) numbers of specimens collected.

Table 6. Mean number of bird species (\pm S.D.) (excluding edge and aquatic species and singletons) per patch and mean values (\pm S.D.) for various biophysical attributes for each of the groups of patches recognized from the classification of the dry season bird data.

Group	1		2		3		4		5		6	
No. of patches	54		18		10		2		5		6	
Bird species	20.5 \pm 7.0		16.6 \pm 7.5		14.8 \pm 5.2		7.5 \pm 0.7		12.0 \pm 2.6		7.5 \pm 5.4	
Patch area (ha)	12.6 \pm 15.5		3.3 \pm 2.3		3.8 \pm 3.5		5.5 \pm 2.8		17.4 \pm 24.2		1.9 \pm 2.1	
Mean ann. rain (mm)	1 120 \pm 150		931 \pm 98		905 \pm 148		1 100 \pm 212		761 \pm 110		654 \pm 135	
Canopy ht (m)	14.5 \pm 5.6		12.4 \pm 3.9		20.6 \pm 5.0		12.5 \pm 0.7		7.4 \pm 3.4		13.2 \pm 6.0	
Flora richness	58.4 \pm 20.2		44.7 \pm 14.4		24.6 \pm 10.0		44.0 \pm 2.8		26.4 \pm 6.2		18.7 \pm 7.2	

Table 7. Summary of relationships between patch groups and substrates, for groups defined in the classification of the dry season bird data.

Group	Substrate				
	Sandstone	Laterites	Volcanics	Alluvium	Sands
1	37	8	6	3	—
2	13	3	2	—	—
3	1	1	—	8	—
4	—	—	2	—	—
5	—	—	—	—	5
6	6	—	—	—	—
Totals	57	12	10	11	5

Table 8. Interpretation of UPGMA patch groupings in terms of biophysical attributes. Most data from Bioclim; see text and McKenzie (this publ.) for details.

Attribute	Cramer value	Attribute	Cramer value
Temperature		Wettest quarter	0.75
Annual	0.50	Driest quarter	0.53
Min. (cold. month)	0.63	Coollest quarter	0.71
Max. (max. month)	0.74	Warmest quarter	0.45
Range	0.70	Geographic	
Coollest quarter	0.57	Area	0.36
Warmest quarter	0.46	Distance to coast	0.69
Wettest quarter	0.51	Altitude	0.58
Driest quarter	0.60	Substrate	
Rainfall		Clay	0.45
Annual	0.73	Biological	
Wettest month	0.79	Flora richness	0.65
Driest month	0.45	Canopy height	0.48
C.V.M.	0.68	Litter depth	0.30

Details of distribution, ecology, food and taxonomy of Western Australian rainforest birds will be dealt with in a later paper by one of us (REJ).

Megapodius reinwardt tumulus Gould

Orange-footed Scrub-fowl

Recorded at 34 patches which ranged in size from two to 100 ha. Substrates were sandstone, laterite, basalt and sand.

Confined to sub-humid north-west Kimberley from Cape Londonderry south-west to mouth of Sale River and inland to Mitchell Plateau and Prince Regent River. Storr (1980) gives Kunmunya as its southern limit. Our records from the mouth of the Sale River extend its known range south by 60 km; Boongaree, Naturalist and an unnamed island near the mouth of George Water (23/2) are new island records.

Locally moderately common but generally uncommon. Mostly in ones and twos and occasionally small groups up to seven. Favouring large dense coastal forests with good leaf litter. Feeds on fallen fruits and often seen scratching and raking the litter for snails and insects. When disturbed, flies almost vertically to perch in the canopy (Johnstone and Smith 1981) or runs rapidly through the forest. Mounds were active in June and October and newly hatched chicks were recorded in March. Three specimens.

Ptilinopus regina ewingii Gould

Red-crowned Pigeon

Recorded at 24 patches which ranged in size from two to 100 ha. Substrates were sandstone, laterite, basalt and sand.

Largely confined to sub-humid coastal north-west Kimberley from Vansittart Bay south-west to Walcott Inlet. Also semi-arid far north of Dampier Land around Cape Leveque and Cygnet Bay and islands in Bonaparte Archipelago, viz. Middle Osborn, South-west Osborn, Bigge, southernmost of Coronation Islands, Boongaree, Augustus and an unnamed island near the mouth of George Water (23/2).

Dry season group labels:		1	2	5	6	5	Dry season group labels:		1	2	5	6	5
		-----							-----				
		111201.111EE.2.EE.E							111201.111EE.2.EE.E				
		2924361.003KK.9.KK.K							2924361.003KK.9.KK.K				
		/////-.///00./00.0							/////-.///00./00.0				
		3213421.24416.2.34.5							3213421.24416.2.34.5				
Species	Group						Species	Group					
Azure Kingfisher		***	Northern Rosella		*	.	.	.	.
Brush Cuckoo		**	*	*	*	.	Blue-faced Honeyeater		*	.	.	.	.
Peaceful Dove		**	*	*	*	.	Restless Flycatcher		*	.	.	.	.
Double-barred Finch		*	*	.	.	.	Rufous Owl		*	.	.	.	.
Red-winged Parrot		*****	.	.	*	*	Barking Owl		*	.	**	.	.
Variegated Fairy-wren		*****	.	.	*	.	Striated Pardalote		*	.	*	.	.
Little Friarbird		*	.	*	*						
Yellow-tinted Honeyeater		*	.	.	*	.	Black-faced Cuckoo-shrike		.	*	.	.	.
Brown Honeyeater		*****	*	*	*	*	Fairy Martin		.	*	.	.	.
White-gaped Honeyeater		**	***	*	*	*	Rufous-throated Honeyeater		.	*	.	.	.
Great Bowerbird		**	****	*	*	*	Fork-tailed Swift		*	*	.	.	.
Mistletoebird		*****	*	*	*	*	Sandstone Shrike-thrush		*	*	.	.	.
Bar-shouldered Dove		*****	*	*	*	*	Common Koel		*	.	.	.	.
Silver-crowned Friarbird		*****	*	*	*	*	Figbird		*	.	.	.	.
Northern Fantail		* ****	*	*	*	*	Rainbow Bee-eater		**	.	.	.	.
Green-backed Flyeater		* ****	*	*	*	*	Singing Honeyeater		*	.	*	.	.
White-bellied Cuckoo-shrike		**	***						
Blue-winged Kookaburra		** *	.	****	.	.	Brolga		.	.	*	.	.
Sulphur-crested Cockatoo		*** *	.	***	.	.	Lemon-bellied Flycatcher		.	.	*	.	.
Red-collared Lorikeet		**	.	****	.	*	Whistling Kite		.	.	*	.	.
Olive-backed Oriole		**	.	**	.	.	Wedge-tailed Eagle		.	.	*	.	.
Sacred Kingfisher		***	*	**	.	.	Pied Butcherbird		.	.	**	.	.
Leaden Flycatcher		*****	.	*	.	.	Sacred Ibis		.	.	*	*	.
White-throated Honeyeater		****	.	*	**	.	Dollarbird		.	.	**	.	*
Yellow Oriole		** ****	.	**	.	.	Torresian Crow		.	.	*	*	*
1 | Little Bronze-Cuckoo		* **	.	*	.	*	Red-backed Fairy-wren		.	.	*	.	*
Rufous Whistler		* **	.	*	*	*	Rufous Night Heron		.	.	*	.	*
Pheasant Coucal		****	.	*	.	*	Black Bittern		.	.	*	.	.
Brahminy Kite		**	Brown Goshawk		.	.	*	.	.
Golden-headed Cisticola		* *	Varied Lorikeet		.	.	*	.	.
Green-winged Pigeon		*** **						
Little Shrike-thrush		*****	Barn Swallow		.	.	.	.	*
Spangled Drongo		*****	Grey Fantail		.	.	.	.	*
Varied Triller		***** *	Mangrove Flyeater		.	.	.	.	*
Torres Strait Pigeon		***** *	Wood (Rufous) Fantail		*	.	.	.	*
Orange-footed Scrubfowl		*****	Yellow White-eye		*	*	.	*	*
Red-crowned Pigeon		*****	.	*						
Rainbow Pitta		*****	Black-chinned Honeyeater		.	.	*	.	.
White-lined Honeyeater		* ** *	*	.	.	.	Galah		.	.	*	.	.
Broad-billed Flycatcher		*	.	.	.	*	Mangrove Golden Whistler		.	.	*	.	.
Grey Butcherbird		**	.	**	.	.	Red-headed Honeyeater		.	.	*	.	.
White-quilled Rock Pigeon		*	.	*	.	.	Tawny Frogmouth		.	.	*	.	.
Oriental Cuckoo		*	.	*	.	.	White-breasted Woodswallow		.	.	*	*	*
↓ Little Woodswallow		*	White-throated Gerygone		.	.	*	*	.

Fig. 6. Two-way table of bird species by patch for the 16 patches visited in March 1989 (wet season), excluding edge and aquatic species. (Dry season group numbers are used for patches only). Patch codes are printed vertically.

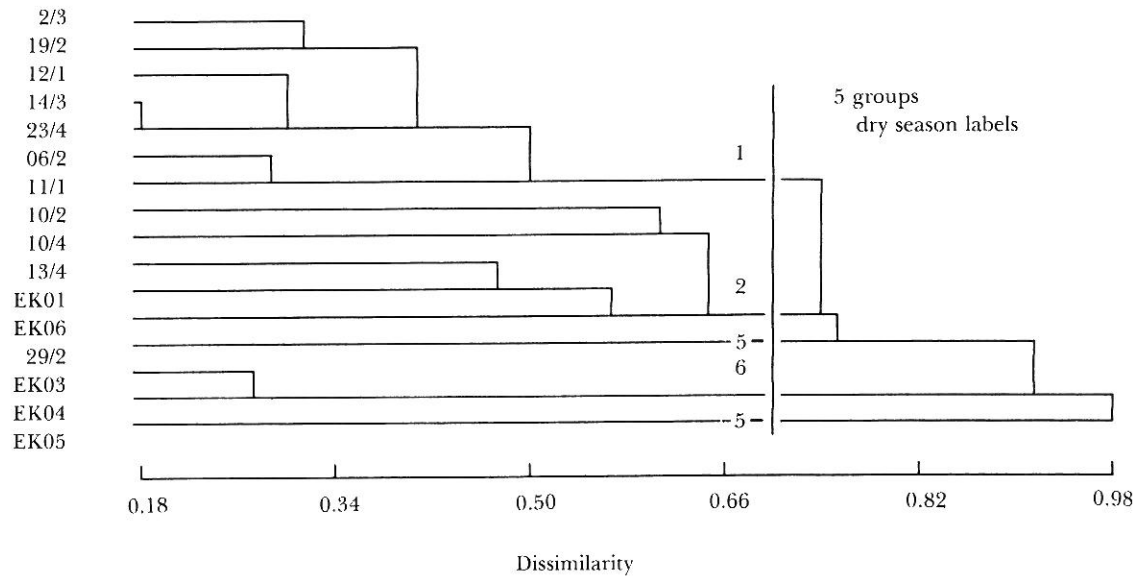


Fig. 7. Dendrogram from the classification of rainforest patches on the basis of wet season bird species occurrence (see text for details).

Moderately common. Ones, twos and small groups up to six. Favouring tall dense vine forests with an abundance of fruiting trees, occasionally in mangal. Rarely leaves cover of canopy but on Dampier Land observed in isolated fruiting trees on coastal dunes and in tall *Melaleuca* forest and woodland. Feeds mainly in canopy, often hanging from and scrambling over outer branches and foliage to get at ripe fruits. Food includes fruits of *Garuga floribunda*, *Polyaulax cylindrocarpa*, *Mimusops elengi*, *Aidia racemosa*, *Ficus virens* and *Ziziphus quadrilocularis*. 12 specimens.

Ducula bicolor spilorrhoea (Gray)

Torres Strait Pigeon

Recorded at 38 patches which ranged in size from 0.3 to 100 ha. Substrates were sandstone, laterite, basalt and sand.

Mainly confined to sub-humid north-west Kimberley. Johnstone (1981) gives its distribution in Kimberley as north to Cape Londonderry and south to Kunmunya with an unconfirmed record further south. During this survey it was recorded near Cape St Lambert on the north-west side of Joseph Bonaparte Gulf and at patches around George Water, Walcott Inlet and Secure Bay, extending its known range by 75 km east and 125 km south.

Moderately common. Mostly in small flocks up to 10, occasionally larger flocks up to 25. Unlike the Northern Territory and Queensland populations, which are migratory, the Kimberley population is resident (Johnstone 1981). Mainly confined to forest patches rich in fruiting trees and shrubs. Also occurs in mangrove forests and waterside vegetation, especially tall *Melaleuca leucadendra* and *Nauclea orientalis*. Small flocks were often seen moving from one patch of forest to another; no single patch appears large enough to support them throughout the year. Feed mainly in canopy, occasionally nearer to ground in low thickets or isolated fruiting trees. Food includes fruits of *Ficus racemosa*, *F. virens*, *Grewia orientalis*, *Melia azedarach*, *Mimusops elengi*, *Myristica insipida*, *Aidia racemosa*, *Eugenia* sp., *Alyxia spicata*, *Cyathostemma micranthum*, *Diospyros maritima* and flowering tips of *Polyalthia australis*. Many germinating seeds and seedlings of *Ficus* and *Mimusops* were found beneath roosts on Augustus Island and near Mt Kitchener (28/2). The movement of birds between patches and the ability of seeds to pass through the digestive system unharmed no doubt contributes substantially to the dispersal of these plant species and the establishment of new patches. Eleven specimens.



Fig. 8. Dendrogram from the classification of bird species on the basis of which of the 95 rainforest patches they were recorded in during the dry season (see text for details).

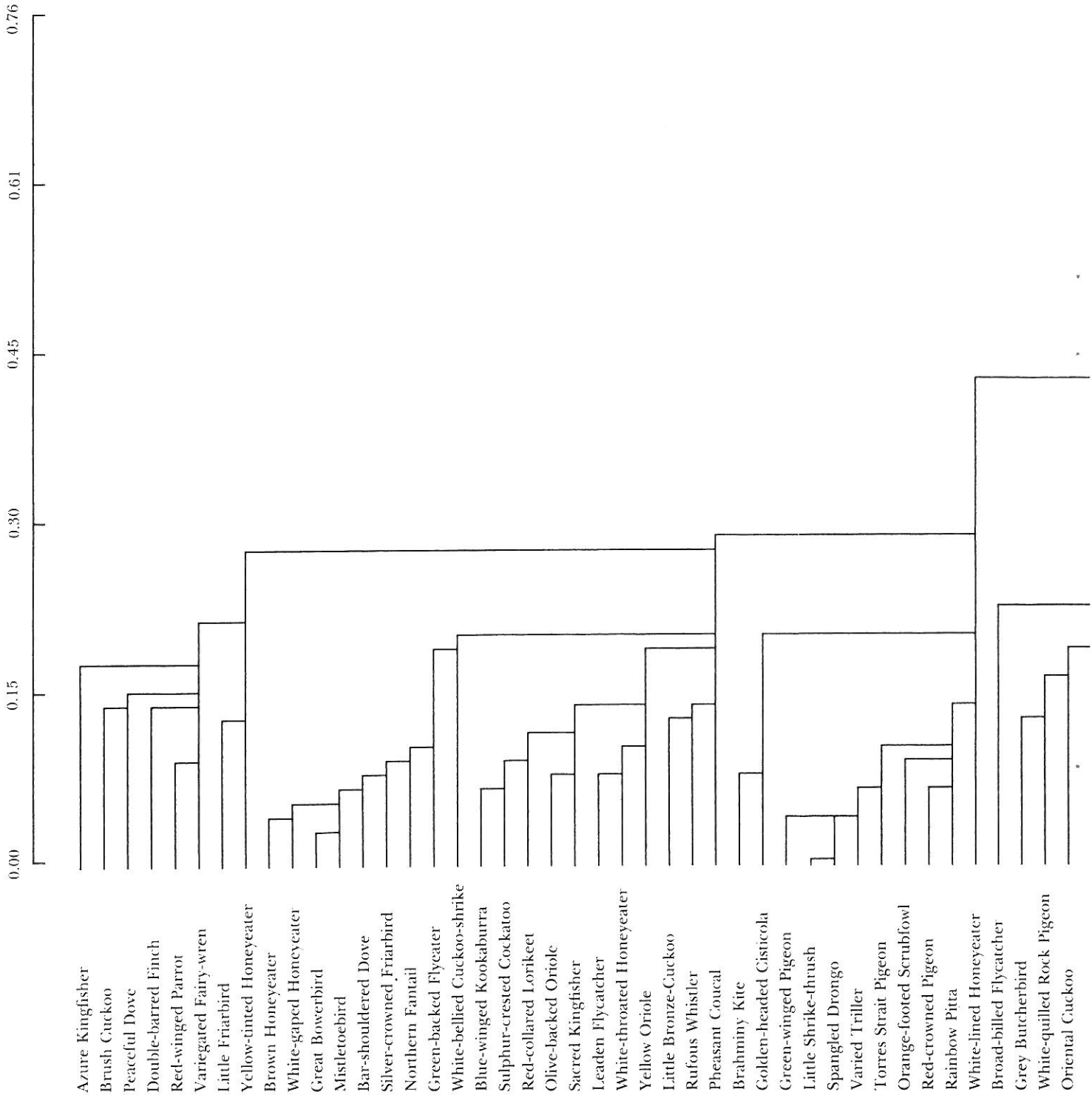


Fig. 9. Dendrogram from the classification of bird species on the basis of which of the 16 rainforest patches they were recorded in during the March (wet season) sampling (see text for details).

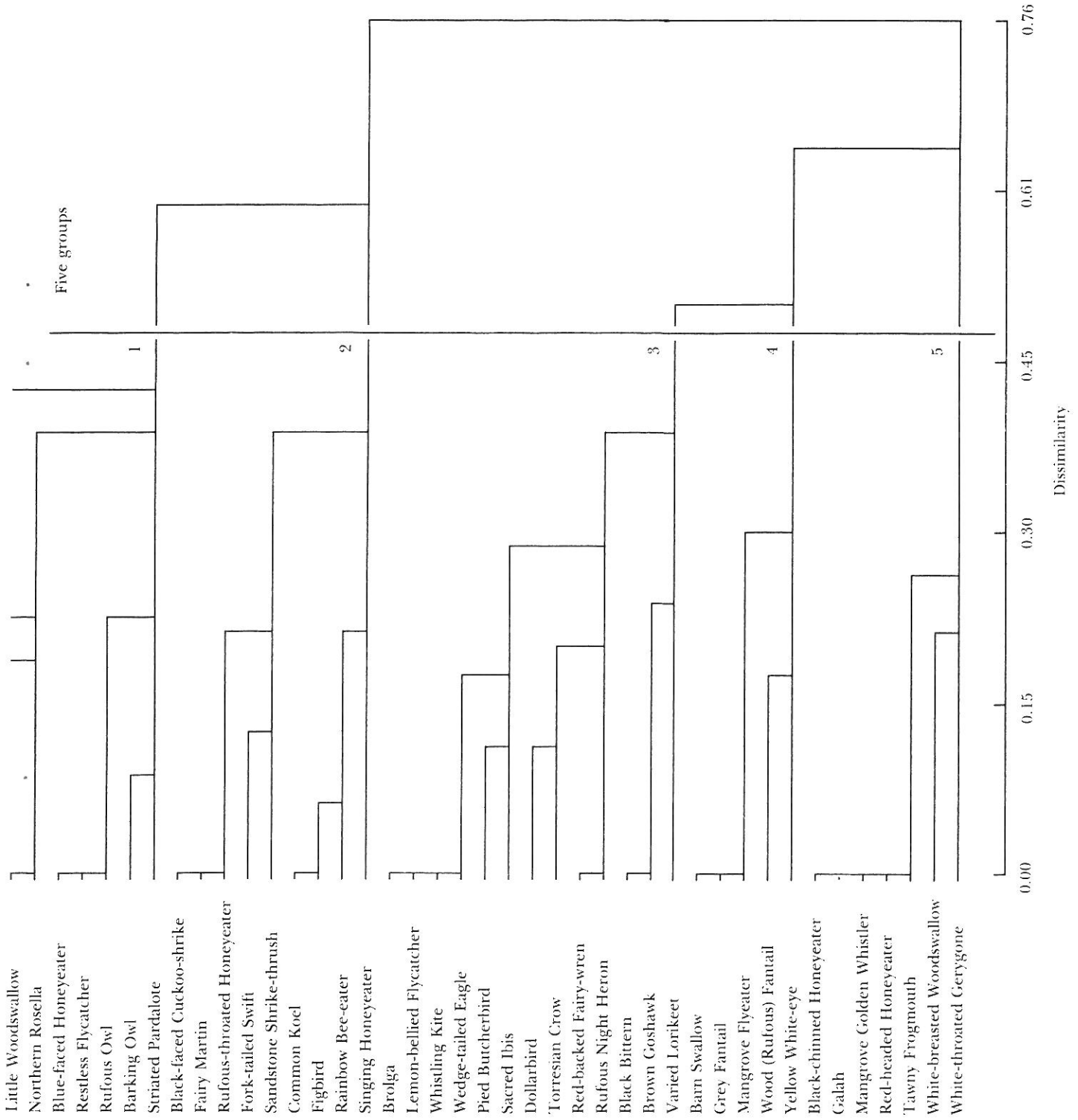


Fig. 9. — continued

Table 9: The number of patches where species with strong preferences for mangroves were recorded for the 15 rainforest patches examined in both wet and dry seasons.

	Number of patches	
	Wet season	Dry season
Little Bronze-Cuckoo	4	0
Mangrove Golden Whistler	1	5
Wood (Rufous) Fantail	2	4
Broad-billed Flycatcher	1	7
Shining Flycatcher	0	3
Red-headed Honeyeater	1	4

Chalcophaps indica longirostris Gould Green-winged Pigeon (Emerald Dove)

Recorded at 22 patches which ranged from 2.5 to 100 ha. Substrates were sandstone, basalt, laterite and sand.

Confined to sub-humid north-west Kimberley from Carson Escarpment, south-west to Secure Bay and ranging inland for 70 km.

Scarce to moderately common. Mostly in ones, twos and threes with occasional larger groups of up to 12. Favours edges of forests and watercourses and open areas within forest. Feeding mostly on the ground; food includes the warty bulbils of *Dioscorea bulbifera*, wild grapes, leguminous seeds and small fallen fruits including those of *Ficus ?platypoda*. Six specimens.

Cuculus saturatus Blyth Oriental Cuckoo

One in forest canopy at 2/3 on 2 March and one in dense riverine forest at 13/4 on 6 March 1989.

A scarce non-breeding visitor to Kimberley.

Cuculus variolosus variolosus Vigors and Horsfield Brush Cuckoo

Recorded at six patches which ranged from six to 60 ha. Substrates were sandstone and sand.

Mainly sub-humid and semi-arid zones. Uncommon. Only recorded in January, March and May (one only, at EK06). Juveniles still begging for food were collected in March at 10/2 and 29/2. Mainly in mid-levels and canopy. In Kimberley most observations are from vine forest, riverine forest and *Acacia* thickets (see Storr 1980). Four specimens.

Chrysococcyx minutillus minutillus Gould Little Bronze-Cuckoo

Recorded at five patches which ranged from two to 20 ha. Substrates were sandstone and sand.

Coastal sub-humid and semi-arid zones. Uncommon. Mainly a mangrove bird but also visiting other dense coastal vegetation, including rainforest, riverside vegetation and *Melaleuca* thickets. Mainly in canopy.

Eudynamys scolopacea cyanocephala (Latham) Common Koel

Recorded at seven patches which ranged from three to 100 ha. Substrates were sandstone and laterite.

Sub-humid north-west from the lower King Edward River south-west to Charnley River.

Ones and twos, mainly in the canopy. One specimen.

Ninox rufa rufa (Gould) Rufous Owl

Recorded at five patches which ranged from three to 26 ha and were all on sandstone except 19/2 which is a large swamp on an alluvial flat overlying sandstone which outcrops nearby.

Confined to the sub-humid coastal north-west. Storr (1980) gives the Prince Regent River as the southernmost Kimberley locality. During this survey it was recorded at George Water (23/2) and Walcott Inlet (19/2) which extends its known range south by 100 km.

Scarce. Ones, twos and once four birds perched close together over a creek. Favours tall forest, especially areas with *Syzygium angophoroides* and *S. forte* and flight paths along water-courses. In March one was flushed from a hollow at 19/2; it was attacked by several Spangled Drongos and returned within a few minutes to the same hollow. In similar rainforest patches in the Northern Territory, Estbergs and Braithwaite (1985) showed that in the dry season, this species fed mainly on a variety of mammals (aerial, arboreal and terrestrial), together with the occasional bird. Two specimens.

Pitta iris Gould

Rainbow Pitta

Recorded at 23 patches which ranged from three to 100 ha. Substrates were sandstone, laterite, basalt and sand.

Confined to sub-humid north-west Kimberley. Storr (1980) gives the Prince Regent River as the southernmost Kimberley record. During this survey it was recorded at Walcott Inlet (19/2) which extends its known range south by 100 km. Middle Osborn, Boongaree, Naturalist and Augustus Islands are new island records.

Locally moderately common. Favours the more luxuriant patches of forest. Forages on the forest floor, raking and probing litter for insects and snails. Juveniles still begging for food were collected in March. Ten specimens.

Coracina tenuirostris tenuirostris (Jardine)

Cicadabird

Not recorded during this survey. The status of this species in Western Australia is still largely a mystery. G. F. Hill (1911) recorded a few pairs that arrived at Napier Broome Bay on 4 December 1909 and left in February; Keast (1958) examined six specimens said to have come from the Fitzroy; R. E. Johnstone collected one from the canopy of a rainforest patch at Mitchell Plateau on 20 February 1973, one from the canopy of rainforest on the lower Roe River on 14 August 1974 and one from the canopy of rainforest at Mitchell Plateau (9/1) on 20 June 1975; J. A. Smith observed several on the lower Drysdale between October 1975 and February 1976. It would appear that this species is either very rare in Kimberley or more likely a visitor (mainly in the wet season) from other parts of Australia.

Lalage leucomela rufiventris (Gray)

Varied Triller

Recorded at 56 patches which ranged from 0.3 to 100 ha. Substrates were sandstone, basalt, laterite and sand.

Mainly sub-humid north-west. Storr (1980) gives Napier Broome Bay as the easternmost Kimberley locality. During this survey it was recorded near Cape Rulhieres and Cape Bernier which extends its known range east by 90 km. Also Bigge, Naturalist, the southernmost of the Coronation Islands and an unnamed island near the mouth of George Water (23/2) are new island records.

Moderately common. Mainly ones and twos, occasionally up to four birds in fruiting trees. Largely confined to rainforest patches and dense riverine forest; occasionally in more open country in search of fruiting trees. Feeds mainly in canopy on fruits of *Ficus virens*, *Cassine melanocarpa*, *Aidia racemosa*, *Drypetes lasiogyna*, *Phyllanthus reticulatus* and *Melia azedarach*. Occasionally also gleans or snatches invertebrates from the canopy. Seven specimens.

Poecilodryas superciliosa cerviniventris (Gould)

White-browed Robin

Recorded at 10 patches which ranged from 0.5 to 26 ha. Substrates mainly alluvial sands but also laterite and sandstone.

Sub-humid north-west from Morgan and King Edward Rivers south-west to Walcott Inlet.

Uncommon to moderately common. Mainly closed waterside forest with *Melaleuca*, *Nauclea*, *Ficus*, *Terminalia*, *Polyalthia*, *Barringtonia* and *Pandanus*. Feed in lower levels and on ground. Smith and Johnstone (1977) discuss the decline of this species on the Fitzroy and Ord Rivers. Four specimens.

Pachycephala melanura melanura Gould

Mangrove Golden Whistler

Recorded at 17 patches which ranged from one to 100 ha. Substrates were sandstone and sand.

Northern and western coasts.

Uncommon. A mangrove specialist but in Kimberley wandering up to 1 km (rarely more) inland into other closed forests including rainforests and *Melaleuca* thickets. In rainforest forages mainly in mid-levels and canopy, taking invertebrates mainly from leaves and small branches. Three specimens.

Colluricincla megarhyncha parvula Gould

Little Shrike-thrush

Recorded at 47 patches which ranged from 0.3 to 100 ha. Substrates were sandstone, basalt, laterite and sand.

Sub-humid north-west from Cape Bougainville south-west to the lower Isdell, Secure Bay and Collier Bay and inland for up to 40 km. Storr (1980) gives Kunmunya as its southern limit in Kimberley. During this survey it was recorded in many patches around George Water and Walcott Inlet and 8 km NNE of Mt Humbert (21/1) and Secure Bay (2/3) and the west side of Collier Bay (25/3), which extend its range south by 130 km. The large unnamed island near the mouth of George Water (23/2) is a new island record.

Common. The most conspicuous rainforest bird. Mainly ones and twos and occasionally small groups up to eight. Largely confined to rainforests; less frequent in closed waterside vegetation and mangal. Forages mainly in mid and low levels of forest where it searches for invertebrates on a variety of surfaces (including the ground), using a variety of strategies. At patch 9/1, one bird was hitting snails (*Amplirhagada* sp(p).) on stones to break their shells before eating them. Three specimens.

Rhipidura dryas Gould

Wood Fantail

Recorded at 15 patches which ranged from two to 100 ha. Substrates were sandstone, basalt, laterite and sand.

Northern and western coasts south to near Cape Brewster (12/3).

Uncommon. Ones and twos. In Kimberley mainly in mangroves but also visiting coastal rainforests and closed riverine forests. Forages for small insects in the canopy and lower levels of forests, mostly by hovering and hawking (for further detail see Johnstone 1990). Juveniles still attended by adults were observed in March. Nine specimens.

Rhipidura fuliginosa alisteri Mathews

Grey Fantail

One collected 9 km ENE of Mt Brookes (16/2) on 16 June 1987. It was feeding in the canopy of tall *Syzygium*, *Nauclea*, *Alstonia* and *Melaleuca* and in company with a Black-faced Monarch (*Monarcha melanopsis*). Two were collected 2 km SW of Pantajan (27/2) on 27 June; they were feeding in the canopy of *Nauclea*, *Melaleuca*, *Ficus* and *Eucalyptus*.

Uncommon winter visitor from southeastern Australia. Storr (1980) gives other Kimberley records from closed waterside forests, mangal and dense *Melaleuca acacioides*. Three specimens.

Myiagra ruficollis mimikae Ogilvie-Grant

Broad-billed Flycatcher

Recorded at 22 patches which ranged from one to 60 ha. Substrates were sandstone and sand.

Mainly west Kimberley from the mouth of the Hunter River south-west to northern Dampier Land (29/1 and 29/2); one record from far north-east — Ningbing (EK05).

Uncommon, in ones and twos. In the Kimberley largely confined to mangal but occasionally visiting closed coastal vegetation including rainforests and dense low closed evergreen thickets. Forages at all levels of forests from the canopy to the ground, mostly by snatching prey but occasionally by hawking. This species frequently uses a rapid sideways movement of the open bill across a leaf to pick up invertebrate prey (see also Johnstone 1990). Ten specimens.

Myiagra alecto (Temminck)

Shining Flycatcher

Recorded at 13 patches which ranged from two to 20 ha. Substrates were sandstone and laterite.

Northern and western coasts from Cape Bernier (10/2) southwest to Secure Bay (2/3).

Uncommon, in ones and twos. In Kimberley largely confined to mangal but occasionally wandering into coastal rainforest patches and along large watercourses. Foraging mainly in the lower-mid levels, mainly by snatching insects from trunks and branches (see also Johnstone 1990). Five specimens.

Gerygone chloronata chloronata Gould

Green-backed Flyeater (*Gerygone*)

Recorded at 71 patches which ranged from 0.2 to 100 ha. Substrates were sandstone, basalt, laterite and sand.

Far north-east around Point Spring, Saw Ranges and Cockburn Range, northern coast from near Cape St Lambert (10/1) north-west to 19 km west of Cape Rulhieres and north-west Kimberley from Carson Escarpment south-west to lower Isdell River and Secure Bay. Also recorded on Middle Osborn, Bigge, Naturalist, southernmost of Coronation Islands and an unnamed island near the mouth of George Water (23/2), all of which are new island records (see Storr 1980).

Common to moderately common in northwestern sub-humid zone, less plentiful in the north-east. A canopy feeder, gleaning invertebrates from leaves and occasionally from small twigs. Eleven specimens.

Oriolus flavocinctus (King)

Yellow Oriole

Recorded at 59 patches which ranged from 0.5 to 100 ha. Substrates were sandstone, laterite, basalt and sand.

Far north-east at Long Spring, Point Spring and Cockburn Range (El Questro) and sub-humid north-west from near Kalumburu north-west to Collier Bay and inland for up to 40 km. Also many continental islands.

Moderately common, mainly in ones and twos. Feeding mainly in the canopy, feeding on fruits including those of *Melia azedarach*, *Ficus ?virens* (23/4) and *Passiflora edulis*. Sometimes also takes invertebrates by pecking or snatching them from leaves. Two specimens.

Specotheres viridis flaviventris Gould

Figbird

Recorded at 14 patches which ranged from three to 40 ha. Substrates were mainly sandstone and laterite.

Sub-humid north-west Kimberley from Cape Bougainville south-west to the lower Isdell River and Secure Bay.

Uncommon. Ones, twos and small groups of up to eight. Largely confined to monsoon forest where it feeds mostly in the canopy on fruits of *Melia azedarach*, *Ficus ?platypoda* and

the red fruits of ? *Aidia* sp. but also visiting isolated fruiting trees, especially *Melia* and *Ficus*. Apparently almost entirely frugivorous in the Kimberley. Five specimens.

Dicrurus megarhynchus bracteatus Gould

Spangled Drongo

Recorded at 41 patches which ranged from 0.5–100 ha. Substrates were sandstone, basalt, laterite and sand.

Sub-humid north-west from the lower King Edward River south-west to Secure Bay and inland for up to 30 km. Middle Osborn, Naturalist and an unnamed island near the mouth of George Water (23/2) are new island records (see Storr 1980).

Moderately common. Mainly in ones and twos, occasionally in small groups of up to four. In Kimberley largely confined to rainforest and dense low closed evergreen thickets; also in mangroves and eucalypt forest. Attracted to fruiting and flowering trees. Foraging mainly in the canopy on insects. Five specimens.

DISCUSSION

Biogeographic Trends

Moisture availability (primarily rainfall), floristic richness and to a lesser extent substrate, appear to influence avian species composition and richness of rainforest patches in the Kimberley. Patch size is also a determinant of species richness, especially in the case of the rainforest specialists. The largest and best developed patches of rainforest occur along the north-west coast from Napier Broome Bay south-west to Walcott Inlet and inland to Mitchell Plateau. This region falls within the 900 mm rainfall isohyet. A feature of these coastal patches is the large number of trees and shrubs producing succulent fruits and many have deep leaf litter rich in invertebrates. Within the study area snails (which are important food items for several rainforest birds including Scrubfowl and Rainbow Pitta) show their greatest species richness in those patches near the north-west Kimberley coast (Solem, this publ.).

Within this coastal zone (which contains Group 1 species assemblages) patches may contain a full complement of rainforest birds. Of these the Red-crowned Pigeon, Torres Strait Pigeon, Green-winged Pigeon, Varied Triller, Yellow Oriole and Figbird are wholly or mainly frugivores. The amount and type of fruit available at any one time appears to fluctuate widely so that some of these birds, specially the Torres Strait Pigeon, Figbird, Yellow Oriole and Koel must move over wide areas in search of food. The Scrubfowl and Rainbow Pitta are both ground feeders and favour patches with dense understorey and dense leaf litter. The former also requires litter for mound building. The Rufous Owl was found only in tall forest with large, deep hollows for breeding and flight paths along creeks, etc. for hunting. The Little Shrike-thrush, Green-backed Flyeater and Spangled Drongo are all insectivores, the Shrike-thrush feeding in the mid and low levels and the Flyeater and Drongo mainly in the canopy.

Many of the coastal patches are also visited by mangrove birds including Little Bronze-Cuckoo, Mangrove Golden Whistler, Wood Fantail, Mangrove Grey Fantail, Broad-billed Flycatcher, Shining Flycatcher, Red-headed Honeyeater and Yellow White-eye. These species are an important component of the Group 1 patches, at least in the dry season. This appears to be different from the situation in Kakadu and near Darwin (Brooker and Parker 1985, Woinarski 1988, Woinarski *et al.* 1988) where, at least in the rainforests studied to date, mangrove birds appear to be less important in terms of the numbers of species present.

Further inland in the Kimberley, rainfall decreases rapidly and rainforest patches are generally smaller, more open and support fewer bird species. For example, there is a general decrease in the number of Group 1 species and rainforest specialists as one goes from the north-west through the outlying Group 1 patches of 4/2 and 4/1 through 10/2 (Group 2) and 10/1 (Group 6) to the north-west of Joseph Bonaparte Gulf. Only four rainforest specialists, the Torres Strait Pigeon, Brush Cuckoo, Varied Triller and Green-backed Flyeater, were recorded in these four patches and only one, the Flyeater, was recorded in most patches on the Carson Escarpment.

The inland waterside and riverine patches are important, however, for the White-browed Robin, a species which has declined in southern and eastern Kimberley (Smith and Johnstone 1977).

The most southern patches on northern Dampier Land (29/1, 29/2 and 29/3) are floristically very depauperate (Kenneally *et al.*, this publ.). Although apparently suitable for the Green-backed Flyeater and Yellow Oriole (the two rainforest birds most widespread in the Kimberley), neither has been able to colonize these patches by crossing King Sound. Of interest here is the Red-crowned Pigeon which is quite common on Dampier Land but otherwise restricted to the lush forests along the north-west coast.

Patches in the far north-east, in the lowest rainfall zone, were also floristically very depauperate (Kenneally *et al.*, this publ.). Only two rainforest birds (Green-backed Flyeater and Yellow Oriole) occur here. The low coastal thicket EK05 contained no rainforest birds (except for the Brush Cuckoo in the dry season) but did contain a number of mangrove specialists including Little Bronze-Cuckoo, Wood Fantail, Broad-billed Flycatcher, Mangrove Flyeater and Yellow White-eye.

Other Birds Using Rainforest

A total of 141 bird species was recorded in rainforest patches during this survey. Apart from those largely confined to rainforests many other species frequently visit these forests to feed, rest or shelter and in some cases to breed, including Bar-shouldered Dove (*Geopelia humeralis*), Red-winged Parrot (*Aprosmictus erythropterus*), Little Cuckoo-shrike (*Coracina papuensis*), Northern Fantail (*Rhipidura rufiventris*), White-gaped Honeyeater (*Meliphaga unicolor*), Brown Honeyeater (*Lichmera indistincta*), Silver-crowned Friarbird (*Philemon argenticeps*), Olive-backed Oriole (*Oriolus sagittatus*), Grey Butcherbird (*Cracticus torquatus*) and Great Bowerbird (*Ptilonorhynchus nuchalis*).

Migrants

Although only a short time was spent at many patches we feel that most of the resident species within each patch have been recorded. More work during the wet season would no doubt add other migrant birds to some patches, including the Oriental Cuckoo which is a non-breeding summer (wet season) visitor from the Palaearctic and the Koel and Dollarbird (*Eurystomus orientalis*) which are breeding summer visitors from the north. The Grey Fantail (*Rhipidura f. alisteri*) and Black-faced Monarch are non-breeding visitors (the latter a vagrant) from southeastern Australia.

Species Turnover

Flowering and fruiting patterns resulted in some differences in species composition within patches, between years. The extent of this is difficult to quantify because of the variation in our sampling efforts between years. However, it was apparent that fruiting phenologies varied both between and sometimes within plant species. For example, *Ficus virens* was fruiting and attracting frugivores at 10/2 but not at 14/3 in March 1989. Presumably, they also varied between years.

The number of honeyeater species varied between visits at a number of patches, apparently in response to flowering phenologies, particularly of *Xanthostemon paradoxus* and *Melaleuca*. For example, Red-headed Honeyeaters were recorded during the brief visit to 10/2 in 1987, but not during the detailed examination in 1988. Only two species of honeyeater were recorded at 10/4 in 1987 but 10 in 1988 when the *Melaleuca viridiflora* was in flower. Most patches appear to be too small and floristically poor to provide a year round food supply for most nectivorous and frugivorous species. Movements between patches by pollen and seed dispersers must have a significant effect on gene exchange between plants of different patches and the establishment of new patches.

Community Composition and Comparisons With Other Regions

Kimberley rainforests are fairly similar to others in the Australasian region in terms of the ratio of passerines to non-passerines. In our data set 42% of species were non-passerine, compared with 40% for Cape York, 47% for the rainforests of the nearby Trans-Fly plains in Papua New Guinea and 43% for Australia as a whole (Schodde and Calaby 1972). However, Bell (1982a) recorded a higher proportion (55%) of non-passerines in his study area at Brown River, Papua New Guinea. This difference is mainly caused by the much higher proportion of pigeons at Bell's site (15.8% compared with 5.3% for the Kimberley) and to a lesser extent by a lower proportion of honeyeaters (14.2% in Kimberley; 10.3% at Brown River) and slightly higher proportions of several other prominent non-passerine orders. Similar differences have also been noted in the Northern Territory rainforest avifauna (Brooker and Parker 1985).

Compared to Kimberley the Northern Territory has a larger area of high rainfall country and thus contains a greater diversity of closed forest and wetland habitats (e.g., Kenneally *et al.* this publ.). This explains why some species such as the Rufous Owl are confined to rainforests in Kimberley but are found in a wider range of habitats in the Northern Territory (cf. Woinarski 1988).

In the Kimberley, frugivores in general are much more common in the rainforest patches than in the surrounding woodlands and some frugivores such as the Red-crowned Pigeon and Figbird are confined to rainforest patches. Kimberley rainforest patches are, however, depauperate in frugivores compared with tropical rainforest elsewhere in the Australasian region (e.g., Crome 1975, 1978). In the New Guinea region Diamond (1977) has shown that, as one goes from areas of high species richness through areas with progressively depauperate faunas, species are progressively lost from the fruit-pigeon guild, with a moderately sized *Ptilinopus* (100–200 g) and a small-medium sized *Ducula* (500–600 g) being the last to go. This also seems to be happening in Australia, with progressive loss of species as one goes from (a) lowland rainforest in Papua New Guinea (e.g., eight species of *Ptilinopus* (five breeding) and five species of *Ducula* (one breeding) on Bell's (1982a,b) 2.5 ha study site at Brown River) to (b) Queensland (up to seven species of fruit-pigeons at a site, although usually only three or four are abundant simultaneously (Crome 1975, 1978)) to (c) the Northern Territory (three species) to (d) the Kimberley (two species). The species in the Kimberley are close to Diamond's (1977) predictions: *P. regina* is about 90 g in the Kimberley and *D. bicolor* weighs 400–550 g (Johnstone 1981).

Effects of Disturbance

During the mid-1970s some rainforest patches on Mitchell Plateau appeared to be expanding (judging from some open country eucalypts which were being engulfed at the edges of patches) and some appeared to be shrinking, apparently as a result of burning (Johnstone and Smith 1981; Johnstone and Smith unpubl.) (e.g., a Scrubfowl mound was found on the outer edge of one patch which had been subject to burning, indicating that the boundary of the patch had receded — see also Russell-Smith and Dunlop 1987).

Feral cattle were first noticed on the eastern side of Mitchell Plateau in October–November 1976 (Smith and Johnstone, unpubl.). The Crusher patch (9/1) was at that time undisturbed by cattle or fire. It was almost impenetrable with the lower level made up of *Citriobatus spinescens*, *Capparis* sp. and the vines *Abrus precatorius* and *Flagellaria indica* scrambling over trees and rocks. By 1987 this lower zone was almost completely destroyed, apparently through trampling by feral cattle. Habitat for ground and mid-level feeders is greatly reduced and this patch now contains fewer birds than during earlier visits. In the early 1970s there were 15–20 Pittas in this 4.5 ha patch, whereas in June 1987 there were probably no more than six. Similarly, there were several Scrubfowl present during early visits but only three records of single birds in June 1987 (possibly only one individual) and one record of a single bird in June 1988. It is suspected that populations of some other species foraging low in the vegetation (such as Little Shrike-thrush) may also be reduced. Of 10 rainforest specialists recorded in the Crusher patch in January/February 1973 (Johnstone and Smith, unpubl.), all

except the Common Koel and Cicadabird were recorded in both June 1987 and June 1988 (Table 10). The Koel is a wet season visitor to the Kimberley (Storr 1980) and not expected to be present in June and the Cicadabird is very rare in the Kimberley.

Because of the disturbance to the litter and lower vegetation, it is surprising that the Scrubfowl and Pitta are still present. It would appear, however, that they are on the verge of being lost from this patch. Willis (1974) predicts that within foraging guilds, the larger species are likely to be lost first from forest remnants; on this basis the Scrubfowl would be lost first.

Table 10. Records of rainforest patch specialists in the Crusher patch, Mitchell Plateau, January/February 1973 (J/F73), June 1975 (J75), October 1976 (O76) (all from R. E. Johnstone, unpublished) and June 1987 (J87), June 1988 (J88) and January 1989 (J89) (present study).

Species	Sampling period					
	J/F73	J75	O76	J87	J88	J89
Orange-footed Scrubfowl	+	+	+	+	+	+
Torres Strait Pigeon	+	+	—	+	+	—
Green-winged Pigeon	+	—	—	+	+	—
Common Koel	+	—	—	—	—	—
Rainbow Pitta	+	+	+	+	+	+
Cicadabird	—	+	—	—	—	—
Varied Triller	+	+	+	+	+	—
Little Shrike-thrush	+	+	+	+	+	+
Green-backed Flyeater	+	+	+	+	+	+
Yellow Oriole	+	+	+	+	+	+
Figbird	+	+	-	+	+	—

Conservation Needs

The conservation of Kimberley rainforest patches poses a difficult problem. Most patches are small and isolated and they vary considerably in their physiography. They contain a relatively rich and varied avifauna including many species with restricted geographical ranges. Some species including the Torres Strait Pigeon and Figbird move between patches over large areas in search of fruiting trees whereas others such as the Orange-footed Scrub-fowl and Rainbow Pitta are largely sedentary. A series of conservation reserves throughout the region, linked where possible with corridors of suitable habitat (riverine or mangal), is required to retain diversity of both species and community types. Proposals for improvements in the reserve system are made in McKenzie and Belbin (this publ.).

During this survey many patches, especially those around Mitchell Plateau, Walcott Inlet and along inland watercourses were found to be degraded by domestic or feral stock. As discussed in McKenzie and Belbin (this publ.), this problem is inextricably connected with the effects of fire on rainforest patches. Ground and lower level foraging species are expected to suffer most from these effects. Future conservation management in the Kimberley must focus on the preservation of rainforest patches and management of fire and feral animals.

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Attachment 1

Bird species which were recorded at only one patch during each season (including edge and aquatic species), showing the patch where they were recorded.

Species	Patch	Species	Patch
<i>Dry Season</i>			
Australian Hobby	09/1	Owlet Nightjar	09/1
Black-faced Monarch	16/2	Common Bronzewing	09/4
Common Koel	08/4	Dollarbird	13/3
Lemon-bellied Flycatcher	EK06	Fairy Martin	25/2
Marsh Harrier	19/2	Tree Martin	06/1
White-winged Triller	EK02	Brown Quail	09/4
Horsfield's Bronze-Cuckoo	15/3	Darter	14/3
Grey-fronted Honeyeater	10/4	Grey Teal	13/4
Wandering Whistling-Duck	13/4	Black Duck	13/4
Azure Kingfisher	22/3	Chestnut Rail	30/1
Blue-faced Honeyeater	10/5	Brush Cuckoo	EK05
Masked Wood-swallow	29/1	Zebra Finch	EK09
Black Grasswren	27/3	Pacific Heron	28/4
Crimson Finch	05/3	Mangrove Flyeater	16/2
Jacky Winter	13/4		
<i>Wet Season</i>			
Barn Swallow	EK05	Varied Sittella	14/3
Australian Hobby	EK06	Greenshank	EK05
Australian Magpie-lark	EK06	Black Bittern	EK01
Lemon-bellied Flycatcher	EK06	Brown Goshawk	EK01
Bar-breasted Honeyeater	2/3	Northern Rosella	2/3
White-bellied Sea-Eagle	12/1	White-winged Tern	EK05
Black-chinned Honeyeater	29/2	Rufous Owl	19/2
Black-faced Cuckoo-shrike	10/4	Grey Fantail	EK05
Blue-faced Honeyeater	19/2	Fairy Martin	10/4
Rufous-throated Honeyeater	10/4	Galah	29/2
Large-billed Flyeater	10/2	Mangrove Flyeater	EK05
Mangrove Golden Whistler	29/2	Glossy Ibis	EK05
White-browed Robin	13/4	Tawny Frogmouth	29/2
Wedge-tailed Eagle	EK06	Varied Lorikeet	13/4
Little Woodswallow	2/3	Little Corella	10/4
Restless Flycatcher	19/2	Tawny Grassbird	EK05

Attachment 2

Bird species recorded only at the edge of rainforest patches, either dry (E) or aquatic (A). The patches where they were recorded are also shown.

<i>Dry Season</i>			
Brolga	10/3, 13/4, 18/4, 19/2	Darter	14/3
Horsfield's Bronze-Cuckoo	15/3	Great Egret	13/4, 18/2
Common Bronzewing	09/4	Diamond Dove	08/2, EK11
Wedge-tailed Eagle	10/2, 14/3, EK08	Black Duck	13/4
Wandering Whistling-Duck	13/4	Grey Teal	13/4
Pacific Heron	28/4	White-faced Heron	16/2, 18/2
Sacred Ibis	13/4, 21/4	Australian Hobby	09/1
Straw-necked Ibis	10/3, 13/4	Osprey	25/2, 26/3
Australian Owllet-nightjar	09/1	Chestnut Rail	30/1
Fairy Martin	25/2	Brown Quail	09/4
Mangrove Grey Fantail	22/1, 30/1	Tree Martin	06/1
Australian Magpie-lark	05/1, 10/3, 11/1, 13/4, 18/4, 19/2, EK07	Black Grasswren	27/3
Chestnut-breasted Mannikin	09/1, 19/2	Crimson Finch	05/3
Masked Woodswallow	29/1		
<i>Wet Season</i>			
Australian Pelican	EK06	Australian Hobby	EK06
White-bellied Sea-Eagle	12/1	Glossy Ibis	EK05
Great Egret	EK06	Little Corella	10/4
Chestnut Rail	11/1, 10/2	Greenshank	EK05
White-winged Tern	EK05	Tawny Grassbird	EK05
Large-billed Flyeater	10/2	Varied Sittella	14/3
Weebill	09/1, 10/2, 10/4, EK04	Crimson Finch	2/3, 19/2
Australian Magpie-lark	EK06	Bar-breasted Honeyeater	2/3



Fruits of the Helicopter Tree (*Gyrocarpus americanus*). This species is ubiquitous in Kimberley rainforests, but also occurs in sclerophyl woodlands and pindan. Now thought to be dispersed by birds as well as wind.
(Photo K. F. Kenneally).