THE RAFFLES BULLETIN OF ZOOLOGY 1997 **45**(1): 1-13

ECOLOGY OF A MANGROVE FOREST BIRD COMMUNITY IN SINGAPORE

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ABSTRACT. - Ecology of a bird community was studied in the Sungei Mandai mangrove forest in Singapore from May to July 1996. We found a total of 42 bird species in the forest. Based on the spot-mapping, the most abundant bird species in the forest was the Black-naped Oriole (*Oriolus chinensis*). With 168 mist-netting hours, we captured 15 bird species. The most common bird species mist-netted was the Asian Glossy Starling (*Aplonis panayensis*). We also recorded two locally-threatened bird species in the area, the White-chested Babbler (*Trichastoma rostratum*) and Oriental Magpie Robin (*Copsychus saularis*). The bird community composition of this area is comparable to a similar site in Singapore (the Sungei Buloh Nature Park). We recorded seven bird species possibly breeding in the area. However, due to the limited survey time, this number most probably is an underestimation. Preliminary foraging observations of six bird species were made in the area. Based on a cluster analysis in which we used 20 foraging-related characteristics (e.g., frequency use of different plant species), we found that leaf-gleaners (the Dark-necked Tailorbird *Orthotomus atrogularis*, Common Iora *Aegithina tiphia*, and Pied Triller *Lalage nigra*) were similar in their overall foraging activities. These leaf-gleaners were different in overall foraging activities from the species that frequently foraged on aerial insects (Pied Fantail *Rhipidura javanica*), that predominantly found prey off the bark of trees (Common Goldenback *Dinopium javanense*), or that primarily foraged from flowers (Olive-backed Sunbird *Nectarinia jugularis*).

KEY WORDS. - Mangrove birds, foraging, breeding, parasites, Singapore.

INTRODUCTION

Few studies have been published on mangrove birds in Southeast Asia (e.g., McClure & Husain, 1968; Nisbet, 1968; Medway & Wells, 1976; Wells, 1985; van Balen, 1989;

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Noske, 1995). In particular, little is known on the mangrove forest birds of Singapore. Mangrove forest is one of the most vulnerable ecosystems in Southeast Asia (Ong, 1995), being threatened by reclamation and logging. Within Singapore, currently only 6.5% of the pre-settlement mangrove forest remains (Hilton & Manning, 1995). Given the past and imminent future habitat loss, there is an urgent need for base-line information of the ecology of mangrove forest bird species from Southeast Asia in general, and from Singapore, in particular.

We studied the ecology of a mangrove forest bird community in the Sungei Mandai mangrove forest (Singapore). This site was proposed to be designated as a Nature Reserve (Briffett, 1990) but is currently under the threat of reclamation (Ho, 1996). Our objectives were: (1) to determine the composition of the bird community of this mangrove forest, (2) to compare the composition of bird community of this forest with that of similar forests in Singapore and Peninsular Malaysia, and (3) to collect preliminary data on the habitat requirements of bird species within this forest. Our ancillary objectives were: (1) to determine the breeding status of bird species within the forest, (2) to obtain preliminary data on the sex ratio and age structure of some resident bird species, and (3) to determine the prevalence of both ecto- and endoparasites in bird species inhabiting the forest.

STUDY AREA AND METHODS

The study was conducted at Sungei Mandai (1°28'N, 103°46'E) in Singapore. The study area lies on the north coast of the island and consists of a 10 ha isolated plot of mangrove vegetation. In 1902, this area was severely damaged by railway construction; but has probably now recovered fully from this disturbance (Murphy & Sigurdsson, 1990). It is hard to exactly determine when this patch was isolated but most likely it was isolated from the nearest mangrove patch by late 1960s. The nearest mangrove forest patch from Sungei Mandai is currently about 3 km away. The canopy is dominated in Sungei Mandai by a few tree species such as *Avicennia officinalis*, *A. alba*, *A. rumphiana*, *Bruguiera cylindrica*, *B. gymnorrhiza*, *Sonneratia alba* and *Rhizophora apiculata* at seaward sides. On the landward side, beside the above trees, other trees present included *Excoecaria agallocha*, *Hibiscus tiliaceus*, *Lumnitzera littorea*, *L. racemosa*, and *Terminalia catappa*. The mangrove is relatively depauperate of undergrowth except on the landward side where shrubs such as *Acanthus ebracteatus* and *A. volubilis* dominate (for details see Murphy & Lee, 1991). The area now suffers extensive pollution from sewage and flotsam originating across the Johor Causeway thus increasing the likelihood of soil and flora being contaminated.

Research was conducted from May to July 1996. The study area was flagged into 100 m x 25 m areas. The birds were sampled using the spot-mapping method (International Bird Census Committee, 1970). A total of eight complete spot-mapping surveys of the whole mangrove were conducted between 0700h and 1000h on days with fair weather. Two mornings were needed to spot map the whole mangrove once. Locations of each bird (seen or heard) were recorded in relations to the flagged areas on a map of the area and were later used to calculate the number of territories for each species. The species appropriately sampled by this technique were songbirds (Passeriformes). Species that could not be adequately sampled using this technique (e.g., corvids) were also recorded to obtain a species list for the area. Additionally, to obtain a complete species list for the area, we also recorded birds while mist-netting or making foraging observations.

To supplement spot-mapping data, we conducted mist-netting within and along the edge of the mangrove forest. Mist-netting was conducted between 0800h and 1700h during four days of fair weather. During each session, seven to nine mist nets (2.6 m x 12 m; mesh size 36 mm) were erected and these were checked every 30 to 45 minutes. A total of 168 mist-netting hours was performed. Each captured individual was identified, sexed by plumage or in monomorphic passerine birds by the presence of cloacal protuberance (males) or brood patch (females) (Ralph et al., 1993). Captured individuals were classified as adults (after first year) or juveniles (first year) based on the amount of skull pneumatization (see Ralph et al., 1993).

To determine ectoparasite prevalence, for each captured individual, we carefully checked the wings and head and recorded the presence or absence of ectoparasites. To determine the prevalence of blood parasites (endoparasites), a small amount of blood was obtained by puncturing a brachial vein. Thin blood smears were made following Bennett (1970) and air dried. The smears were subsequently fixed in methanol and stained for 20 min using 3% Giemsa's stain. The prevalence of blood parasites (*Haemoproteus* sp., *Trypanosoma* sp., *Splendidofilaria* sp., *Plasmodium* sp., and *Leucocytozoon* sp.) was determined following Sodhi et al. (1996).

To determine the breeding status of birds, while making spot-mapping observations, each individual encountered was observed as long as in sight (maximum 10 min). An individual was considered breeding if it was observed carrying nest material or food, or was followed by fledgling(s).

Foraging behaviour and habitat use were recorded for a selected bird species. The species were selected to cover most foraging guilds in the area and for which we at least could obtain seven observations (scientific names of bird species recorded during the present study are listed in Table 1). All observations were made between 0700h and 1100h on days with fair weather. We recorded: (1) plant species in which foraging activities took place, (2) foraging height (visually estimated), (3) substrate where foraging activities took place (ground, tree bark [outer surface of parts of the tree such as trunk, limb, branch, twig], leaves, flowers, and air), and (4) foraging method. We identified six foraging methods: glean (pick up food from substrate), poke (penetrate beak into substrate), probe (insert beak into cracks or holes or directly into soft surfaces), scale (scale bark off a tree in search of food), hawk (catch insects on wing), and hover (pick up prey from substrate while in flight without landing). Before recording observations, we waited for 5 sec to minimize the chances of recording only conspicuous behaviours. We recorded all foraging moves of an individual within a plant (Voucher specimens of mangrove plants have been deposited in the National University of Singapore Herbarium [SINU]). To obtain statistical independence, we only recorded alternate foraging sequences from an individual. We defined a "sequence" as a series of moves that began when a bird moved to a new plant and ended when it left that plant. We pooled data from both sexes of a species. Because male and female of a species can forage differently (Holmes, 1986; Sodhi & Paszkowski, 1995), this pooling helped to represent a wider range of behaviour and habitat use for a given species.

We used *G*-tests to determine if the frequency use of plants, substrates, and foraging methods differed among different bird species. To compare foraging behaviour and habitat use among species simultaneously, we performed a cluster analysis on the data matrix consisting of six species and 20 foraging-related characteristics following Holmes et al. (1979). Analysis used the nearest neigbour pair-group clustering and Euclidean distance coefficients

(McCune & Mefford, 1995). The variables that were in percentages were log transformed (log [x + 1]) to approximate normal distribution. These were: the percentage use of eight plant species, the percentage use of four foraging substrates, and the percentage use of six foraging methods. The remaining two variables not log transformed were: mean and standard deviation of foraging height. All columns were standardized by subtracting the column mean from each value in the column (Holmes et al., 1979; Sodhi & Paszkowski, 1995).

We also compared the bird community composition in our study area with mangroves elsewhere in Singapore (Sungei Buloh Nature Park; surveyed in 1996, Charlotte Yap, personal communication), and in peninsular Malaysia (Noske, 1995). Noske's (1995) sites are recently studied and are in less disturbed and more extensive mangrove forests (Tanjung Keramat, South Bandjar, Kapar South, and Kapar North; all in Peninsular Malaysia) than at our study area. We performed a cluster analysis using the presence or absence of bird species. Because we were using the presence or absence data, we did not attempt to normalize data sets as above for the foraging data. The cluster analysis data matrix consisted of six sites (two in Singapore and four in Malaysia) and 56 bird species. The bird species used for the cluster analysis were: Osprey, Brahminy Kite, Slaty-breasted Rail, White-breasted Waterhen, Spotted Dove, Emerald Dove *Chalcophaps indica*, Long-tailed Parakeet, Blue-crowned Hanging-Parrot *Loriculus galgulus*, Chestnut-bellied Malkoha *Phaenicophaeus sumatranus*, Common Kingfisher *Alcedo atthis*, Stork-billed Kingfisher *Pelargopsis amauropterus*, Collared Kingfisher, Blue-throated Bee-eater, Dollarbird, Rufous Woodpecker, Laced Woodpecker *Picus vittatus*, Brown-capped Woodpecker, Common Goldenback, Greater Goldenback *Chrysocolaptes lucidus*, Mangrove Pitta *Pitta megarhyncha*, Pied Triller, Ashy Minivet *Pericrocotus divaricatus*, Common Iora, Yellow-vented Bulbul, Olive-winged Bulbul *Pycnonoyus plumosus*, Crow-billed Drongo *Dicrurus annectans*, Ashy Drongo *D. leucophaeus*, Greater Racket-tailed Drongo, Black-naped Oriole, Large-billed Crow, Great Tit *Parus major*, Velvet-fronted Nuthatch *Sitta frontalis*, White-chested Babbler, Oriental Magpie Robin, Flyeater, Arctic Warbler *Phylloscopus borealis*, Common Tailorbird, Dark-necked Tailorbird, Ashy Tailorbird, Rufous-tailed Tailorbird, Yellow-bellied Prinia, Asian Brown Flycatcher *Muscicapa dauurica*, Mangrove Blue Flycatcher *Cyornis rufigaster*, Mangrove Whistler *Pachycephala grisola*, Pied Fantail, Yellow Wagtail *Motacilla flava*, Asian Glossy Starling, Jungle Myna *Acridotheris fuscus*, Plain-throated Sunbird, Ruby-cheeked Sunbird *Anthreptes singalensis*, Purple-throated Sunbird, Copper-throated Sunbird, Olive-backed Sunbird, Crimson Sunbird, Scarlet-backed Flowerpecker, and Oriental White-eye *Zosterops palpebrosus*.

RESULTS

We recorded a total of 42 bird species (Table 1) plus 18 other species in the edges or water or mud areas within the mangrove. However, it is likely that some of the species recorded at the edges such as the Pink-necked Green-Pigeon, Banded Woodpecker, Abbott's Babbler, and Striped Tit-Babbler may also be using the mangrove forest. Based on spot-mapping, the most common species in the mangrove was the Black-naped Oriole (Table 1). The total density of all birds recorded in the forest was 15.2 individuals/ha. Using mist nets, we captured 15 bird species (Table 2). The species that was most frequently mist-netted was the Asian Glossy Starling. Only one individual of the Yellow-vented Bulbul was retrapped. Two species that were mist netted, the White-chested Babbler and Slaty-breasted Rail, were not recorded while spot-mapping (Tables 1 and 2). Five other bird species were recorded while only making foraging observations, Osprey, Rufous Woodpecker, Greater

Table 1. Bird species recorded in the Sungei Mandai (Singapore) mangrove forest between May and July 1996. Numbers within the table refer to density/ha; density estimates for species that could be sampled appropriately using the spot-mapping method are calculated. SM = species recorded during spot-mapping, MN = species not recorded during spot-mapping but recorded during mist-netting, and OT = species not recorded either during spot-mapping or mist-netting but recorded at other times while surveying the area. At the bottom of the table, species that were recorded along the edge of the forest and waterbird species are listed. The order, common names, and scientific names mostly follow Gregory-Smith (1996).

Species	Record/Density
Osprey *Pandion haliaetus*	OT
Brahminy Kite *Haliastur indus*	SM
Slaty-breasted Rail *Gallirallus striatus*	MN
White-breasted Waterhen *Amaurornis phoenicurus*	SM
Rock Pigeon *Columba livia*	SM
Spotted Dove *Streptopelia chinensis*	SM
Greater Coucal *Centropus sinensis*	OT
Long-tailed Parakeet *Psittacula longicauda*	SM
Asian Koel *Eudynamys scolopacea*	SM
Large-tailed Nightjar *Caprimulgus macrurus*	SM
House Swift *Apus affinis*	SM
Collared Kingfisher *Todirhamphus chloris*	SM
Blue-throated Bee-eater *Merops viridis*	SM
Dollarbird *Eurystomus orientalis*	SM
Rufous Woodpecker *Celeus brachyurus*	OT
Brown-capped Woodpecker *Picoides moluccensis*	0.3
Common Goldenback *Dinopium javanense*	0.1
Pacific Swallow *Hirundo tahitica*	SM
Pied Triller *Lalage nigra*	0.3
Common Iora *Aegithina tiphia*	0.5
Yellow-vented Bulbul *Pycnonotus goiavier*	0.6
Greater Racket-tailed Drongo *Dicrurus paradiseus*	OT
Black-naped Oriole *Oriolus chinensis*	0.8
House Crow *Corvus splendens*	SM
Large-billed Crow *C. macrorhynchos*	SM
White-chested Babbler *Trichastoma rostratum*	MN
Oriental Magpie Robin *Copsychus saularis*	0.1
Flyeater *Gerygone sulphurea*	0.1
Common Tailorbird *Orthotomus sutorius*	0.3
Dark-necked Tailorbird *O. atrogularis*	0.3
Ashy Tailorbird *O. ruficeps*	0.5
Rufous-tailed Tailorbird *O. sericeus*	0.1
Yellow-belied Prinia *Prinia flaviventris*	0.3
Pied Fantail *Rhipidura javanica*	0.3
Asian Glossy Starling *Aplonis panayensis*	SM
Javan Myna *Acridotheres javanicus*	SM
Plain-throated Sunbird *Anthreptes malacensis*	0.2
Purple-throated Sunbird *Nectarinia sperata*	OT
Copper-throated Sunbird *N. calcostetha*	0.1
Olive-backed Sunbird *N. jugularis*	0.4
Crimson Sunbird *Aethopyga siparaja*	OT
Scarlet-backed Flowerpecker *Dicaeum cruentatum*	0.1

Grey Heron *Ardea cinerea*, Great Egret *Casmerodius albus*, Black-crowned Night-Heron *Nycticorax nycticorax*, Pacific Golden-Plover *Pluvialis fulva*, Whimbrel *Numenius phaeopus*, Common Redshank *Tringa totanus*, Common Greenshank *Tringa nebularia*, Pink-necked Green-Pigeon *Treron vernans*, Zebra Dove *Geopelia striata*, White-throated Kingfisher *H. smyrnensis*, Banded Woodpecker *Picus mineaceus*, Abbott's Babbler *Malacocincla abottii*, Striped Tit-Babbler *Macronous gularis*, Common Myna *Acridotheres tristis*, Zitting Cisticola *Cisticola juncidis*, Baya Weaver *Ploceus philippinus*. Scaly-breasted Munia *Lonchura punctulata*, and White-headed Munia *L. maja*.

Table 2. Bird species mist-netted within and along the Sungei Mandai (Singapore) mangrove forest between May and July 1996. Scientific names of the bird species are in Table 1.

Species	No. Trapped	Relative abundance*
Slaty-breasted Rail	1	1.7
White-breasted Waterhen	1	1.7
Zebra Dove	2	3.4
Collared Kingfisher	7	12.1
Pacific Swallow	5	9.0
Pied Triller	6	10.3
Yellow-vented Bulbul	8	13.8
Black-naped Oriole	1	1.7
White-chested Babbler	1	1.7
Rufous-tailed Tailorbird	1	1.7
Pied Fantail	2	3.4
Asian Glossy Starling	19	32.7
Plain-throated Sunbird	1	1.7
Olive-backed Sunbird	1	1.7
Scaly-breasted Munia	2	3.4

* % of all species.

Table 3. The use of plant species for foraging activities by bird species in the Sungei Mandai (Singapore) mangrove forest between May and July 1996. Data presented are the number of times the species was found using a particular plant species. DKTB = Dark-necked Tailorbird, PIFT = Pied Fantail, CMIO = Common Iora, CMGB = Common Goldenback, OBSB = Olive-backed Sunbird, and PITR = Pied Triller.

Plant species	Bird species					
	DKTB	PIFT	CMIO	CMGB	OBSB	PITR
Avicennia alba	5	3	10	4	2	4
A. officinalis	2	4	5	5	0	0
A. rumphiana	2	0	2	0	0	0
Bruguiera gymnorhiza	0	0	0	1	4	0
Excoecaria alba	3	0	0	0	0	2
Hibiscus tiliaceous	1	0	0	0	0	0
Lumnitzera littorea	0	0	0	0	1	0
Sonneratia alba	0	0	2	1	0	2

Racket-tailed Drongo, Purple-throated Sunbird, and Crimson Sunbird (Table 1). The cluster analysis revealed that the bird community composition of Singapore mangroves were similar and differed from those in Malaysian mangroves (Fig. 1).

We recorded breeding activities for seven bird species in the area, namely the Collared Kingfisher (estimated number of breeding pairs = 4), Common Goldenback (1), Common Iora (1), Black-naped Oriole (2), Stripped Tit-Babbler (1), Flyeater (1), and Ashy Tailorbird (1). For the three most commonly mist-netted species (Pied Triller, Yellow-vented Bulbul, and Asian Glossy Starling) the sex ratio did not depart significantly from 50:50 (Chi-squared or Fisher's exact tests, $P > 0.50$). However, all Asian Glossy Starlings were adults whereas all Pied Trillers and Yellow-vented Bulbuls were juveniles.

Our sample sizes to determine foraging behaviour and habitat use were small. Therefore, we pooled certain variables and had to delete certain species from the statistical analyses. *Avicennia alba* was the most frequently used tree species for finding prey by the Dark-

Table 4. Parasite prevalence (%) in bird species trapped within and along the Sungei Mandai (Singapore) mangrove forest between May and July 1996. Sample sizes are in parentheses. Scientific names of the bird species are in Table 1.

Species	% infected with blood parasities[1]	% infected with ectoparsites[2]
Slaty-breasted rail	0 (1)	100 (1)
White-breasted Waterhen	0 (1)	0 (1)
Zebra Dove	0 (1)	0 (1)
Collared Kingfisher	42.8 (7)	71.4 (7)
Pacific Swallow	0 (5)	100 (5)
Pied Triller	0 (6)	50 (6)
Yellow-vented Bulbul	0 (8)	50 (8)
Black-naped Oriole	0 (1)	0 (1)
White-chested Babbler	—	0 (1)
Rufous-tailed Tailorbird	0 (1)	0 (1)
Asian Glossy Starling	0 (19)	57.9 (19)
Plain-throated Sunbird	0 (1)	0 (1)
Olive-backed Sunbird	0 (1)	0 (1)
Scaly-breasted Munia	0 (1)	0 (1)

[1] *Haemoproteus* spp were only detected.

[2] Family Acarina and Sub-Order Mallophaga were only detected.

necked Tailorbird, Common Iora, and Pied Triller (Table 3). The frequency use of *Avicennia* spp. versus all other plant species combined differed significantly among the Dark-necked Tailorbird, Common Iora, Common Goldenback, Olive-backed Sunbird, and Pied Triller (G = 11.44, df = 4, P = 0.02; Table 3).

The six bird species used only four substrates for foraging (air, leaf, flower, and bark) (Fig. 2A). Leaves were the most frequently used foraging substrate by the Dark-necked Tailorbird, Pied Fantail, Common Iora, and Pied Triller (Fig. 2A). The Common Goldenback exclusively took prey off the bark of trees (Fig. 2A), while the Olive-backed Sunbirds most frequently fed from flowers (Fig. 2A). The frequency use of air and bark versus all other substrates differed significantly for the Pied Fantail and Common Iora (G = 3.45, df = 1, P = 0.03; Fig. 2A). Gleaning was the most frequently used foraging method by the Dark-necked Tailorbird, Pied Fantail, Common Iora, and Pied Triller (Fig. 2B), while probing was the most frequently used foraging method by the Common Goldenback and Olive-backed Sunbird (Fig. 2B). The frequency use of glean, hawk and hover, and poke, probe, and scaling differed significantly between the Common Iora and Olive-backed Sunbird (G = 34.26, df = 2, P = 0.0001; Fig. 2B).

The cluster analysis separated the three leaf-gleaners (Dark-necked Tailorbird, Common Iora, and Pied Triller) from the Common Goldenback which primarily foraged off the bark of trees and the Olive-backed Sunbird which primarily foraged from flowers (Fig. 3). The Pied Fantail, which combines leaf-gleaning with aerial foraging occupied an intermediate position (Fig. 3).

We recorded the presence of blood parasites only in one species, the Collared Kingfisher, out of the 13 species examined (Table 4). Six (43%) out of 14 species examined were infected with ectoparasites (Table 4).

DISCUSSION

Mangrove forest is an important habitat for many bird species. About 130 bird species (both resident and migrant species) are known to occur in mangroves and mudflats in Singapore (Murphy & Sigurdsson, 1990) and in other parts of Southeast Asia (Nisbet, 1968; van Balen, 1989). Mangroves provide high quality habitat for birds because they contain relatively safe nesting and roosting sites, and abundant prey (Nisbet, 1968; van Balen, 1989). Although, many mangrove bird species in Southeast Asia have colonized anthropogenic habitats (e.g. Ward, 1968; Sodhi & Briffett, 1996), it is unclear if these birds have comparable foraging and reproductive success in both mangrove and anthropogenic habitats.

The number of bird species (42) recorded by us at the Sungei Mandai mangrove forest is higher than (27-33 species) at each site surveyed by Noske (1995) in Selangor, Peninsular Malaysia. Fifty-five bird species were recorded in the mangrove forest of the Sungei Buloh Nature Park (Charlotte Yap, personal communication). However, bird richness values are not directly comparable among these studies. Noske (1995) surveyed his sites for a shorter duration than us (about one and a half months) and his sites were smaller (2-3 ha in area) compared to Sungei Mandai. Birds at the Sungei Buloh Nature Park are surveyed almost weekly (Charlotte Yap, personal communication) and the mangrove area there is bigger (23 ha) compared to Sungei Mandai. Our overall bird density estimates are within the range of those estimated by Noske (1995) for three of his sites in Peninsular Malaysia (Tanjung Keramat, South Bandjar, and Kapar South: estimates 14-26 individuals/ha). Our study also shows that there is a need to use more than one censusing techniques to obtain a more complete species list.

Some of mangrove specialist bird species such as the Lesser Adjutant (*Leptoptilos javanicus*) and Greater Goldenback (*Reinwardtipicus lucidus*) have already gone extinct from Singapore (Lim, 1992). It is unclear what processes were involved in the extinction of these species but the loss of mangrove habitats could be one of the possible reasons. Furthermore few data are available on long-term population trends of mangrove birds in Singapore. Except the Copper-throated Sunbird, none of the mangrove forest specialist species (Brown-winged Kingfisher, Ruddy Kingfisher, Greater Goldenback, and Mangrove Pitta, see Noske, 1995) were recorded at our site. In Singapore, the population of one of the birds that we recorded, the Ashy Tailorbird, may almost be entirely dependent upon mangroves (Hails & Jarvis, 1987). However, many bird species that may have originated from the mangroves and now may depend on this habitat for survival (Ward, 1968) were recorded by us such as the Pied Triller, Common Iora, Oriental Magpie Robin, and Pied Fantail. We also recorded two locally-threatened species in the study area, White-chested Babbler and Oriental Magpie Robin (Lim, 1992).

Our study also shows that the overall bird community composition of the Sungei Mandai mangrove forest is comparable with mangroves at the Sungei Buloh Nature Park (Fig. 1). The avian communities of both sites within Singapore were distinct from similar sites in Peninsular Malaysia (Fig. 1). The community difference (or similarity) among similar sites may depend upon the differences in vegetation composition, the amount of disturbance, and/or competition from other bird species (Nisbet, 1968; van Balen, 1989).

We recorded seven bird species likely breeding in the area, using shrubs, snags, and trees as nest substrates. However, due to the limited time spent to determine the breeding status of birds in the area, our bird breeding list most likely is an underestimation. Based on 50

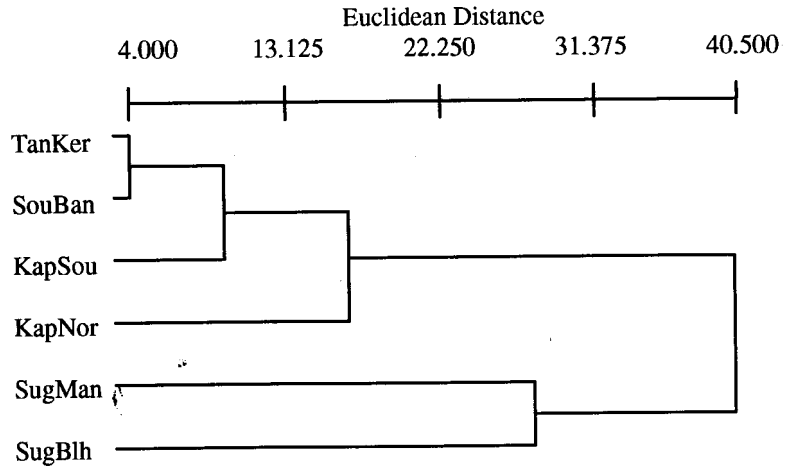

Fig. 1. Dendrogram of mangrove forest bird communities in Tanjung Keramat (TanKer), South Banjar (SouBan), Kapar South (KapSou), Kapar North (KapNor) (Peninsular Malaysia; data from Noske 1995), Sungei Mandai (Singapore, present study; SugMan) and the Sungei Buloh Nature Reserve (Singapore, data supplied by Charlotte Yap; SugBlh).

visits to mangroves on the west coast of Peninsular Malaysia, Nisbet (1968) recorded 45 bird species nesting in these mangroves. McClure & Husain (1968) extensively searched for nests in a coconut-mangrove area near Klang (Selangor, Peninsular Malaysia) over two years. They located 545 nests belonging to 28 bird species.

There has been concern over male-biased sex ratios of some birds in isolated forest patches (Gibbs & Faaborg, 1990; Porneluzi et al., 1993; Villard et al., 1993). This may be detrimental for the long-term viability of bird species in those isolated patches (Gibbs & Faaborg, 1990). Our study shows that sex ratios were almost even for at least three bird species. It is unclear, however, if this trend can be extrapolated to other bird species in the area and if this trend will hold with larger samples.

Our study shows that there are a variety of foraging niches occupied by the bird species in the area ranging from leaf-gleaners to nectar feeders (Fig. 3). The bird species use at least eight plant species for finding food. Our preliminary foraging observations suggest that the current level of plant diversity should be maintained in the area to cater for the foraging requirements of the resident bird species. However, due to small sample sizes our study is limited in determining if resource competition shapes up observed interspecific foraging differences (see Noske, 1996).

The most frequently used plants for foraging were different for some of the bird species at our site (Table 3) compared to sites in Peninsular Malaysia (Noske, 1995). Unlike those at our site, the most frequently used plant for foraging by the Pied Fantail was *B. parviflora* in Peninsular Malaysia (Noske, 1995). Similarly, unlike at our site, the most frequently used plant for foraging by the Common Iora, Common Goldenback, and Olive-backed Sunbird was *S. alba* at Noske's (1995) sites. These foraging differences can be related to factors such as the differences in the relative abundance of individual plant species between our site and sites surveyed by Noske (1995) (Adams & Morrison, 1993).

Noske (1995) found that the most important foraging substrates for the Pied Fantail, Common Iora, Common Goldenback, and Olive-backed Sunbird were air, leaves, trunk/

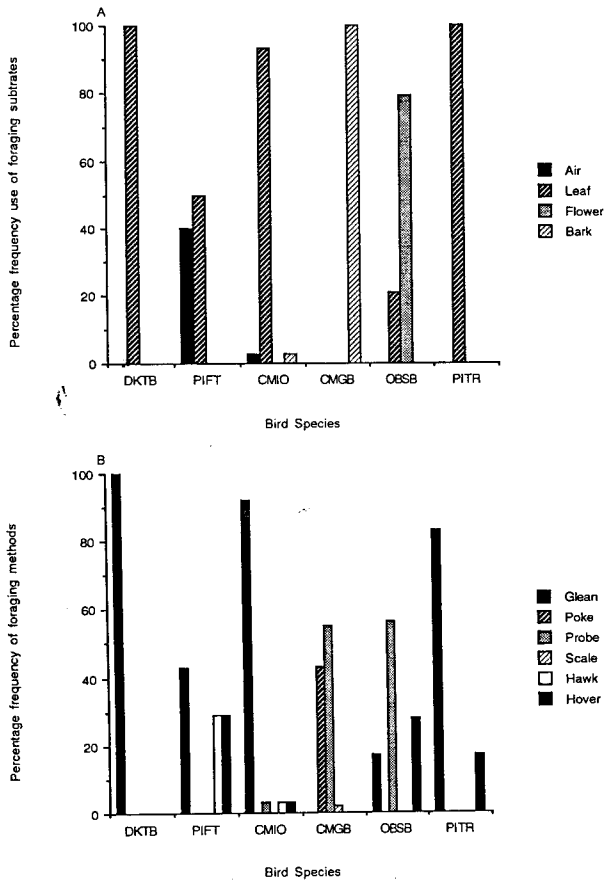

Fig 2. Foraging by bird species in the mangrove forest of Sungei Mandai (Singapore). A: Frequency use (%) of substrates and B: Frequency use (%) of foraging methods. DKTB (49), PIFT (7), CMIO (38), CMGB (53), OBSB (18), and PITR (7). The number of times a species observed to be foraging is indicated in parentheses after bird species abbreviations. For bird species abbreviations see Table 3.

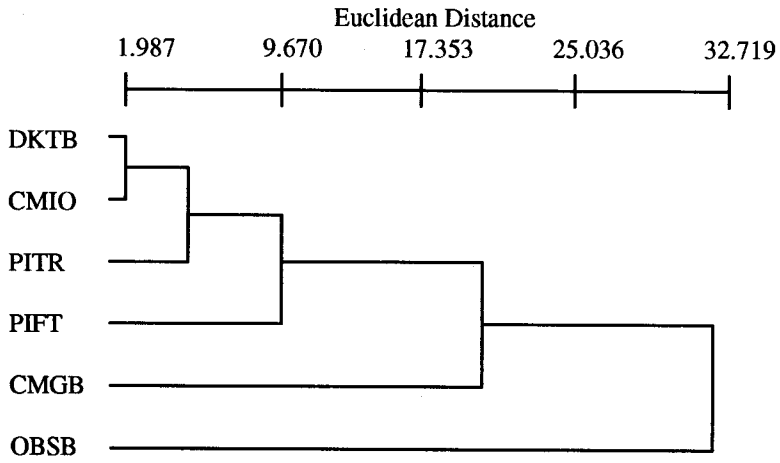

Fig. 3. Dendrogram showing foraging similarity in six bird species. Observations obtained in the mangrove forest of Sungei Mandai (Singapore). For variables used see the methods. For bird species abbreviations see Table 3.

branch (cf. bark at our site), and spider web, respectively. We found similar results for the Common Iora and Common Goldenback (Fig. 2A). However, we found that the Pied Fantail and Olive-backed Sunbirds used leaves and flowers as the most important foraging substrates at our site, respectively (Fig. 2A). For the latter species, the overall substrate use was generally similar between the two areas. These results suggest that despite some differences in frequently used plants as foraging sites, the bird species usually were using similar foraging substrates at all the sites.

The Pied Fantail most frequently gleaned at our site (Fig. 2B) while it most frequently hawked at Noske's (1995) sites. Similarly, the Olive-backed Sunbird most frequently probed at our site (Fig. 2B) while it most frequently hovered at Noske's sites. However, the Common Iora most frequently gleaned at all sites. The foraging similarity between the two regions can reflect a species-specific stereotypic behaviour (Martin & Karr, 1990), while the foraging differences may be related to differences in foraging sites (plant species) and/or the types of available prey at different times of year (Robinson & Holmes, 1982; Holmes & Schultz, 1988; Whelan, 1989). The observed bird foraging differences between our sites and Noske's sites could also possibly be due to other reasons such as the differences in interpretation and terminology, and small samples sizes at our site.

Because blood parasites and ectoparasites can be detrimental to the reproduction and survival of bird species (Loye & Zuk, 1991; Davidar & Morton, 1993; Richner et al., 1995), it has been suggested that parasites deserve more attention in avian conservation biology (Sodhi, 1995). Little comparative data on avian ectoparasites are available from Southeast Asia. However, out of 59 bird species examined for blood parasite prevalence, 37 (62.7%) were infected at Mt. Brinchang forest (Pahang, Malaysia) (McClure et al., 1978). Out of 82 bird species examined for blood parasite prevalence, 17 (20.7%) were infected in mixed habitat consisting of coconuts, palms, and mangroves at Rantau Panjang (Selangor, Malaysia) (McClure et al., 1978).

We recommend that this mangrove forest be preserved in its present condition because: (1) it contains a diverse bird community comprising of 42 species of which two species are locally-threatened, (2) the composition of bird community in the forest is diverse and comparable to the only nature park in Singapore that has mangroves (the Sungei Buloh Nature Park), (3) the area is being used for breeding activities by a number of bird species, (4) some bird species in the area probably require the existing diversity of flora for foraging and nesting requirements, and (5) based on preliminary data, at least some species have viable populations (based on sex ratios, breeding records, and low parasitic prevalence). All mangrove remnants are of conservation value because this is one of the most threatened ecosystems in Singapore (Hilton & Manning, 1995).

ACKNOWLEDGEMENTS

This study was funded by the National Parks Board of Singapore and the National University of Singapore (RP960316). Shyamalatha assisted us in the field. S. Chan and C. Chia provided maps and information. J. Yong and L. M. J. Chen helped in the identification of the mangrove plants and Dr. H. T. W. Tan kindly provided herbarium facilities. Charlotte Yap supplied data from the Sungei Buloh Nature Park. Paddy Murphy helped us in various ways. Drs. Richard Noske and Hugh Ford made helpful comments on an earlier draft. We thank them all.

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Received 24 Oct 1996
Accepted 10 Jan 1997