Tropical lowland rainforest birds on a highly urbanized island: monitoring, losses and lessons

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Abstract

We studied tropical lowland rainforest birds in Singapore. Forest loss in Singapore, primarily due to urbanization, has been heavy, with 95% of the native forest being cleared. We found that between 1923 and 1998, 61 (67%) out of 91 forest dependent bird species (species that occur only within primary/secondary rainforest) have gone extinct. Based on observations of 2 forest dependent bird species (the Asian Fairy-Bluebird *Irena puella* and Short-tailed Babbler *Malacocincla malaccensis*), we found that these species occupied remnants that were larger and less isolated than unoccupied remnants. Artificial nest experiments revealed that predation on artificial nests (80%) was higher in Singapore than reported by similar studies done elsewhere. Detailed studies in 2 larger remnants showed that the abundance of some bird species seemed to be affected by factors such as food abundance and vegetation structure. However, bird diversity in these 2 remnants was poor and different from other larger forests within Southeast Asia. We recommend that existing forest remnants within Singapore should be preserved so that the remaining level of bird biodiversity is maintained. Large forest reserves within Southeast Asia should be preserved so that forest birds in other countries do not face the same fate as in Singapore.

INTRODUCTION

Human activities such as urbanization and logging have already cleared about 24% of all tropical lowland rainforests (FAO 1993). Because of this heavy deforestation, many tropical lowland rainforests now occur in small patches (remnants or fragments) (Turner and Corlett 1996). This heavy rainforest loss and fragmentation can be detrimental to biodiversity because of factors such as negative edge effects (e.g. high nest predation in fragmented forest) and reduced habitat quality and quantity. Considering that a large number of endemic bird species could go extinct because of heavy deforestation (Brooks et al. 1997), it is important to monitor birds in tropical lowland rainforest remnants so that the existing biodiversity can be maintained.

Singapore (103°50′E, 1°20′N) is an island state containing the main island of 584 km^2 and 60 small offshore islands (total area 52 km^2). Singapore experiences typical equatorial climate with mean annual rainfall of 2375 mm. Singapore has one of the highest human population densities on our planet with 6615 people/km^2. Due to heavy urbanization, Singapore offers one of the worst-case scenarios for forest destruction with 95% of native forest being cleared with the existing forest remnants scattered throughout the island (Turner et al. 1994). Therefore, Singapore provides an ideal location to determine the effect of tropical rainforest loss due to heavy urbanization on native forest bird species of Southeast Asia. Our overall objectives were to determine: 1) the extent of loss of forest bird species from Singapore, 2) current bird diversity level in rainforest remnants of Singapore and compare this diversity with similar forests within Southeast Asia, 3) the possible factors (forest area, forest isolation, forest structure and food resources) affecting forest bird diversity, abundance and occurrence within Singapore, and 4) demographics of forest bird species within Singapore. We hope that with this study, we will be able to make precise recommendations for the conservation of forest bird species of Singapore. Here we present preliminary results from our research.

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METHODS

To determine the extent of bird species loss from Singapore, 20 fragments (9 - 795 ha) were surveyed. Using transect surveys, a one and half year round study (June 1997 to November 1998) was conducted sampling every 2 months each of the 5 late secondary/primary forests (> 50 years old), 8 young secondary forests (< 50 years old) and 7 woodland forests (abandoned plantations). These data were supplemented with mist-netting surveys. Based on transect counts and mist-netting, a species list was made for the forest birds of Singapore. This species list was compared with that made by Chasen (1923). Reliable species records present in Chasen's list but absent from our list were considered to be of species gone locally extinct from Singapore. We used 2 other lists to confirm extinctions (Gibson-Hill 1949, Lim and Gardner 1997).

Habitat requirements of forest dependent bird species

Thirteen forest remnants (4 - 795 ha) were surveyed from 29 July to 5 October 1996 (toward the end of peak breeding season in Singapore; Hails and Jarvis 1987) to determine how remnant size and isolation affect the distribution of forest dependent and non-forest dependent species. A remnant is defined as a patch of native vegetation around which most or all of the original vegetation has been cleared. In this study, forest remnants, patches, sites, and fragments are used interchangeably. All 13 remnants contained secondary forest with different dominant plant species; 2 of them also contained primary forest. The study fragments were surrounded by a variety of edges such as track, road, reservoir and pipeline.

Remnants were surveyed 3 times each to determine the presence or absence of each of the 4 target bird species. Two species (the Asian Fairy-Bluebird *Irena puella* and Short-tailed Babbler *Malacocincla malaccensis*) were forest dependent species (only occur within the primary/secondary rainforest), while 2 species (the Olive-winged Bulbul *Pycnonotus plumosus* and Striped Tit-babbler *Macronous gularis*) were forest non-dependent species (do not exclusively occur within the primary/secondary rainforest). A single line transect (with unlimited distance) was placed in each remnant along forest trails, paths, or small roads in such a way to cover as much area as possible. Target species were searched for while walking slowly along the transect between 7:00 and 10:00 am on fair weather days (a period of 2 or more mornings was required to conduct surveys in large fragments). All 13 remnants were surveyed once without using playback of pre-recorded songs. The subsequent 2 surveys involved song playback to confirm absences. The songs of the 4 target species were played in a random order at every 100-m interval along the transect. The song of each species was played for 2 min followed by a waiting period of 1 min for that specific species to respond. Hence, a total of 12 min was spent at every 100-m interval. A target species was considered present if visual or auditory contact was made.

Patch area and isolation distance were determined for each remnant. These 2 variables describe the remnants in relation to the surrounding landscape. To determine the isolation of a remnant, distance to the nearest forest remnant was measured from all 4 cardinal directions (north, south, east and west) and a mean was calculated from these 4 values (isolation distances for the study remnants ranged from 75 - 1510 m).

Artificial nest predation experiment

We used 5 forest fragments (2 primary forests, 2 secondary forests, and 1 abandoned rubber (*Hevea brasiliensis*) plantation) within Singapore. For the nest predation experiment, chicken eggs were used. The use of chicken eggs served to simulate the eggs of the Red Jungle Fowl (*Gallus gallus*), a ground-nesting bird which occurs in Singapore. Fresh chicken eggs (bought on the same day of experiment set-up) were used. In addition to real eggs, plasticine eggs were used to determine the type of predators that attacked the eggs by the bite-marks left on the plasticine. The imitation eggs were hand-made from brown plasticine. The plasticine chicken eggs were then painted with poster colors to give a 'chicken-egg' color. During the handling of the real and plasticine eggs, rubber gloves were worn to reduce contamination with human scent.

The number of transects at the sites ranged from 15 to 20. Each transect started from the edge of the forest (here defined as the first tree or shrub) and ran 100 m into the forest. The egg experimental stations (containing 1 real chicken egg and 1 plasticine egg) were located at the 0 m, 50 m and 100 m positions. The experimental stations were placed at random distances (1-5 m) and at random directions (left or right) from the transect. To facilitate relocation, they were usually placed near buttresses of trees or the base of larger saplings. We attempted to cover the eggs by adjusting the vegetation, such that when viewed directly from above, at a height of 1.8 m, the percentage cover directly above the eggs was about 50%. Although no attempt was made to construct an artificial nest, we designated the egg experiment stations as artificial nests because many ground-nesting bird species do not build elaborate nests. The transects within a fragment were spaced 50 m from each other. Paths were not cleared along the transects and every effort was made to minimize the impact of setting up the experiment. The experi-

ments were performed in August 1996, which is during the end of the peak breeding season in Singapore. To avoid pseudoreplication (Hurlbert 1984), we conducted experiments only once at each site.

To determine the predation rates, experimental nest stations were checked on day 8. Nests were considered as preyed upon if: (i) an egg was missing, (ii) there were cracks or peck marks on the real chicken egg, (iii) the chicken egg was smashed, or (iv) bite-marks were on the plasticine eggs. Predation by small mammals and other predators was determined by examining the bite marks imprinted on the plasticine eggs.

Bird biodiversity in 2 remnants

Detailed studies were conducted in 2 remnants; the MacRitchie forest (521 ha) included primary forest interspersed with secondary forest and the Nee Soon forest (795 ha) included mostly secondary forest embracing 15 ha of disturbed freshwater swamp forest.

Bird census techniques — Line transects of approximately 4.5 km were selected for each site. The transects were selected such that they spanned the length of the remnant. Each transect was surveyed 8 times from 7:00 to 9:30 am, between 14 July and 24 September 1997. The surveys were carried out in the morning as maximum diurnal bird detectability is observed around dawn (Shields 1979). Two mornings were needed to cover each transect in order to obtain an optimal walking speed of about 1 km/h. All birds seen or heard were recorded. Surveys were only conducted on days with fine weather when there would be maximal bird activity.

In addition, mist-netting was carried out 3 mornings during each of the following 5 months: March, May, July, August and September 1997. The advantage of mist-netting is that it may result in trapping bird species that are inconspicuous and/or seldom vocalize. The mist nets (12 x 2.6 m, 30 mm mesh) were set up by about 7:00 am and checked every 45 min, until they were taken down at 12:30 pm. All birds trapped were identified using field guides. Mist net hours conducted in MacRitchie and Nee Soon were 760.5 and 960.5, respectively. The birds were grouped according to their diets (carnivores, insectivores, frugivores or nectarivores) (Kang and Hails 1995). All birds were also classified by vertical feeding zones following the system used by Gregory-Smith (1996).

Arthropod sampling — Foliage along the transects was sweep-sampled for the presence of understory arthropods. Each transect was sampled for arthropods on 5 different occasions. Sweep-sampling was conducted at intervals of 150 m to obtain a minimum sample size of 30 sweep-samples per day of sampling. Each sweep-sample consisted of 16 sweeps using a butterfly net with a mesh-size small enough to prevent the escape of most arthropods. Sweep-sampling in each subsequent sampling occasion began 20 m from the start of the previous sample in order to evenly sample each transect.

Vegetation sampling— Vegetation was sampled at intervals of 150 m along each transect (MacRitchie 35 plots and Nee Soon 32 plots). Each 5 m radius plot was randomly located either to the left or right of the transect by tossing a coin. In each plot, the diameter at breast height (dbh) of all trees was measured using dbh tape. A tree is defined as any plant at least 2 m in height possessing a woody trunk. The trees in the plots were counted and classified as understory trees (< 10 m tall) or medium story/canopy trees (> 10 m tall) (Wong 1986). The percentage of canopy cover was measured using a spherical densiometer (Lemmon 1957). Percent shrub cover was visually estimated by 2 independent observers. By inserting a ruler vertically into the leaf litter at 13 fixed points in each plot, leaf litter depth was measured and an average was calculated. The number of fruiting trees along each transect was surveyed 2 times (late August and late September) and grouped as understory or canopy trees.

Comparison with other forested areas in the region — The bird diversity of MacRitchie and Nee Soon forests was compared with other lowland forests in the region to determine avian species richness. Nine forested areas, including continuous forests and remnants, were chosen from Bransbury (1993). To determine similarities in species composition among the forests, a cluster analysis using the program PC-ORD (McCune and Mefford 1995) was carried out on data matrix consisting of all 11 sites (including MacRitchie and Nee Soon) x 246 forest bird species.

Data analyses — Data analyses were carried out using various statistical programs (e.g. StatView SE + Graphicsä) following standard statistical techniques. Statistical significance for all tests was set at a = 0.05. In text and table, ± refers to standard error.

RESULTS

Local extinctions and habitat requirements of selected bird species

Between 1923 and 1998, of 91 forest dependent bird species, 61 (67%) have gone extinct from Singapore. Patch area and isolation affected the distribution of forest dependent species. Non-forest dependent species, the Striped Tit-babbler and Olive-winged Bulbul occurred in 13 (100% of the remnants surveyed) and 9 remnants, respectively. The Asian Fairy-Bluebird and Short-tailed Babbler, both forest dependent species, occupied the same 4 remnants. The remnants occupied by these 2 species were larger (537.75±251.68 ha) than unoccupied

remnants (32.22+4.89 ha; Mann-Whitney U = 36, df = 9, 4, P = 0.006). Similarly, the remnants occupied by these 2 species were less isolated (341.25±109.06 m) than unoccupied remnants (960.00±151.79; U = 31.5, df = 9, 4, P = 0.04). However, the areas and isolation of occupied remnants did not differ significantly from those of unoccupied remnants for the Olive-winged Bulbul (Mann-Whitney U-tests, $P \geq 0.09$).

Artificial nest predation rates

The predation rate on artificial ground nests for all the 5 fragments combined was 80% (264/328 nests). Much of this predation was by small mammals (55%; 146/264 nests). As mentioned, of the 5 fragments, 2 contained primary forests (artificial nest predation rates: 68% and 91%), 2 contained secondary forests (80% and 91%) and 1 contained abandoned rubber plantation (86%). Predation rates differed between the primary forests (G = 6.94, df = 1, P = 0.01). Predation rates did not differ between secondary forests and among these 2 forests and rubber plantation (G-tests, $P > 0.11$). Secondary forests and the rubber plantation combined had higher predation rates than 1 of the primary forests (G = 6.0, df = 1, P = 0.01) but not the other (G = 1.06, df = 1, P = 0.30). No significant differences were detected in nest predation rates relative to the distance from the edge in any of the fragments (Kruskal-Wallis ANOVAs, $P > 0.16$).

Bird communities of 2 remnants

Plots of the cumulative number of species recorded with each successive survey revealed that adequate sampling was done both for transect counts and mist-netting in both MacRitchie and Nee Soon. Based on transect counts, the mean number of species recorded was 29.0±1.97 and 25.5±1.24 in MacRitchie and Nee Soon, respectively (U = 21.5, df = 8,8, P = 0.26). The mean number of individuals counted was 380.1±29.26 and 362.5±35.3 in MacRitchie and Nee Soon, respectively (U = 26, df = 8,8, P = 0.52). Forty-three and 40 bird species were recorded in MacRitchie and Nee Soon, respectively (Table 1). Thirty-nine species were common to the both remnants; however, there were some differences in species occurrences and abundance between the remnants (Table 1).

Mist-netting yielded 1 extra bird species for each site; Emerald Dove (*Chalcophaps indica*) for MacRitchie and White-chested Babbler (*Trichastoma rostratum*) for Nee Soon. Forty and 51 bird species were trapped in MacRitchie and Nee Soon, respectively. The retrapping rate was 12.5% and 11.8% for MacRitchie and Nee Soon, respectively.

Data from the transect counts and mist-netting were pooled for the following analyses. The mean number of understory insectivore bird individuals (White-rumped Shama *Copsychus malabaricus*, Dark-necked Tailorbird *Orthotomus atrogularis*, Abbott's Babbler *M. abbotti*, Short-tailed Babbler and Chestnut-winged Babbler *Stachyris erythroptera*) did not differ significantly between MacRitchie (73.63±63) and Nee Soon (87.88±7.57; U = 19, df = 8,8, P = 0.17). The mean number of arthropods also did not differ between the 2 forests (11.8±0.39 and 9.66±0.67; U = 4, df = 5,5, P = 0.07). More frugivore bird individuals (Red-crowned Barbet *Megalaima rafflesii*, Long-tailed Parakeet *Psittacula longicauda* and Pink-necked Green-Pigeon *Treron vernans*) were recorded in MacRitchie (maximum number = 45) than in Nee Soon (10; c^2 = 22.27, df = 1, P = 0.0001). More fruiting trees were available in MacRitchie (maximum number = 352) than in Nee Soon (285; c^2 = 7.06, df = 1, P = 0.007).

There were more canopy trees in MacRitchie (560) than in Nee Soon (326; c^2 = 61.8, df = 1, P = 0.0001). Based on transect counts and mist-netting, more individuals of bird species strictly foraging in the canopy and upper story (e.g. Hill Myna *Gracula religiosa*) were found in MacRitchie (286) than in Nee Soon (165) (c^2 = 32.46, df = 1, P = 0.0001). There was higher shrub cover in Nee Soon (70.0±4.47) than in MacRitchie (54.36±4.61; U = 363.5, df = 35,32, P = 0.01). Based on transect counts and mist-netting, more individuals of understory species (e.g. Chestnut-winged Babbler) were found in Nee Soon (163) than in MacRitchie (102; c^2 = 14.04, df = 1, P = 0.0002). None of the other vegetation variables recorded seemed to affect the bird fauna.

The cluster analysis showed that the bird communities of MacRichie and Nee Soon were most similar to each other and similar to those found on the island of Pulau Tioman. Many of the larger continuous forests such as Taman Negara (n = 182 bird species) and Endau-Rompin (n = 175) had the most different bird communities from MacRitchie and Nee Soon.

DISCUSSION

A large proportion of forest dependent birds have gone extinct from Singapore (e.g. all members of families Trogonidae, Bucerotidae and Eurylamidae). There may be many factors causing the extinction of forest dependent bird species in Singapore. The most important may be the habitat loss, followed by illegal trapping and competition from exotic bird species (e.g. Javan Myna *Acridotheres tristis*). Some of the current forest depend bird species may exist in small numbers and may go extinct in the future. For example, there is only 1 pair of the White-bellied Woodpecker (*Dryocopus javensis*) currently surviving in Singapore. Therefore, extinctions of forest dependent bird species probably will continue unless

concrete conservation measures are implemented.

Habitat requirements of Southeast Asian forest dependent bird species have been poorly documented. We found that the remnants in which 2 forest bird species (the Asian Fairy-Bluebird and Short-tailed Babbler) occurred were larger and less isolated than unoccupied remnants. The territory sizes and feeding ranges of these species are not known, but may be related to their need for relatively large remnants. The 4 remnants that these 2 species occupied had been connected until the early 1990s. This may have affected the occupancy of these particular remnants as they may have occurred across the contiguous area prior to isolation.

Results of artificial nest predation experiments showed that predation rates were relatively high in Singapore compared to similar studies done elsewhere (Yahner and Wright 1985, Gibbs 1991, Burkey 1993). The unusually high artificial nest predation rates in Singapore could be due to several reasons. First, matrix (area surrounding remnants) is highly urbanized and may harbor relatively high densities of potential nest predators such as feral animals (e.g. cats) and corvids. Second, due to heavy loss of native forests, many potential predators (e.g. monkeys) may be confined only to remaining pockets of forests. Last, it is possible that the use of artificial painted eggs may have resulted in high levels of predation of experimental nests.

The bird communities of MacRitchie and Nee Soon were broadly similar despite some differences in forest composition (e.g. primary forest in MacRitchie). Some food resources (fruiting tree availability) seemed to affect the abundance of frugivores. Similar results have been previously reported (Wong 1986). Unlike some previous studies (Janzen 1973, Wong 1986), we failed to find a significant relationship between insectivores and arthropod abundance. This may be due to our small sample size. Some variables of vegetation structure (e.g. shrub cover) affected the abundance of some species. We found that the bird diversity in Singapore's 2 larger remnants was poor compared to other similar but larger forests in Southeast Asia. Larger forests may contain diverse species composition because of factors such as high quantity and quality (high habitat heterogeneity and low human disturbance) of existing forests.

This study shows that many forest dependent bird species have gone extinct from Singapore and that existing avifauna is depauperate compared to other larger forests within Southeast Asia. We recommend that existing native forests in Singapore be preserved so that the current level of biodiversity is maintained. Large forest reserves within Southeast Asia should be maintained so that forest birds in other countries do not face the same fate as in Singapore.

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Table 1. The mean number of individuals (± standard error) of different bird species recorded in 2 forest remnants of Singapore between 14 July and 24 September 1997. Data based on the transect counts made in each remnant. The species that showed a significant difference (Mann-Whitney *U*-Test, $P < 0.05$) in abundance between the 2 remnants are highlighted in bold. Scientific names not mentioned here are in the text.

Bird Species	**MacRitchie**	**Nee Soon**
Rufous Woodpecker *(Celeus brachyurus)*	1.50 ± 0.42	0.88 ± 0.52
Banded Woodpecker *(Picus miniaceus)*	7.63 ± 0.63	6.50 ± 0.68
Red-crowned Barbet	1.88 ± 0.58	1.50 ± 0.38
Dollarbird *(Eurystomus orientalis)*	0.38 ± 0.18	0.25 ± 0.16
White-throated Kingfisher *(Halcyon smyrnensis)*	0.75 ± 0.25	0.38 ± 0.38
Collared Kingfisher *(Todirhamphus chloris)*	-	0.63 ± 0.26
Blue-throated Bee-eater *(Merops viridis)*	4.00 ± 1.18	2.13 ± 0.58
Chestnut-bellied Malkoha *(Phaenicophaeus sumatranus)*	1.50 ± 0.38	0.38 ± 0.26
Greater Coucal *(Centropus sinensis)*	-	0.25 ± 0.25
Long-tailed Parakeet	0.13 ± 0.13	0.25 ± 0.16
Swiftlet *(Collocalia* spp.*)*	5.13 ± 0.95	5.50 ± 0.80
Spotted Dove *(Streptopelia chinensis)*	1.75 ± 0.65	0.13 ± 0.13
Pink-necked Green-pigeon	9.25 ± 4.39	4.13 ± 0.44
Brahminy Kite *(Haliastur indus)*	0.13 ± 0.13	-
White-bellied Fish-eagle *(Haliaeetus leucogaster)*	0.88 ± 0.35	0.50 ± 0.33
Grey-headed Fish-eagle *(Ichthyophaga ichthyaetus)*	0.13 ± 0.13	-

Changeable Hawk-eagle *(Spizaetus cirrhatus)*	0.25 ± 0.16	0.13 ± 0.13
Asian Fairy-bluebird	4.00 ± 1.04	3.75 ± 1.13
Greater Green Leafbird *(Chloropsis sonnerati)*	-	0.13 ± 0.13
Blue-winged Leafbird *(Chloropsis cochinchinensis)*	0.25 ± 0.16	0.25 ± 0.25
House Crow *(Corvus splendens)*	5.63 ± 5.20	0.38 ± 0.18
Large-billed Crow *(Corvus macrorhynchos)*	20.00 ± 4.89	8.75 ± 1.46
Black-naped Oriole *(Oriolus chinensis)*	**14.00 ± 2.00**	**7.50 ± 1.07**
Greater Racket-tailed Drongo *(Dicrurus paradiseus)*	24.88 ± 2.44	24.25 ± 3.07
Common Iora *(Aegithina tiphia)*	0.25 ± 0.25	-
White-rumped Shama	0.38 ± 0.18	-
Asian Glossy Starling *(Aplonis panayensis)*	13.38 ± 3.72	9.00 ± 3.51
Javan Myna	2.88 ± 1.43	1.00 ± 0.53
Hill Myna	**8.25 ± 1.76**	**3.63 ± 0.60**
Pacific Swallow *(Hirundo tahitica)*	1.38 ± 0.53	0.88 ± 0.52
Yellow-vented Bulbul *(Pycnonotus goiavier)*	**11.25 ± 1.94**	**3.88 ± 1.17**
Olive-winged Bulbul	**15.25 ± 1.86**	**37.13 ± 4.07**
Cream-vented Bulbul *(Pycnonotus simplex)*	1.88 ± 0.61	2.63 ± 0.96
Red-eyed Bulbul *(Pycnonotus brunneus)*	0.13 ± 0.13	0.25 ± 0.25
Dark-necked Tailorbird	47.13 ± 4.91	57.50 ± 6.57
Abbott's Babbler	0.25 ± 0.16	-
Short-tailed Babbler	19.38 ± 1.96	18.63 ± 1.18
Chestnut-winged Babbler	**6.50 ± 1.16**	**11.75 ± 1.16**
Striped Tit-babbler	93.00 ± 9.06	76.50 ± 7.98

Orange-bellied Flowerpecker *(Dicaeum trigonostigma)*	**21.75 ± 2.33**	**30.75 ± 3.71**
Scarlet-backed Flowerpecker *(Dicaeum cruentatum)*	1.25 ± 0.37	1.00 ± 0.50
Brown-throated Sunbird *(Anthreptes malacensis)*	4.50 ± 1.32	8.13 ± 3.01
Purple-throated Sunbird *(Nectarinia sperata)*	3.00 ± 2.08	2.38 ± 1.03
Crimson Sunbird *(Aethopyga siparaja)*	17.75 ± 3.91	21.13 ± 7.35
Little Spiderhunter *(Arachnothera longirostris)*	4.63 ± 1.81	3.38 ± 1.22
Flowerpecker (*Dicaeum* spp.)	1.25 ± 0.90	-
Sunbird spp.	0.38 ± 0.26	4.50 ± 2.95
Scaly-breasted Munia *(Lonchura punctulata)*	0.38 ± 0.38	-