The Urban Avifauna of Kuching, Borneo, and the possible impact of cats on its structure

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Summary: Urban landscapes have depauperate avifaunas, but there have been few studies of urban bird communities in Southeast Asia. Domestic cats can attain very high densities in urban environments, and are known to have detrimental effects on local avian assemblages. The aim of this study was to describe the urban bird assemblage of Kuching, an equatorial city in Borneo, and to investigate its potential relationship with the abundance of cats. The density of birds and domestic cats was examined in ten discrete urban areas from November 2014 to April 2015 using line transects. A total of 1,844 bird observations were made, involving 27 species. Bird species richness and diversity were negatively related to cat density ($R^2 = 0.41$ and 0.43, respectively), but cat density did not significantly affect bird density ($R^2 = 0.032$). Bird species richness was strongly correlated with the size of urban areas ($R^2 = 0.76$, $P = 0.001$) suggesting that larger areas offer additional habitat or niches (e.g. street trees, parks, waterways), which in turn support more species. Reduction of habitat heterogeneity and type of surrounding matrix, as well as the presence of abundant introduced predators may play important roles in structuring the composition and population dynamics of this urban bird community. Urban areas do have some biodiversity conservation value, but the challenge is to enhance this value through better planning.

Ringkasan: Lanskap kota memiliki avifauna yang telah berkurang keanekaragaman jenisnya, namun hanya sedikit penelitian tentang komunitas burung perkotaan di Asia Tenggara. Kucing domestik dapat mencapai kepadatan yang sangat tinggi di lingkungan perkotaan, dan diketahui memiliki efek merugikan pada kelompok unggas lokal. Tujuan dari penelitian ini adalah untuk mendeskripsikan kumpulan burung perkotaan Kuching, sebuah kota khatulistiwa di Borneo, dan untuk menyelidiki hubungan potensial dengan kelimpahan kucing. Kepadatan burung dan kucing domestik diperiksa di sepuluh daerah perkotaan terpisah mulai November 2014 sampai April 2015 dengan menggunakan transek garis. Sebanyak 1.844 pengamatan burung dilakukan, melibatkan 27 spesies. Kekayaan dan keragaman spesies burung secara negatif terkait dengan kepadatan kucing, namun kepadatan kucing tidak mempengaruhi kepadatan burung secara signifikan. Kekayaan spesies burung berkorelasi kuat dengan ukuran daerah perkotaan menunjukkan bahwa daerah yang lebih luas secara struktural dan floristik lebih beragam yang menawarkan relung habitat tambahan dan justru itu mendukung lebih banyak spesies. Daerah perkotaan tidak boleh dianggap tiada nilai konservasi namun tantangannya adalah melihat bagaimana meningkatkan nilai habitat daerah-daerah ini melalui perencanaan yang lebih baik.

Introduction

Urbanisation has played a major role in the extirpation of wildlife through wholesale destruction of natural habitats such as forests and wetlands (Savard *et al*. 2000; McKinney 2002; Czech 2005; Shochat *et al*. 2010; Litteral & Wu 2012; Baharudidin *et al*. 2014). In 2015, the urban population Malaysia accounted for 74.7% of the total population, and the annual rate of urbanisation from year 2010 to 2015 was 2.66% (Central Intelligence Agency 2017). While the great majority of native bird species declines with expanding urban areas, introduced species often thrive (Bezzel 1985; McKinney 2002; Lim & Sodhi 2004; Carbo-Ramirez & Zuria 2011), leading to urban bird communities that are dominated by relatively few species (Jokimaki *et al*. 1996; Chong *et al*. 2012). In expanding metropolitan areas, such as Kuala Lumpur, bird species richness appears to decline with the loss of green areas (Baharuddin *et al*. 2014).

Domestic cats *Felis catus* are popular pets in most urban areas round the world (Baker *et al.* 2008; Sims *et al*. 2008). They have been associated with humans for thousands of years (Brickner 2003). They have been listed among the hundred worst invasive species in the world, and number well over 600 million (Lowe *et al.* 2000; O'Brien & Johnson 2007). While cats benefit humans by preying on rats, mice and other pest species, they are detrimental to native bird populations in urban and surrounding areas (Kauhala *et al*. 2015). Dauphine & Cooper (2009) concluded that cats have caused declines among birds worldwide and that they are key drivers of global bird extinctions. Sims *et al*. (2008) found that domestic cat densities reflect human population densities, as cats are provisioned by their owners, so their populations are not limited by the availability of prey species (Woods *et al.* 2003; Van Heezik *et al.* 2009). Many pet cats spend most of their time outdoors, where they are freely allowed to roam and hunt wildlife (Woods *et al.* 2003; Baker *et al.* 2005).

Most studies on the impact of cat density on birds have been carried out in temperate regions, so little is known about their impact in tropical regions, which generally have higher biodiversity. Moreover, the relationship between habitat area and bird species diversity in urban residential areas is poorly understood. Habitat heterogeneity and vegetation density in urban areas can increase bird species richness (Zakaria *et al*. 2009). The habitats surrounding urban areas can also affect urban bird community structure (Clergeau *et al*. 2001; Mohd-Azlan & Lawes 2011; Mohd-Azlan *et al.* 2015).

The aim of the present study was to characterise the structure of bird communities in residential areas of an equatorial city in Borneo in terms of its diversity, density and species composition, and to examine the influence of the density of domestic cats, size of urban area and distance to forest on these structural characteristics.

Material and Methods

The study was conducted in Kuching region, western Sarawak. Kuching is sometimes referred to as 'cat city' because the word 'kucing' translates to 'cats' in Bahasa Malaysia. Sampling was conducted at spatially separated suburban residential areas (n=10) that varied in size (Table 1). Three sites (Samajaya Apartments, Medan Universiti and MidwayLink) were close to secondary forest, but two (Medan Universiti and MidwayLink) were closer to the expressway. Both Taman Rimba and Stutong Indah were near Samajaya Nature Park, which consists of peat swamp forest. Two other sites (Riveria and Tabuan Jaya Baru 2) were adjacent to secondary forest and nipa palm (*Nypa fruticans*) forest. Other sites (Muara Tabuan, UnijayaJ and Desa Ilmu) were relatively far (> 600 m) from forest.

Table 1. Total bird density and diversity with species richness estimators for 10 sampling sites in Kuching region, Sarawak.

ACE mean	28.72
Chao 1 mean	29.25
Jack 1 mean	31.5
Bird diversity (H´)	1.91
Bird density (ind. ha^{-1})	32.19
Evenness	0.25

Birds are generally most active in the early morning (MacKinnon & Phillipps 1993; Bednekoff & Houston 1994). Reflecting this, cats are also known to take most birds in the morning (Barratt 1977). In our study, birds and cats were counted twice a month at each site by a single observer walking along a known length of transect. To increase the probability of detection, the surveys were conducted once in the morning (06:30-08:30 hrs) and once in the evening (16:30-18:30 hrs) for a period of five months (November 2014 to April 2015), giving a total of 10 censuses per site. The number and length of transects sampled was proportional to the size of the residential area (Linear regression, $R^2 = 0.83$, $P = 0.012$, $F_{1,8} = 37.78$). Transects followed existing roads, and were spaced at least 250 m apart to avoid counting the same individual birds (Bibby *et al*. 1992). Birds that flew by without stopping within the transect were not recorded. To avoid bias, the walking speed was standardized at 1.0–1.5 km h^{-1}. Birds encountered along transects were identified using binoculars (ORION Scenix 7x50 multi-coated optics Model 09332). The sighting distance (χ) between the observer and the animal was estimated to the nearest metre, and the angle (θ) measured using a compass. The perpendicular distance (d) from the transect line to the animal was calculated using the formula: $d = \chi \sin\theta$. Bird species were categorised according to their feeding guilds based on literature (MacKinnon & Phillipps 1993).

Data analysis

Rarefaction curves of species accumulation were plotted to examine species richness using EstimateS 9.1.0 (Colwell *et al.* 2012). To extrapolate the asymptote of species richness, we applied three species richness estimators to the data. The Abundance-based Coverage Estimator (ACE) separates rare from abundant groups, and uses the former only to estimate the number of missing species. The other two estimators, Chao 1 and Jack 1, use the number of singletons (species represented by only one individual) and doubletons (two individuals) to estimate the number of missing species (Burnham & Overton 1979; Chao 1984).

The density and detection probability of bird species were derived from calculated perpendicular distances analysed using Distance 6.2 (Thomas *et al*. 2010). The half-normal key function was fitted to the ungrouped, non-truncated data (distance w was at least as large as the largest recorded distance) with cosine series of expansion (Buckland *et al*. 2001). The density was estimated by:

$$\widehat{D} = \frac{n}{2wL\widehat{P_a}}$$

Distance 6.2 also estimated the effective strip width (ESW), encounter rates and coefficient of variance (CV) as the measure of the uncertainty of the density estimate (Thomas *et al*. 2010). The Shannon diversity index (H') and evenness were estimated using PAST 3 (Hammer *et al*. 2001). SPSS Version 20.0 (IBM Corporation 2011) was used for linear regressions in order to examine the relationships between species and area (estimated using Google Earth), and between cat density and bird diversity or density. The completeness of bird samples was calculated using the completeness ratio (C), where:

$$C = \frac{(\text{Number of species observed})}{(\text{Estimated number of species})}$$

If all bird species were well sampled, the expected value of C should be close to one (Soberon *et al*. 2000).

Table 2. Relative abundance and feeding guilds of bird species and their conservation status according to Sarawak Wildlife Protection Ordinance (SWLPO) (1998).

Common name	Scientific name	Observations (n)	SWLPO (1998)[a]	Feeding guild[b]
Eurasian Tree Sparrow	*Passer montanus*	860	NL	G
Asian Glossy Starling	*Aplonis panayensis*	222	NL	O
Common Myna	*Acridotheres tristis*	221	NL	O
Spotted Dove	*Streptopelia chinensis*	175	NL	G
Yellow-vented Bulbul	*Pycnonotus goiavier*	70	NL	O
Chestnut Munia	*Lonchura atricapilla*	54	NL	G
Pacific Swallow	*Hirundo tahitica*	50	NL	I
Zebra Dove	*Geopelia striata*	46	NL	G
Olive-backed Sunbird	*Nectarinia jugularis*	22	NL	N
Pink-necked Green-Pigeon	*Treron vernans*	19	NL	F
White-breasted Waterhen	*Amaurornis phoenicurus*	19	NL	O
White-breasted Woodswallow	*Artamus leucorynchus*	19	NL	I
Intermediate Egret	*Mesophoyx intermedia*	12	P	C
Long-tailed Shrike	*Lanius schach*	9	NL	C
Common Sandpiper	*Actitis hypoleucos*	8	NL	C
Collared Kingfisher	*Todiramphus chloris*	8	P	C
Magpie Robin	*Copsychus saularis*	5	NL	I
Javan Myna	*Acridotheres javanicus*	5	NL	O
Barn Swallow	*Hirundo rustica*	4	NL	I
Little Egret	*Egretta garzetta*	3	P	C
Dusky Munia	*Lonchura fuscans*	3	NL	G
Pied Fantail	*Rhipidura javanica*	3	NL	I
Cinnamon Bittern	*Ixobrychus cinnamomeus*	2	P	C
Rock Pigeon	*Columba livia*	2	NL	G
Pied Triller	*Lalage nigra*	1	NL	I
Crimson Sunbird	*Aethopyga siparaja*	1	NL	N
Little Spiderhunter	*Arachnothera longirostra*	1	NL	N

[a] NL, not listed; P, protected. [b] C, carnivore; G, granivore; O, omnivore; I, insectivore; N, nectarivore.

Results

Bird censuses totalling 55 hours of observation along 60.2 km of transects yielded 1,844 records (Table 2). Of the 27 species encountered, four species accounted for 80.2% of all birds counted. These were Eurasian Tree Sparrow *Passer montanus* (46.6%), Asian Glossy Starling *Aplonis panayensis* (12.0%), Common Myna *Acridotheres tristis* (12.0%), and Spotted Dove *Streptopelia chinensis* (9.5%). The family with the highest number of species was Columbidae, with four species, comprising Pink-necked Green-Pigeon *Treron vernans*, Spotted Dove *Streptopelia chinensis*, and the introduced Zebra Dove *Geopelia striata* and Rock Pigeon *Columba livia* (Table 1). All species are categorized as Least Concern by IUCN (2016) though four species are categorized as Protected according to the Sarawak Wild Life Protection Ordinance (1998).

Sampling saturation was achieved for most of the sites by the 8th sample (Fig. 1). However, urban areas adjacent to secondary forest may require additional surveys to achieve sampling saturation. The completeness ratio (C) was 0.9, suggesting that most of the species present in each urban area were detected. Bird density ranged among sites from 21.8 ± 4.01 individuals ha^{-1} at TJB2 to 55.4 ± 7.09 individuals ha^{-1} at MU (Table 4). The mean total density of urban birds was 32.2 individuals ha^{-1} (SE = 1.8; CV = 5.61%). The detection probability was 8.3% with an encounter rate of 82.5%. Among feeding guilds, species richness of granivores (22%), insectivores (22%), carnivores (22%) and omnivores (19%) were approximately equally co-dominant (Fig. 2), though in terms of abundance, granivores (62%) dominated, followed by omnivores (29%).

Of three models for the species-area regressions, the semi-log model (S = c + z log A) provided the best fit (b_1 = 10.10) (Table 3). According to this model, bird species richness was significantly related to the size of urban areas ($F_{1,8}$ = 25.73, R^2 = 0.76, P = 0.001; Fig. 3). There was no significant relationship between cat density and bird density (Table 3). However, bird diversity and species richness were marginally significantly and negatively related to cat density ($F_{1,8}$ = 6.13, R^2 = 0.43, P = 0.04, Fig. 4; and $F_{1,8}$ = 5.50, R^2 = 0.41, P = 0.05, respectively). The distance between sites and the nearest forest had no significant influence on bird species richness ($F_{1,8}$ = 0.24, R^2= 0.003, P = 0.88), bird density ($F_{1,8}$ = 0.74, R^2=0.009, P = 0.79) or diversity ($F_{1,8}$ = 0.11, R^2=0.001, P = 0.92).

Table 3. Regression statistics for relationship between bird species and site area, and between cat density and bird density/ diversity. The semi-log regression plot provided the best fit.

Category	b_1	c	$F_{1,8}$	R^2	P
Log-log species-area regression	0.39	1.00	23.18	0.74	0.001
Species-area regression	2.5	7.75	16.8	0.68	0.003
Semi log species-area regression	10.10	10.13	25.73	**0.76**	**0.001**
Bird density vs. cat density	-1.35	35.91	0.26	0.03	0.62
Bird species richness vs. cat density	-0.96	13.17	5.50	**0.41**	**0.05**
Bird diversity (H') vs. cat density	-0.05	0.76	6.13	**0.43**	**0.04**

*b_1, slope; c, constant; $F_{1,8}$, degree of freedom; R^2, R square value, ; p, p-value.

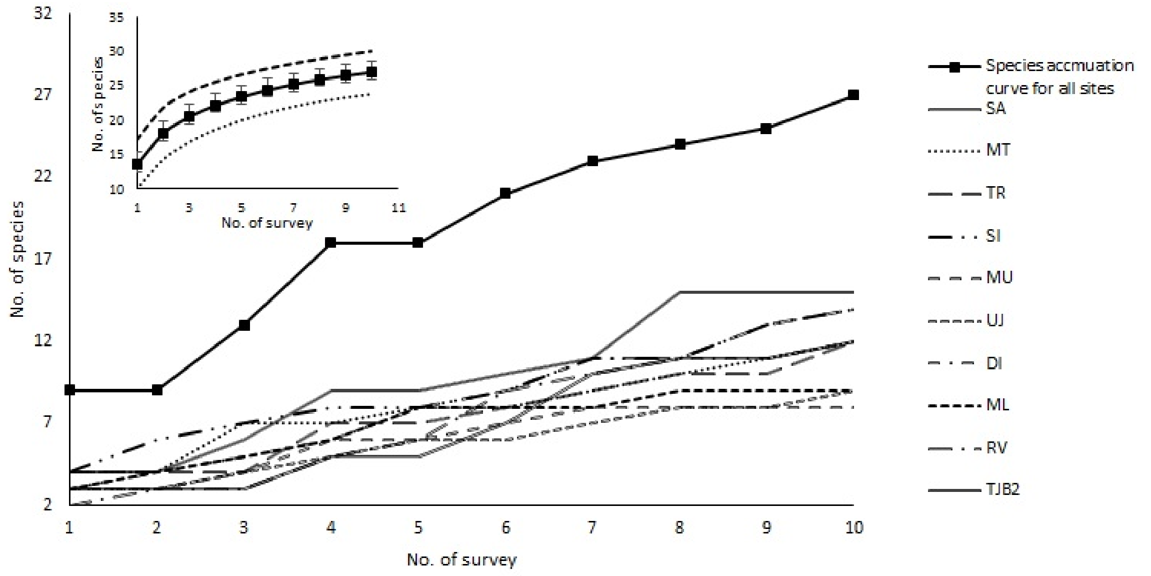

Fig. 1. Cumulative number of species detected as number of censuses increased for all sites and each of the study area (Acronyms are in Table 4). Inset: Rarefaction curve of bird species recorded in urban area throughout the sampling period. Vertical bars describe standard deviation of species estimated.

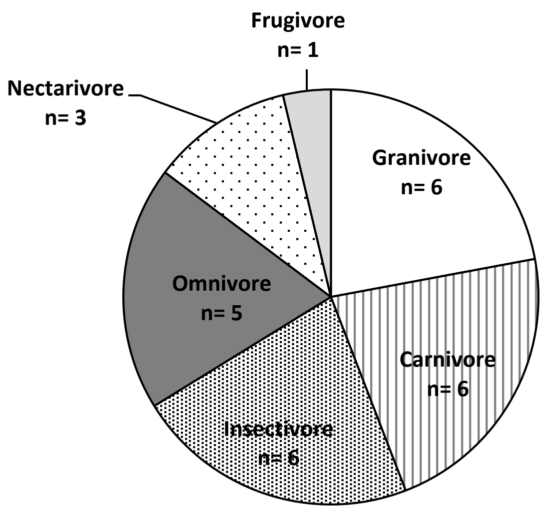

Fig. 2. Foraging guilds of 27 species recorded in urban areas of Kuching, western Sarawak.

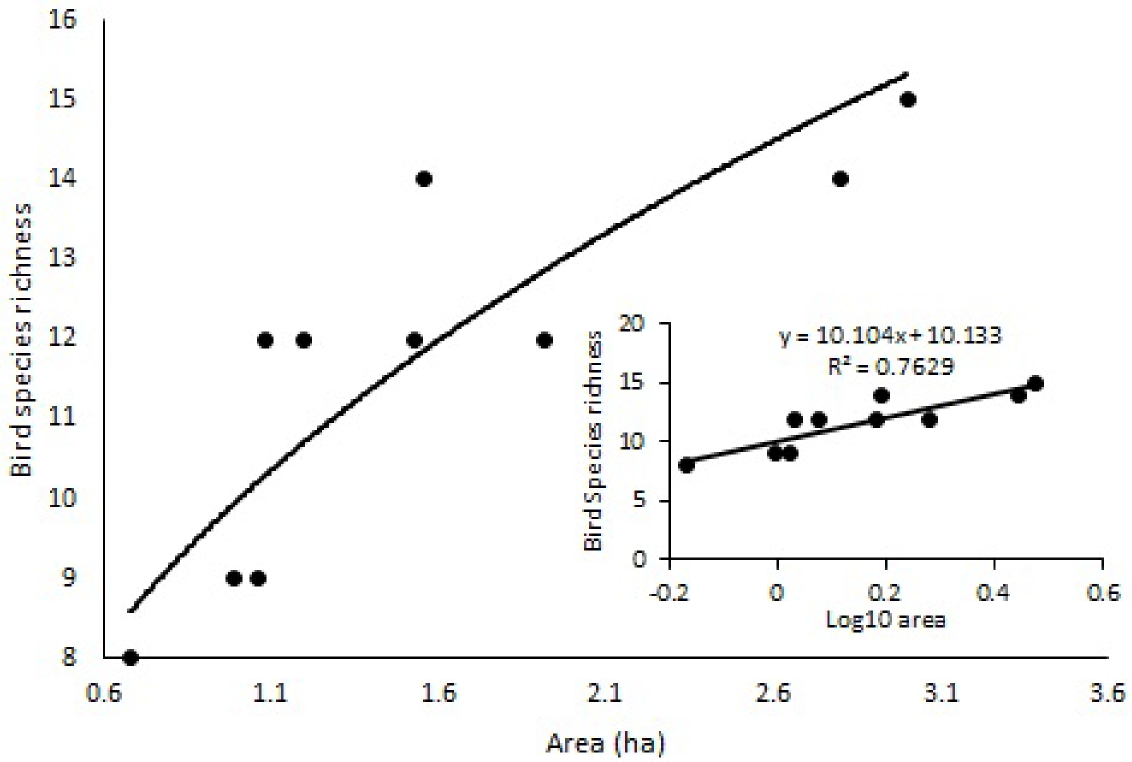

Fig 3. Power curve fitted to species-area relationship (S = 9.98 $A^{0.40}$) showing increase in species with area. Inset: semi-log species area regression plot: S = c + z log A ($F_{1,8}$ = 25.73, R^2 = 0.76, P = 0.001).

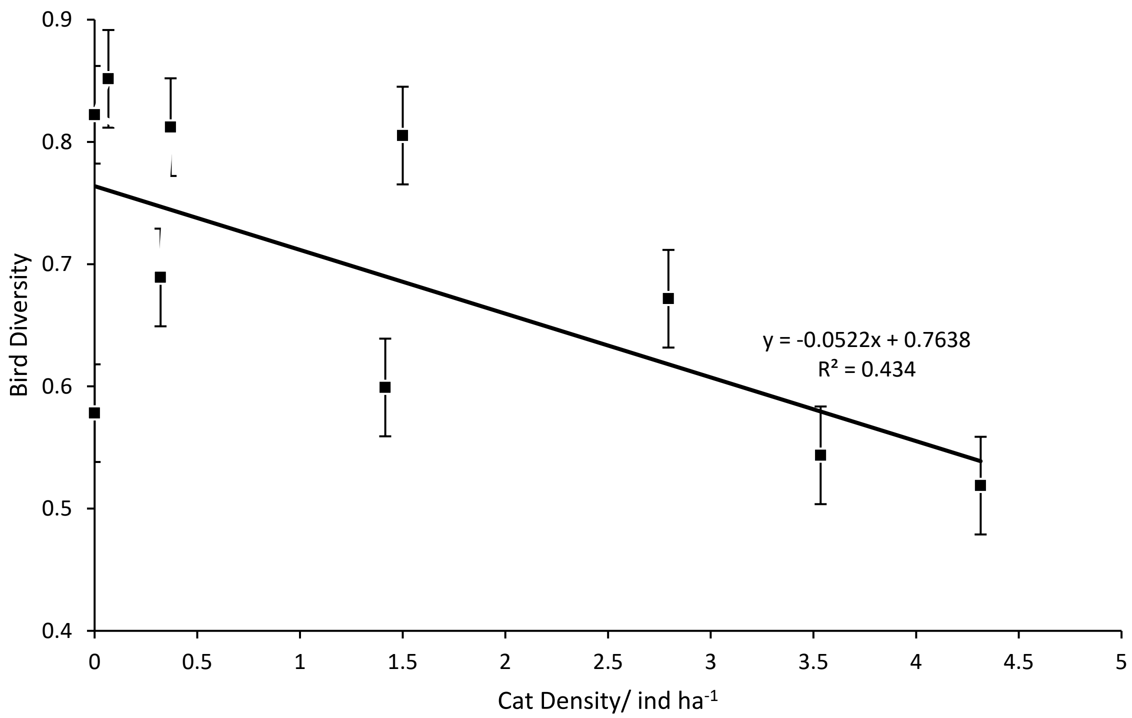

Fig 4. Bird diversity plotted against cat density for the 10 study sites, showing negative relationship between these two variables.

Table 4. Bird species richness, density and diversity, and cat density for 10 sampling sites in urban areas within Kuching region, with Shannon Diversity index in each area. Acronyms for sites are given below the table.

Site	**SA**	**MT**	**TR**	**SI**	**MU**	**UJ**	**DI**	**ML**	**RV**	**TJB2**
Area (ha)	1.92	1.20	1.08	2.80	0.68	1.06	1.53	0.99	1.56	3.00
Transect length (km)	0.62	0.60	0.45	1.00	0.34	0.53	0.85	0.55	0.60	1.00
Min. distance to forest (m)	200	600	200	130	100	150	600	100	100	90
No. observations	261	160	141	227	184	212	194	119	174	172
Species richness	12	12	13	14	8	9	12	9	14	15
No. bird families	11	8	10	10	7	6	9	7	11	12
Bird density ind. ha^{-1}	50.7	37.5	40.0	24.8	55.4	32.9	22.2	22.1	32.5	21.8
Bird diversity (H´)	1.31	1.88	1.89	1.66	1.43	1.3	1.52	1.23	1.98	2.25
Evenness	0.31	0.55	0.55	0.38	0.52	0.41	0.29	0.38	0.52	0.63
Effective strip width (m)	3.99	3.27	3.73	3.35	3.57	3.74	3.34	3.54	3.66	3.72
Cat density ind. ha^{-1}	0	1.5	0.37	0.32	2.79	1.42	4.31	3.54	0	0.07

*SA, Samajaya Apartments; MT, Muara Tabuan; TR, Taman Rimba; SI, Stutong Indah; MU, Medan University; UJ, Unijaya; DI, Desa Ilmu; ML, MidwayLink; RV, Riveria; TJB2, Tabuan Jaya Baru 2.

Discussion

Species composition of the urban avifauna

Throughout the ten sampling surveys, the Eurasian Tree Sparrow was the most frequent species, consistent with a study in Kuala Lumpur (Baharuddin *et al*. 2014). This species has adapted well to anthropogenic landscapes in Borneo (Smythies 1981; Phillipps & Phillipps 2014). In urban areas, sparrows forage on leftover food and are mostly observed near waste disposal areas and small drains, indicating that this species is not dependent on natural food resources. The second most abundant bird species was the Asian Glossy Starling, which has also adapted well to human settlement (Chong *et al.* 2012), and is frequently observed on electrical wires and on buildings where they build their nests. This species was observed in flocks with up to 12 individuals and is regarded as a pest by many human residents. The overall bird diversity at our study sites (H´ = 1.91) was lower than that reported on a university campus in western Sarawak (H´ = 2.5) that is surrounded by mixed dipterocarp, mangrove and peat swamp forests (Voon *et al*. 2014), suggesting that the bird diversity of suburbs is linked to habitat heterogeneity of the surrounding matrix.

In this study, the species composition of the urban avifauna was dominated almost equally by granivores, insectivores, carnivores and omnivores, but granivores were the most abundant. In urban areas of Singapore, Lim & Sodhi (2004) reported that the most abundant foraging guilds were granivores and omnivores. Owing to its ability to scavenge on disposed human food, the Eurasian Tree Sparrow represented 75% of the granivores, and thus elevated the overall abundance of this guild. Similarly, the Asian Glossy Starling and Common Myna represented 82% of omnivores, raising the importance of this guild. The presence of the nectarivorous Olive-backed Sunbird *Nectarinia jugularis,* Crimson Sunbird *Aethopyga siparaja* and Little Spiderhunter *Arachnothera longirostra* in these urban areas reflects the ability of these species to exploit nectar from the flowers of ornamental plants. As in Singapore

(Lim & Sodhi 2004), frugivores were the least well represented in our study due to the lack of fruit trees, typical of high density residential development.

In natural forests, large areas tend to have higher bird species richness than small remnants due to greater structural complexity and floristic diversity, providing more niches for ecologically specialised species (e.g. Mohd-Azlan & Lawes 2011; Mohd-Azlan *et al.* 2015). This partly explains the strong species-area relationship in urban areas as larger suburbs appeared to have a greater variety of exotic and ornamental plant species than smaller suburbs. Furthermore, the occurrence in large suburbs of fruit trees, like papaya, pomelo and banana, probably attracted frugivorous and omnivorous species (e.g. Asian Glossy Starling and Yellow-vented Bulbul *Pycnonotus goiavier*). Tabuan Jaya Baru 2 had the highest species richness (15 species) because it was not only the largest area in this study, but it was also surrounded by secondary and nipa palm forest, which may have been the source of some species that utilised the sites.

Impact of cats on bird diversity and abundance

Many studies around the world have shown that domestic cats have a significant negative impact on birds. In Britain, Woods *et al.* (2003) estimated that cats brought home 5.4 million birds per month, and in Bristol, domestic cats were considered a major cause of mortality of some bird species (Baker *et al*. 2008). In New Zealand, Van Heezik *et al*. (2009) found that birds were the most common type of prey killed by domestic cats (37%). In Finland, Kauhala *et al*. (2015) found that 18% of identified prey animals that cats brought home (n=1,488) were birds. In Brazil, Campos *et al.* (2007) found that 13% of scats (n=97) from domestic cats contained birds.

Like the present study, Sims *et al.* (2008) found a negative correlation between bird species richness and cat density in Britain. In contrast, in Perth, Western Australia, Grayson *et al*. (2007) found that bird species richness was unaffected by cat density, but instead, was significantly affected by housing density and distance to forest. In the present study, the distance from study sites to the nearest forest patch did not influence bird species richness or density, but the vast majority of Australian forests are much more open than tropical rainforests, so we would expect Australian birds to be more pre-adapted to urban landscapes.

Our study failed to show any relationship between cat and bird densities. Surprisingly, Sims *et al.* (2008) found that bird and cat densities in Britain were positively correlated, a finding they attributed to the consistently high cat densities in their study areas (minimum density, 132 cats km^{-2}), and thus uniformly high impacts of cat populations on urban avian assemblages. Yet this density is well below that of another study in Britain, in which mean cat density was 348 cats km^{-2} (Baker *et al.* 2008). Baker *et al.* (2008) showed that cat-killed birds were in significantly poorer body condition than those killed by accidental collisions with vehicles and windows, consistent with the hypothesis that cat predation represents a compensatory rather than additive form of mortality. In Perth, the mean density of cats (3.30 cats ha^{-1} or 330 cats km^{-2}) was commensurate with that in the latter study (Grayson *et al.* 2007), but the authors did not measure bird density or abundance. In our study, cat density was similar to that found by Sims *et al.* (2005), but it is possible that this is an under-estimate, since we did not count cats at night.

Concluding remarks

This study is probably the first to attempt to understand the processes involved in structuring urban bird communities in Borneo. Such information is potentially useful to city and town planners in maintaining and enhancing birdlife in Borneo’s expanding cities. We believe that urban planners should consider maintaining or creating forest corridors between urban areas, as well as encouraging the planting of suitable indigenous trees that can provide fruit and nectar resources to avian frugivores and nectarivores, which in turn provide seed dispersal and pollination services for plants grown in parks and gardens. Future research could focus on understanding the temporal and spatial effects of streets, intensity of traffic, and various other indicators of the human footprint on the distribution and density of domestic predators. This may provide insights on how domestic predators affect the composition and density of bird populations in Asian cities.

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