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BIRD ABUNDANCE AND ITS RELATIONSHIP WITH MICROCLIMATE AND HABITAT VARIABLES IN OPEN-AREA AND SHRUB HABITATS IN SELANGOR, PENINSULAR MALAYSIA

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ABSTRACT

Malaysia characterized by diverse habitats, such as forests, open areas, shrub lands and woodlands, that attract a wide array of bird species. Microclimate and habitat structure are major driving forces that influence avian community composition in particular habitats. This study examined the effects of open-area and shrub habitats on bird species composition and abundance. Bird abundance was determined using the distance sampling point count method. The relationship between bird abundance and microclimate and habitat structure was determined using canonical correspondence analysis. A total of 5,144 birds belonging to 84 species representing 35 families were detected. Open areas contained 62.44% of all the birds (3,212 individuals representing 75 bird species and 35 families), and shrub lands contained the remaining 37.56% (1,932 individuals representing 68 bird species and 33 families). Flowering and fruiting trees dominated the open-area habitat, whereas densely clustered young woody saplings and shrubs (i.e., less than 10 ft tall and less than 10 cm dbh) were abundant in the shrub habitat. The findings of this study indicate that the bird species composition and distribution in both habitats are influenced by various factors of microclimate (i.e., temperature, relative humidity and light intensity) and habitat structure (i.e., vegetation cover, vegetation composition and distribution).

Key words: Microclimate, Open Area, Shrub Habitat, Distance Sampling, Relative Abundance, Birds, Correlationship, Habitat Structure

INTRODUCTION

Malaysia is blessed with a wide array of habitats, e.g., forests, open areas, shrub lands, wetlands, lakes, rivers, aquacultural ponds, woodlands, agricultural lands, rice fields and wastewater treatment areas (Rajpar and Zakaria, 2011), that are rich in avian diversity, including 525 residents, 200 migrants, 92 vagrants and 42 endemic bird species (MNS, 2010). Approximately 45 bird species in Malaysia are threatened due to habitat loss and degradation (World Bank Report, 2011). Anthropogenic habitat loss and degradation have caused a significant decline in avian diversity around the world (Taylor and Pollard, 2008). Reducing the loss of avian habitat is a much more efficient way to enhance the bird populations in dwelling areas than attempting to restore habitat. Therefore, the conservation of natural habitats across the country is the most important factor in maintaining bird populations.

The clearance of natural forests for agricultural purposes has seriously threatened the survival of many bird species (Peh *et al*., 2006). The rapid decrease in the natural forested area has pressured avian species into utilizing shrub and open-area habitats for their survival and reproduction. Shrub habitats consist of understory woody or sapling vegetation generally measuring less than 3 m in height (Hunter *et al*., 2001) that exhibits specific environmental features that are rich in food resources (such as berries and insects) and offer safe shelter and nesting sites for a diversity of bird species. Birds inhabiting shrub habitats have received relatively little attention as compared to species that inhabit forests (Hunter *et al.*, 2001; Peterjohn, 2006). Bird populations inhabiting shrub habitats have experienced consistent declines over the past 40 years due to habitat reduction and loss (Peterjohn, 2006; Pardieck and Sauer, 2007).

The relative abundance of a species is often associated with the vegetation community, food resources and habitat structural complexity (Rajpar and Zakaria, 2011). Determining the avian relative abundance is highly important because this variable indicates the proportion of an existing population in a particular habitat. The distance sampling point-count method is widely used and an appropriate for the estimation of bird abundance and distribution in different habitats (Thompson, 2002; Kissling and Garton, 2006; Alldredge *et al.*, 2007). Microclimate and habitat structures are major factors that influence avian survival rate, reproduction success, time of breeding, species dispersal and habitat selection (Zharikov and Skilleter, 2002; Norvell *et al*., 2003; Rajpar and Zakaria, 2011).

To date, no detailed study has been conducted in open-area and shrub habitats to determine the particular association of birds with microclimate and habitat

variables in Malaysia. Therefore, there is an urgent need to assess how microclimate and habitat variables affect avian distribution patterns and richness. The objective of this study was to determine the relative abundance, distribution and association of bird species with microclimate and habitat variables in open-area and shrub habitats. The findings are expected to improve our understanding of the effects of microclimate and habitat structures on bird species.

MATERIALS AND METHODS

Study Site: The study area is located within the quadrant of 101°10′ to 101°50′ longitude and 2°50′ and 3°00′ latitude (Figure 1). In this study, open areas are habitats with scattered flowering and fruiting trees (i.e., *Cinnamonum iners, Melicope glabra*, *Ficus rubiginosa*, *F. benjamina, Syzygium grande, S. polyanthum, Caryota mitis*, *Delonix regia*, and *Fragraea fragrans*) planted by the Department of Wildlife and National Parks, Peninsular Malaysia. The ground is densely covered by *Imperata cylindrica*, *Cynodon dactylon*, and *Distichlis spicata*. During the flowering season, these flowering tree species attract a variety of insects, sunbirds, spider-hunters, and flower-peckers that feed on nectar and hunt for insects. Similarly, fruiting trees bear fruits throughout the year, attracting insects, insectivores and frugivorous birds.

In contrast to open areas, shrub habitats are mosaics of densely clustered woody plants dominated by *Melastoma malabathricum, Dillenia suffruticosa* and young saplings typically measuring less than 10 ft tall and 10 cm dbh, such as *Acacia auriculiformis* and *A. mangium*. Approximately 70.0% of the area of shrub habitats is densely covered with grasses, i.e., Cogon Grass (*I. cylindrica*), Climbing Fern (*S. palustris*), Fern Tree (*Gleichenia linearis*) and Giant Weed (*S. molesta*), and the remaining 30.0% is a barren area devoid of vegetation. Shrub habitats create different vegetation structure layers, serve as suitable foraging sites by providing a diversity of fruits and flowers throughout the year, and provide safe breeding and roosting sites for terrestrial birds (Rajpar and Zakaria, 2010).

Bird Surveys: Birds were surveyed using a distance sampling point count technique (Buckland *et al.* 2004) for 18 consecutive months from November 2007 to January 2009. A total of 42 point count stations was established at 300 m intervals within both habitat types, i.e., open-area and shrub habitats. This distance was selected to avoid double counting the same bird individuals at more than one station. The point count stations were accessed by walking along trails s*et al*ong the walking paths. The birds were surveyed for eight days each month, and each point count station was surveyed for 10 min. During each survey, all bird species and individuals seen or heard were recorded. Any flushed birds with known original positions were also recorded and included in the analysis. The distance from bird individuals to observer was recorded using visual estimation for each bird individual within the range of 100 m. The surveys were conducted by a single observer between 0730 and 1100 hrs. This period of time is appropriate because most birds are active early in the morning. The survey methodology was based on Bibby *et al.* (2000), Buckland *et al*. (2004), Aborn (2007), Lee and Marsden (2008) and Nadeau *et al.* (2008).

Vegetation Survey: We examined the microclimate and habitat variables simultaneously at the locations where the birds were detected to determine the influence of these variables on bird abundance and distribution. The vegetation species composition (i.e., trees, shrubs, and grasses) was determined by employing the quadrant method (10 m x 10 m), which is the most accurate method to survey vegetation variables in a variety of habitats (Hudon, 1997; Fernandez–Alaez *et al.*, 2002). Trees were categorized in different height and dbh (diameter at breast height) classes to determine the effects of habitat heterogeneity on birds. In each sample plot, a ground covered by vegetation (%), species richness, vegetation type (such as trees, shrubs and grasses), vegetation height (meters) and vegetation diameter (inches) were determined.

Microclimate Data: The term microclimate refers to temperature, relative humidity and light intensity, while the term habitat structure refers to the vegetation cover percentage (ground cover occupied by plants), vegetation richness (number of plants), vegetation type (trees, shrubs and grasses), vegetation height (meters) and vegetation diameter (inches). Microclimate data were recorded simultaneously using a Psychrometer, and light intensity was also recorded using a LUX meter. The procedures described in Isacch *et al.* (2005), Chettri *et al*. (2005) and Champlin *et al*. (2009) were followed.

Data Analysis: *Relative Abundance of Avian Species*: The relative abundance (%) of bird species was determined using the following expression: n/N x 100 (where n is the number of observations for a particular bird species and N is the total number of observations detected for all species) (Zakaria *et al*., 2009).

Correlationship of Avian Species with Microclimate and Habitat Variables: Multivariate analysis using Canonical Correspondence Analysis Software (CCA; Version 4.5) by ter Braak and Smilauer (2002) was employed to examine the relationship between the bird species, microclimate and habitat variables in order to understand the avian community structures in the study area. Because the beta value was less than three, the association of birds, microclimate and

habitat structure was analyzed using constrained redundancy ordination (RDA).

RESULTS

Overall, a total of 5,144 bird individuals representing 84 species and 35 families were detected within the two habitats, i.e., the open-area (75 bird species and 35 families) and the shrub habitat (68 bird species and 33 families). Fifty-nine species were commonly detected in both habitats. However, nine bird species—Oriental Reed Warbler (*Acrocephalus orientalis*), Rufous Woodpecker (*Celeus brachyurus*), Arctic Warbler (*Phylloscopus borealis*), Common Moorhen (*Gallinula chloropus*), White-browed Crake (*Porzana cinerea*), Little Green Pigeon (*Treron olax*), Rusty-rumped Warbler (*Locustella certhiola*), Slaty-breasted Crake (*Gallirallus striatus*), and White-bellied Fish Eagle (*Haliaeetus leucogaster*)—were absent from the open-area habitat. Likewise, sixteen species—House Crow (*Corvus splendens*), Plain Sunbird (*Anthreptes simplex*), Eurasian Tree Sparrow (*Passer montanus*), Lesser Whistling Duck (*Dendrocygna javanica*), White-headed Munia (*Lonchura maja*), Hill Myna (*Gracula religiosa*), Common Sandpiper (*Tringa hypoleucos*), Black Baza (*Aviceda leuphotes*), Common Kingfisher (*Alcedo atthis*), Brahminy Kite (*Haliastur indus*), Chestnut-winged Cuckoo (*Clamator coromandus*), Common Asian Koel (*Eudynamys scolopacea*), Purple-throated Sunbird (*Nectarinia sperata*), Rufescent Prinia (*Prinia rufescens*), Western Marsh Harrier (*Circus aeruginosus*), and Yellow-breasted Bunting (*Emberiza aureola*)—were absent from the shrub habitat (Table 1).

Relative Abundance of Birds in the Open-Area Habitat: In the open-area habitat, a total of 3,212 bird observations (62.44% of all observations) were recorded, representing 75 bird species and 35 families. The results highlighted that Pink-necked Green Pigeon (*Treron vernans* (9.74%)), Yellow-vented Bulbul (*Pycnonotus goiavier* (8.50%)), and Spotted Dove (*Streptopelia chinensis* (5.31%)) were the three most abundant bird species. In contrast, fourteen bird species—Zitting Cisticola (*Cisticola juncidis*), Blue-breasted Quail (*Coturnix chinensis*), Mangrove Whistler (*Pachycephala grisola*), Plaintive Cuckoo (*Cacomantis merulinus*), Common Kingfisher (*Alcedo atthis*), Copper-throated Sunbird (*Nectarinia calcostetha*), Black-throated Sunbird (*Aethopyga saturate*), Brahminy Kite (*Haliastur indus*), Chestnut-winged Cuckoo (*Clamator coromandus*), Common Asian Koel (*Eudynamys scolopacea*), Purple-throated Sunbird (*Nectarinia sperata*), Rufescent Prinia (*Prinia rufescens*), Western Marsh Harrier (*Circus aeruginosus*), and Yellow-breasted Bunting (*Emberiza aureola*)—were the rarest birds, as each was recorded only once (0.02% each) (Table 1).

Relative Abundance of Birds in the Shrub Habitat: In the shrub habitat, a total of 1,932 bird observations (37.56% of all counts) were recorded, representing 68 bird species and 33 families. Two species—*Treron vernans* (7.15%) and *Pycnonotus goiavier* (6.34%)—were relatively common. In addition, the ten rarest bird species—Pintail Snipe (*Gallinago stenura)*, Black-shouldered Kite (*Elanus caeruleus*), Black-shouldered Kite (*Elanus caeruleus*), Ashy Tailorbird (*Orthotomus ruficeps*), Little Spiderhunter (*Arachnothera longirostra*), Greater Flameback (*Chrysocolaptes lucidus*), Plaintive Cuckoo (*Cacomantis merulinus*), Copper-throated Sunbird (*Nectarinia calcostetha*), Rusty-rumped Warbler (*Locustella certhiola*), Slaty-breasted Crake (*Gallirallus striatus*) and White-bellied Fish Eagle (*Haliaeetus leucogaster*)—were considered the rarest species because they were detected only once (0.02% each) (Table 1).

Microclimate and Characteristics of the Open-Area Habitat: The mean temperature in the open-area habitat was 29.3°C, the mean relative humidity was 76.1%, and the mean light intensity was 270.6 Lux. In addition, the open-area habitat was dominated by large trees, followed by intermediate and young saplings (Table 2).

Microclimate and Characteristics of the Shrub Habitat: A mean temperature of 25.4°C, mean relative humidity of 95.3% and mean light intensity of 160.58 Lux were recorded in the shrub habitat. More than 75.00% of the area was covered with vegetation; 70.0% was dominated by shrubs and woody vegetation while30.00% was covered by grasses (Table 2).

Correlation of Birds with Microclimate and the Open-Area Habitat: The correlationship of the bird species, microclimate and habitat variables of the first two axes was 100.00%; this result suggests that all the variation could be explained by the RDA biplot diagram. The correlation analysis showed that the bird species in the open-area habitat were strongly associated with the microclimatic factors of that habitat (Table 3).

The ordination biplot diagram of the open-area habitat indicated that Peaceful Doves, Barred Button Quails, Richard's Pipits, and Red Junglefowl were closely associated with grasses. Oriental Magpie Robins, Pied Trillers, Blue-tailed Bee-eaters, and Philippine Glossy Starlings had a relationship with sparse vegetation (26–50%). Brown Shrikes, Green Ioras, Ashy Minivets, Ashy Tailorbirds, Brown-throated Sunbirds and Pied Fantails showed a positive correlationship with young saplings and relative humidity. The abundance of Lesser Coucals, Common Flamebacks, Common Ioras, and Pink-necked Green Pigeons showed a positive correlation with the presence of mature trees (Figure 2).

Correlation of Birds with Microclimate and Shrub Habitat: The first two axes indicated that all variables could be explained by utilizing the RDA biplot diagram.

The association of birds, microclimate and habitat variables of the first two axes were 100%. In addition, the results showed that the distribution of bird species was influenced by microclimatic such as temperature, relative humidity, light intensity and habitat variables, (Table 4).

The RDA biplot of the shrub habitat showed that Brown-throated Sunbirds and Black-naped Orioles were closely associated with moderate vegetation cover (26-50%). Richard's Pipits, Barred Button Quails, Oriental Magpie Robins and Common Tailorbirds had a strong relationship with dense vegetation cover (75–100%). White-vented Mynas, Common Ioras, Common Flamebacks and Pink-necked Green Pigeons had a close relationship with the trees to a height of 21–30 m. Green Ioras and Pied Trillers had a preference for humid areas with a vegetation cover of 51–75% that were dominated by mature trees with a 16–45 cm diameter and a 11–20 m height. In addition, Yellow-vented Bulbuls, Baya Weavers and Lesser Coucals showed a preference for warmer temperatures (Figure 3).

DISCUSSION

Birds often prefer to utilize multiple habitats and depend on the quality and productivity of the habitats in terms of food availability, shelter (from harsh weather and predators) and breeding sites in order to maintain viable populations (Villard *et al*., 1999; Söderström and Pärt, 2000). Monitoring the association of birds with microclimate and habitat variables is particularly important to understand the importance, productivity and suitability of a particular area and how these factors affect bird habitat selection and distribution. The observations of 75 bird species in open-area habitats and 68 bird species in shrub habitats indicated that open-area habitats played a more important role than shrub habitats in attracting higher bird species composition and diversity. This pattern indicated that open-area habitats supported a higher assemblage of avian species than shrub habitats, which might be due to the birds' preference to forage in open areas with sparse vegetation, despite the availability of higher food relative abundance in areas with dense vegetation such as shrub habitats, due to increased prey accessibility and reduced predation risk (Jama and Zeila, 2005; Schaub *et al.*, 2010). It has been reported that open-area habitats support a large bird populations (Rudd *et al*., 2002; Daniels and Kirkpatrick, 2006; van Heezik and Seddon, 2012).

A distinctive feature of open-area habitats is the diversity of fruiting and flowering trees such as Wild Cinnamon, Blume Tree, Rusty Fig, Weeping Fig, Jambu Air Laut or Sea Apple, Fishtail Palm, Flame Tree and Heritage Tree that bear flowers and fruits throughout the year. The correlation analysis of open-area habitats showed that certain bird species have a strong association with microclimate variables (such as; temperature, relative humidity, and light intensity) and habitat structure such as trees, shrubs and grasses. This finding indicated that birds often select available habitat based on resources such as food, nesting materials and shelter. For example, in open-area habitats, waterhens, doves, pipits, quails and junglefowl were closely related with the grasses. This association was due to the richness of seeds, insect larvae and vegetation cover from harsh weather and predators in grassy surroundings. The grasses also provide safe chick-rearing sites for these birds. Perkins *et al*. (2000) also found that the prevalence of seed-eating birds is positively associated with seed availability.

Robins, mynas, trillers, bee-eaters, starlings and cuckoos were associated with high light intensity and a vegetation cover of 26–50%. Light intensity may affect fruit production, attracting arthropods and increasing food availability for avian species, as reported by Banks and Cintra (2008). Moreover, these bird species preferred open areas with sparse vegetation, mostly to forage on insects through sallying and gleaning for insect larvae in tree foliage that had been attracted by flowers and fruits. Moreover, woodpeckers, kingfishers and pigeons showed a positive association with large-diameter trees. Woodpeckers prefer these mature trees for their thick bark that contain insects, whereas kingfishers use them for perching, and pigeons are attracted by the diversity of these trees' fruits. Food availability, tree size, tree height and cover percentage are paramount factors affecting bird species composition, distribution, relative abundance and richness (Shochat *et al.*, 2002; Carrascal and Diaz, 2006; Honkanen *et al*., 2010; Godinho *et al*., 2010). The richness and diversity of food resources may increase habitat suitability, reduce the amount of time required for food searching and increase the rate of food intake with respect to energy expenditure. In addition, bulbuls, weavers and coucals showed a positive link with temperature. La Sorte *et al.* (2009) and Canterbury (2002) reported that bird distribution and relative abundance are strongly associated with an optimal thermal environment (temperature), as this parameter affects food availability, food intake and energy expenditure; fruit productivity; and arthropod activities. Rajpar and Zakaria (2011) and Gonzalez-Gajardo *et al.* (2009) also found that habitat size and diversity of vegetation can provide numerous microhabitats, thereby attracting a greater number of bird species due to the availability of diverse food resources, suitable breeding and chick-rearing sites and cover from harsh weather.

Shrub habitats are dominated by high densities of medium-sized, predominantly evergreen shrubs (such as Malabar Melastone, Simpoh Ayer and Acacia) and dense herbaceous plants (e.g., Giant Weed, Climbing Fern, Fern Tree and Cogon Grass) that provide optimal cover for birds, insects and small animals. The ordination biplot of the shrub habitat revealed that kingfishers, starlings, dollar birds, crows and mynas were strongly

associated with shrub vegetation. These shrubs created spatial niches for invertebrates and small vertebrates, which are major sources of food for a wide array of avian

Table 1. Relative abundance of bird species recorded in open-area and shrub habitats

Family Name	Scientific Name	Common Name	No. of Observations			
			Open Area	% of all Observations	Shrub	% of all Observations
Columbidae	*Treron vernans*	Pink-necked Green Pigeon	501	9.74	368	7.15
Pycnonotidae	*Pycnonotus goiavier*	Yellow-vented Bulbul	437	8.50	326	6.34
Columbidae	*Streptopelia chinensis*	Spotted Dove	273	5.31	97	1.86
Columbidae	*Geopelia striata*	Peaceful Dove	240	4.67	165	3.21
Sturnidae	*Acridotheres fuscus*	Jungle Myna	204	3.97	81	1.57
Sturnidae	*Acridotheres tristis*	Common Myna	177	3.44	43	0.84
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	111	2.16	89	1.73
Ploceidae	*Ploceus philippinus*	Baya Weaver	97	1.89	49	0.95
Motacillidae	*Anthus richardi*	Richard's Pipit	93	1.81	23	0.45
Meropidae	*Merops philippinus*	Blue-tailed Bee-eater	81	1.57	21	0.41
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	76	1.48	43	0.84
Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	75	1.46	34	0.68
Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	75	1.46	38	0.74
Turdidae	*Copsychus saularis*	Oriental Magpie Robin	68	1.32	19	0.37
Estrildidae	*Lonchura malacca*	Black-headed Munia	44	0.86	45	0.87
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	43	0.84	51	0.99
Sturnidae	*Aplonis panayensis*	Philippine Glossy Starling	40	0.78	14	0.27
Laniidae	*Lanius cristatus*	Brown Shrike	40	0.78	28	0.54
Sturnidae	*Acridotheres grandis*	White-vented Myna	38	0.74	13	0.25
Rallidae	*Porphyrio porphyrio*	Purple Swamphen	33	0.64	20	0.39
Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia	32	0.62	37	0.72
Coraciidae	*Eurystomus orientalis*	Dollar Bird	29	0.56	7	0.14
Rhipiduridae	*Rhipidura javanica*	Pied Fantail	27	0.52	44	0.86
Aegithinidae	*Aegithina viridissima*	Green Iora	27	0.52	24	0.47
Phasianidae	*Gallus gallus*	Red Junglefowl	27	0.52	19	0.37
Cuculidae	*Centropus bengalensis*	Lesser Coucal	26	0.51	20	0.39
Ardeidae	*Ardea purpurea*	Purple Heron	22	0.43	9	0.17
Scolopacidae	*Gallinago stenura*	Pintail Snipe	19	0.37	1	0.02
Campephagidae	*Lalage nigra*	Pied Triller	17	0.33	12	0.23
Corvidae	*Corvus splendens*	House Crow	17	0.33	0	0
Campephagidae	*Pericrocotus divaricatus*	Ashy Minivet	17	0.33	5	0.10
Picidae	*Dinopium javanense*	Common Flameback	16	0.31	12	0.23
Aegithinidae	*Aegithina tiphia*	Common Iora	15	0.29	12	0.23
Meropidae	*Merops viridis*	Blue-throated Bee-eater	15	0.29	3	0.06
Ardeidae	*Ixobrychus sinensis*	Yellow Bittern	14	0.27	17	0.33
Nectariniidae	*Anthreptes simplex*	Plain Sunbird	14	0.27	0	0
Accipitridae	*Elanus caeruleus*	Black-shouldered Kite	12	0.23	1	0.02
Nectariniidae	*Anthreptes malaccensis*	Brown-throated Sunbird	11	0.21	6	0.12
Passeridae	*Passer montanus*	Eurasian Tree Sparrow	9	0.17	0	0
Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck	8	0.16	0	0
Sylviidae	*Orthotomus sutorius*	Common Tailorbird	7	0.14	11	0.21
Cuculidae	*Chrysococcyx minutillus*	Little Bronze Cuckoo	7	0.14	4	0.08
Sylviidae	*Orthotomus ruficeps*	Ashy Tailorbird	6	0.12	1	0.02
Turnicidae	*Turnix suscitator*	Barred Button Quail	6	0.12	6	0.12
Cuculidae	*Centropus sinensis*	Greater Coucal	5	0.10	4	0.08
Caprimulgidae	*Caprimulgus affinis*	Savanna Nightjar	5	0.10	3	0.06

Estrildidae	*Lonchura maja*	White-headed Munia	5	0.10	0	0
Hirundinidae	*Hirundo tahitica*	Pacific Swallow	4	0.08	17	0.33
Pycnonotidae	*Pycnonotus plumosus*	Olive-winged Bulbul	4	0.08	3	0.06
Sturnidae	*Gracula religiosa*	Hill Myna	4	0.08	0	0
Nectariniidae	*Nectarinia jugularis*	Olive-backed Sunbird	3	0.	4	0.08
Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher	3	0.06	7	0.14
Scolopacidae	*Tringa hypoleucos*	Common Sandpiper	3	0.06	0	0
Corvidae	*Corvus macrorhynchos*	Large-billed Crow	2	0.04	7	0
Ardeidae	*Ixobrychus cinnamomeus*	Cinnamon Bittern	2	0.04	2	0.04
Rallidae	*Gallicrex cinerea*	Water Cock	2	0.04	2	0.04
Caprimulgidae	*Caprimulgus macrurus*	Large-tailed Nightjar	2	0.04	7	0.14
Accipitridae	*Aviceda leuphotes*	Black Baza	2	0.04	0	0
Columbidae	*Treron bicincta*	Orange-breasted Green Pigeon	2	0.04	21	0.41
Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	2	0.04	1	0.02
Picidae	*Chrysocolaptes lucidus*	Greater Flameback	2	0.04	1	0.02
Cisticolidae	*Cisticola juncidis*	Zitting Cisticola	1	0.02	2	0.04
Phasianidae	*Coturnix chinensis*	Blue-breasted Quail	1	0.02	2	0.04
Pachycephalidae	*Pachycephala grisola*	Mangrove Whistler	1	0.02	2	0.04
Cuculidae	*Cacomantis merulinus*	Plaintive Cuckoo	1	0.02	1	0.02
Alcedinidae	*Alcedo atthis*	Common Kingfisher	1	0.02	0	0
Nectariniidae	*Nectarinia calcostetha*	Copper-throated Sunbird	1	0.02	1	0.02
Nectariniidae	*Aethopyga saturata*	Black-throated Sunbird	1	0.02	2	0.04
Accipitridae	*Haliastur indus*	Brahminy Kite	1	0.02	0	0
Cuculidae	*Clamator coromandus*	Chestnut-winged Cuckoo	1	0.02	0	0
Cuculidae	*Eudynamys scolopacea*	Common Asian Koel	1	0.02	0	0
Nectariniidae	*Nectarinia sperata*	Purple-throated Sunbird	1	0.02	0	0
Cisticolidae	*Prinia rufescens*	Rufescent Prinia	1	0.02	0	0
Accipitridae	*Circus aeruginosus*	Western Marsh Harrier	1	0.02	0	0
Emberizidae	*Emberiza aureola*	Yellow-breasted Bunting	1	0.02	0	0
Sylviidae	*Acrocephalus orientalis*	Oriental Reed Warbler	0	0	9	0.17
Picidae	*Celeus brachyurus*	Rufous Woodpecker	0	0	4	0.08
Sylviidae	*Phylloscopus borealis*	Arctic Warbler	0	0	3	0.06
Rallidae	*Gallinula chloropus*	Common Moorhen	0	0	2	0.04
Rallidae	*Porzana cinerea*	White-browed Crake	0	0	2	0.04
Columbidae	*Treron olax*	Little Green Pigeon	0	0	2	0.04
Sylviidae	*Locustella certhiola*	Rusty-rumped Warbler	0	0	1	0.02
Rallidae	*Gallirallus striatus*	Slaty-breasted Crake	0	0	1	0.02
Accipitridae	*Haliaeetus leucogaster*	White-bellied Fish Eagle	0	0	1	0.02
		Total	3,212		1,932	

species (Fang, 2005; Daniels and Kirkpatrick, 2006; Sandström *et al.*, 2006). Sunbirds and orioles were associated with a vegetation cover of 26–50%. In addition, pipits, junglefowl, lapwings, quails, robins and tailorbirds showed a strong relationship with dense ground vegetation cover (75–100%). The ground vegetation may harbor abundant populations of invertebrates that can be detected and captured easily, as reported by Moorcroft *et al*. (2002), Butler and Gillings (2004) and Martinez *et al*. (2010). Mynas and doves were strongly associated with high light intensity and grassy lawns due to the abundance of small seeds, insect larvae and worms. Light intensity and the amount of litter affect avian communities directly or indirectly by offering a wide range of food resources (Pearman, 2002; Pringle *et al*., 2003; Cintra *et al.*, 2006; Barros and Cintra, 2009; Champlin *et al.*, 2009). Ioras, fantails, and minivets were associated with medium-sized trees. The reason for this pattern was that these birds foraged in the canopy, mostly on insects and caterpillars. Bird distribution in the shrub habitat was affected by the richness and diversity of food resources (i.e., insects, fishes, amphibians, reptiles, small mammals, and vegetable matter such as fruits, flowers, grains) and vegetation diversity and richness (i.e., trees, shrubs, and grasses), as reported by Chace and Walsh (2006), Daniels and Kirkpatrick (2006) and Gonzalez-Gajardo *et al.* (2009). Microclimate and habitat structures influence avian survival rate, reproduction success, time of breeding, species dispersal and habitat selection

(Zharikov and Skilleter, 2002; Norvell *et al*., 2003; Rajpar and Zakaria, 2011).

Overall, our results indicate that aspects of microclimate and vegetation structure such as species composition, vegetation cover percentage, habitat structure and heterogeneity are the most important factors that influence bird species composition, richness and relative abundance. In addition, adjacent landscape characteristics such as oil palm plantations, peat swamp forest and proximity to water (such as wetlands and lake areas) promote high species diversity and abundance due to their wide diversity of habitat characteristics and increased prey availability (Stralberg *et al*., 2003; Cintra and Naka, 2012).

Table 2. Microclimate and habitat variables in the open-area and shrub habitats

S. No	Habitat Variables	Mean Value (Range)	
		Open Area	Shrub
1	**Microclimate Variables**		
	(a) Average Temperature	29.3°C (25–30°C)	25.4°C (22–32°C)
	(b) Average Relative Humidity	76.1% (60–97%)	95.3% (89–97%)
	(c) Average Light Intensity (LUX)	270.60 (35–95 Lux)	160.58 (91–309 Lux)
2	**Habitat Variables**		
	(a) *Vegetation Cover Percentage*	50.00%	> 75.00%
	(b) Grasses	10.00%	30.00%
	(c) Shrubs	8.00%	70.00%
	(d) Trees		
	i Diameter (centimeter)		
	Diameter “DA” (0–15 cm)	50	180
	Diameter “DB” (16–30 cm)	35	14
	Diameter “DC” (31–45 cm)	48	6
	ii Height (meter)		
	Height “HA” (0–10 m)	48	178
	Height “HB” (11–20 m)	32	11
	Height “HC” (21–30 m)	45	5

Table 3. Summary of RDA ordination for bird assemblages in the open-area habitat

Term	Axis				
	1	2	3	4	Total
Eigenvalues	0.470	0.160	0.098	0.060	1.000
Species-environmental correlations	1.000	1.000	1.000	1.000	
Cumulative percentage variance of species data	47.0	63.0	72.8	78.8	
Cumulative percentage variance of species–environment relation	47.0	63.0	72.8	78.8	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					1.000

Table 4. Summary table of RDA ordination for bird assemblages in the shrub habitat

Term	Axis				
	1	2	3	4	Total
Eigenvalues	0.423	0.204	0.114	0.099	1.000
Species-environmental correlations	1.000	1.000	1.000	1.000	
Cumulative percentage variance of species data	42.3	62.8	74.2	84.0	
Cumulative percentage variance of species–environment relation	42.3	62.8	74.2	84.0	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					1.000

Figure 1. Location map of study sites

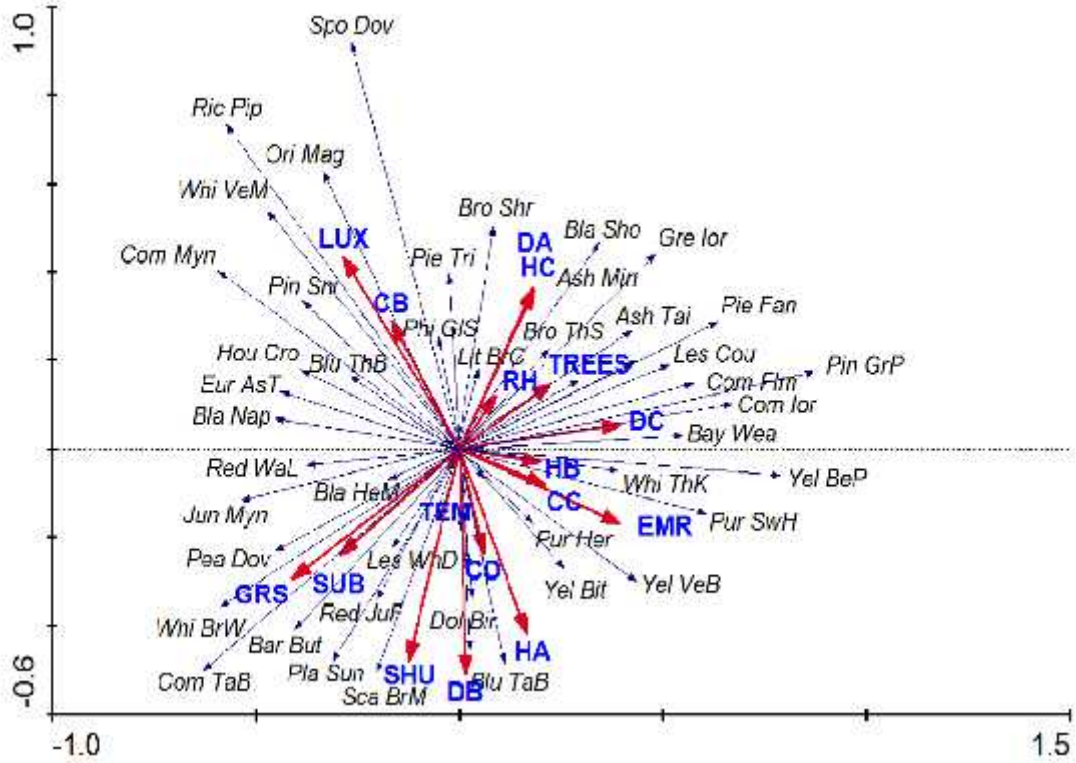

Figure 2. The ordination biplot diagram of the first two axes from the canonical correspondence analysis, displaying the correlations between the environmental variables (arrows) and the open-area bird species.

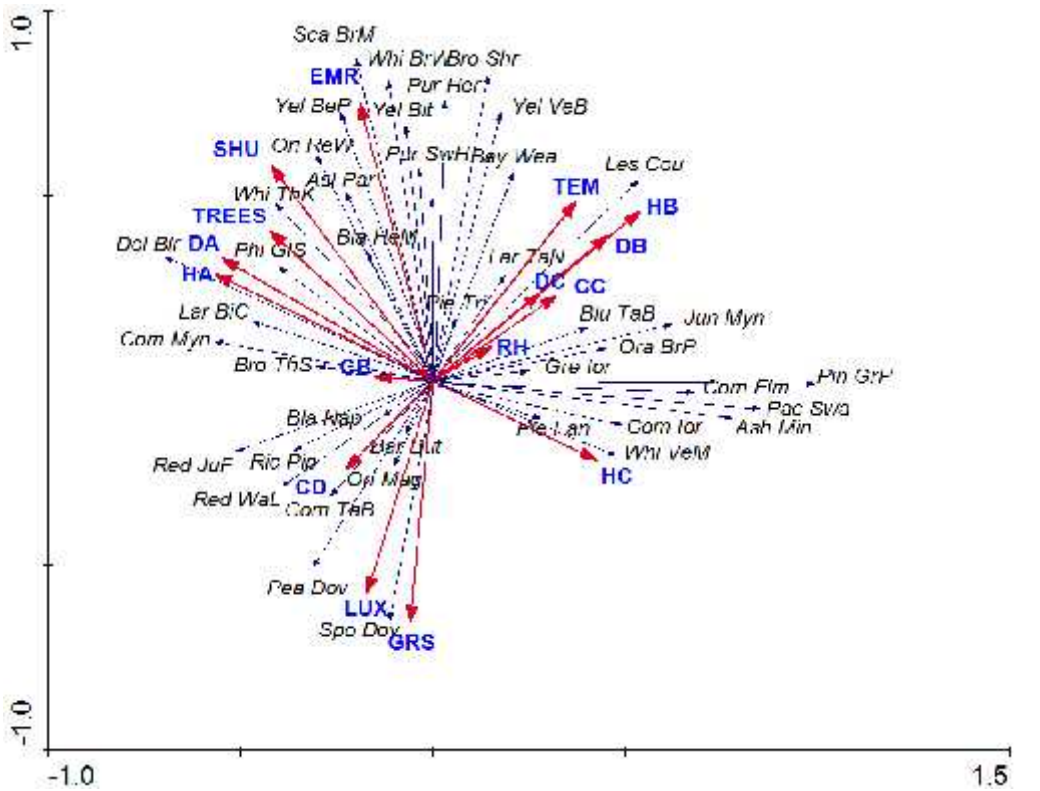

Figure 3. The ordination biplot diagram of the first two axes from the canonical correspondence analysis, displaying the correlations between the environmental variables (arrows) and the bird species of the shrub habitat.

Conclusion: The results of this study demonstrate that open-area and shrub habitats attract a wide array of avian species. Bird species composition and distribution are influenced by microclimate factors (i.e., temperature, relative humidity and light intensity) and habitat structure (i.e., vegetation cover, vegetation composition and distribution).

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