ASSESSING THE HABITAT SUITABILITY OF TWO DIFFERENT ARTIFICIAL WETLAND HABITATS USING AVIAN COMMUNITY STRUCTURES

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ABSTRACT

Artificial wetlands have become highly important habitat for a variety of bird species particularly waterbirds due to loss and degradation of natural wetlands. Avian community structures in two artificial wetland habitats i.e., man-made marsh and lake were investigated to identify the suitability of the habitats for avian species, habitat preference and food resources. Distance sampling point count method detected 35272 bird individuals of 98 species from July to November 2010. Ninty four bird species were recorded from man-made marsh and thirty one species from the lake area. *Acridotheres tristis* (6.34% of all detections) was the most dominant bird species of man-made marsh and *Passer montanus* (0.41%) was the most dominant bird species of lake habitat. On the contrarily, *Microhierax fringillarius* and *Turdoides earlei* (each 0.01%) were the rarest species of man-made marsh and *Dinopium javanense* (0.02%) was the rarest species of the lake habitat. The bird relative abundance of man-made marsh and lake habitats was significantly different ($F_{1,194} = 50.3$, p<0.05). Community analysis indicated that bird species of man-made marsh were more diverse i.e., Shannon's index ($N_1 = 3.92$) and rich i.e., Margalef's index ($R_1 = 8.93$) than the lake habitat. Insectivore (marsh; 21.13% and lake area; 1.21%) was the most dominant guild in man-made marsh and lake area. In contrast, Piscivore (0.14%) was the rarest guild comprised of only one species in marsh habitat. The results of this study revealed that the man-made marsh was more capable to attract a higher number of bird species and diversity than the lake habitat.

Keywords: Birds, Community Structure, Diversity, Habitat, Marsh, Lake and Feeding Guild

1. INTRODUCTION

Worldwide, more than 50% of natural wetland areas have been lost due to human activities which had adversely affected hydro system, plant growth and avian communities that depend on wetland habitats directly and indirectly for various activities (Fraser and Keddy, 2005; Coleman *et al*., 2008; Mitsch, 2010). Due to loss and degradation of natural wetlands, man-made marshes and lake areas had become ecological important habitats for many avian species (White, 2003; Yaukey, 2011; Zakaria and Rajpar, 2013).

Artificial wetland is a type of aquatic habitat constructed manually and planted with herbaceous vegetation to trap the sediments from surrounded catchement areas and also to retain water for drinking or irrigation purpose (Vymazal, 2010). As the wastewater flows from catchment area through the length of the aquatic habitat, suspended solids and matter settle out and bottom sediments trapped toxic contaminants and pollutants through microbial interaction (Kirby, 2002). Vegetation plays a vital role in hydrological processes, reducing soil erosion, filter and trap sedimentation from catchment inflows, reduced turbidity that had contributed to high water quality and aquatic life (Loaiza, 2008; Li and Yang, 2009; Ekert, 2009).

Man-made marshes are dominated by extensive growths of herbaceous plants (such as grasses, sedges,

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reeds and cattails) rooted in and usually protruding from, shallow water that stands above the ground surface to harbor wide array of birds, amphibians, reptiles, fishes and aquatic invertebrates (Ma *et al.*, 2010; Haber, 2011; Ramírez *et al.*, 2012). These habitats can promote sustainable use of local resources and are environmental friendly (Kadlec *et al.*, 2000; Sim, 2003). They have potential to provide alternative habitat instead of natural habitat for avian species and can mitigate the adverse effects of wetland loss and degradation (Connor and Gabor, 2006; Sim *et al.*, 2008; Ma *et al.*, 2010; Rajpar and Zakaria, 2013).

Birds are the bioindicators of aquatic habitats such as man-made marshes and lake areas. Their occurrence or absence of bird species may indicate the habitat characteristics and productivity of the particular habitat (Noble *et al.*, 2008; Larsen *et al.*, 2010; Rajpar and Zakaria, 2011a; BLI, 2013). Investigating avian community structures (i.e., abundance, diversity, feeding guilds and habitat preference) is a crucial tool to determine the habitat suitability and to detect the changes within particular habitat during specific period (DeSante *et al.*, 2005). Information related to avian community structures in artificial wetlands such as man-made marshes and lake areas of Malaysia is still lacking. To date, no detailed study has been in such types of artificial wetland habitats. The aim of this research was to assess the habitat suitability of artificial wetland habitats i.e., man-made marsh and lake area to understand the importance of each habitat as alternative habitat to natural one for future conservation and management planning.

2. MATERIALS AND METHODS

2.1. Study Area

Man-made marsh and lake habitat is situated about 26 km south of Kuala Lumpur within the quadrant of 2° 57' 43" latitude and 101° 41' 47" longitude (**Fig. 1**). Man-made marsh occupy an area of 200 ha and lake cover 400 ha. This man-made marsh and lake was constructed in 1997 to trap the pollutants derived from upstream sources, to control the inflow of flood water from catchment areas of the Chua and Bisa Rivers, to retain water for domestic use and increased the aesthetic value of the Putrajaya administrative city. These areas straddle the water from Chua River, Bisa River and three tributaries. This man-made marsh and lake is still in an early phase of succession and is far less complex than the natural wetland (Ismail *et al.*, 2012). These artificial wetlands (man-made marsh and lake) is dominated by a wide range of aquatic plants (e.g., spike rush-*Eleocharis varigata*, water chestnut-*E. dulcis*, blue sedge-*Lepironia articulate*, water

hyacinth-*Eichhornia crassipes* and duckweed-*Lemna* sp.), fruiting trees (e.g., brush cherries-*Eugenia* sp., weeping fig-*Ficus benamina* and golden ficus-*F. microcarpa*), flowering trees and bushes (e.g., flame tree-*Delonix regia*, beach hibiscus-*Hibiscus tiliaceus* and gelam-*Melaleuca cajuputi*) and shrubs (e.g., fish-tailed palm-*Caryota mitis*, island lychee-*Pometia pinnata* and simpoh ayer-*Dillenia suffruticosa*) (Rajpar and Zakaria, 2013).

2.2. Bird Surveys

Bird were surveyed employing the distance sampling point count technique to determine the aian community structures i.e., relative abundance, diversity, feeding guilds and habitat preference from July to November, 2010. A total of 89 point count stations (i.e., 45 point count stations in man-made marsh and 43 point count stations in the lake habitat) were established at 300 m intervals along the wetland edges. This distance was selected to obtain more reliable data and avoid the detection of the same bird individual at more than one station. The birds were surveyed in each month for eight days and each point count station was surveyed for 10 min by walk along trails set along the dikes. During each survey, all bird species and individuals seen or heard were recorded. The flushed birds with known original positions were also recorded and included in the analysis. The distances from bird individual 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 h. This period of time is an appropriate, as most birds are active early in the morning. The survey methodology was based on (Buckland *et al.*, 2004; Nadeau *et al.*, 2008; Aynalem and Bekele, 2008; Zakaria *et al.*, 2009).

2.3. Data Analysis

2.3.1. Relative Abundance (%)

Relative abundance refers to the number of bird individual detections of a particular species as percent of the total detected in man-made marsh and lake habitats. We estimated relative abundances for each species using average detection values obtained by dividing the total number of a species detected at man-made marsh and lake habitats. The relative abundance (%) of bird species was estimated using the following expression:

$$\text{Relative abundance} = n/N \times 100$$

Where:
n = Number of a particular detected bird species and
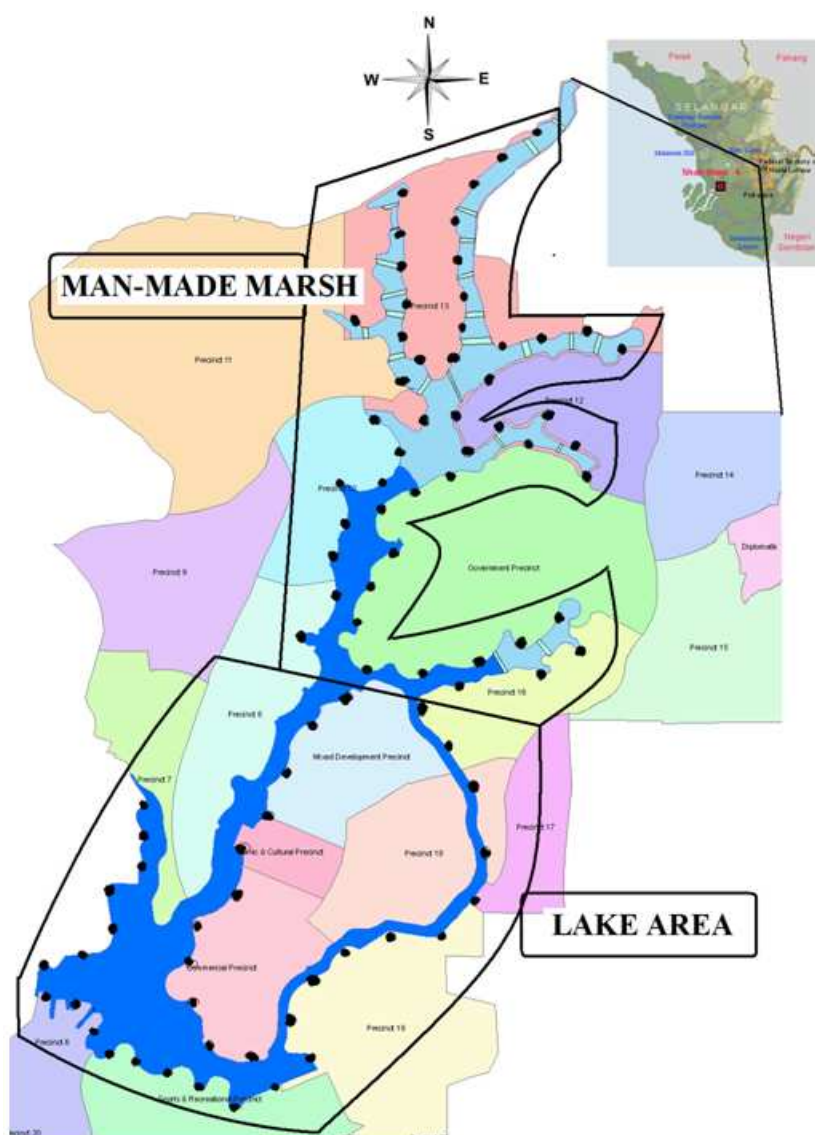N = Total detected bird individuals in man-made marsh and lake habitats

Fig. 1. Map location of the distance sampling point count stations in man-made marsh and lake area at Putrajaya Wetland, Peninsular Malaysia

2.3.2. Bird Diversity Indices

Avian species diversity, species richness and species evenness in man-made marsh and lake habitats were analyzed using Community Analysis Package Software (CAP, Version 4.0) (Henderson and Seaby, 2007).

Shannon-weiner diversity index:

$$H' = \sum_{i=1}^{R} p_i \ln p_i$$

Where:

S   = Total number of individual

P_i = N_i/N = proportion of individuals of the total sample belonging to $_i$th species

Ni = number of individuals (N) belonging to the $_i$th species and

N = total number of individuals

Margalef's richness index was calculated using the following equation:

$$R_1 = (S-1) / \ln(n)$$

Where:

S = Number of taxa and

n = Number of individuals

McIntosh evenness index E was calculated using the following equation:

$$\text{Mc E} = \left[N - \sqrt{\left(\sum n_i^2 \right)} \right] / [N - (N / \sqrt{S})]$$

Where:

Mc E = McIntosh evenness index

n_i = Number of individuals belonging to i species

S   = Total number of species and

N   = Total number of individuals

2.3.3. Feeding Guild

Bird species was grouped into functional guilds that may reflect the exploitation of same food resources and foraging technique in a similar way in a particular habitat. Thus, we assigned all recorded bird species into eight major feeding guilds such as Insectivore, Frugivore/Insectivore, Granivore, Omnivore, Piscivore/Carnivore/Insectivore, Granivore/Insectivore, Nectarivore/Insectivore, Frugivore, Insectivore/Nectarivore/Frugivore, Piscivore/Insectivore, Carnivore/Insectivore, Piscivore/Carnivore, Carnivore and Piscivore based on their major food resources, foraging behavior and habitat selection (Zakaria *et al.*, 2009; BLI, 2013).

2.3.4. Significant Difference among Different Aged Post-Harvested Forest Habitats

A One-Way Analysis of Variance (ANOVA) and Tukey's (HSD) test (Analytical Software, version 8.1) by McGraw-Hill (2008) was conducted in order to investigate the difference in bird richness and habitat characteristics between primary and logged hill dipterocarp tropical rainforest.

3. RESULTS

From July to November, 2010, a total of 35272 bird observations representing 98 species and 38 families was recorded in man-made marsh and lake area. Twenty seven species were recorded in both habitats. Sixty seven bird species were recorded only in the man-made marsh which were absent in the lake habitat. Likewise, four species were only detected in the lake area and were absent in man-made marsh habitat.

3.1. Relative Abundance of Birds in Man-Made Marsh Habitat

A total of 33,464 bird detections, that is 94.87% of all detections were recorded in the man-made marsh area. The bird belongs to 94 species and 36 families. Three species, *Acridotheres tristis*-Common Myna (6.34% of all detections), *Pycnonotus goiavier*-Yellow-vented Bulbul (5.85%) and *Acridotheres fuscus*-Jungle Myna (4.68%) indicated the highest relative abundance. In contrast, two bird species, *Microhierax fringillarius*-Black-thighed Falconet and *Turdoides earlei*-Striated Babbler (0.01% each) were the least abundant species in the marsh area (**Table 1**).

3.2. Relative Abundance of Birds in Lake Habitat

A total of 1,808 bird individuals (5.13% of all detections) was recorded in the lake area which included 31 species and 22 families. *Passer montanus*-Eurasian Tree-Sparrow (0.4% of all detections), *Acridotheres tristis*-Common Myna (0.35%), *Pycnonotus goiavier*-Yellow-vented Bulbul (0.33%) were the three most abundant birds in the lake area. Whereas, two bird species, *Artamas leucorynchus*-White-breasted Wood Swallow (0.03%) and *Dinopium javanense*-Common Flameback (0.02%) were the least common in the lake area (**Table 1**).

3.3. Comparison of Bird Species Diversity in Man-made Marsh and Lake Habitats

Results indicated that bird mean relative abundance of man-made marsh is significantly different from lake area ($F_{1, 194} = 50.3$, p<0.05; **Table 2**). Community analysis indicated that higher species diversity, i.e., Shannon's index; $N_1 = 3.92$ and species richness, i.e., Margalef's index; $R_1 = 8.93$ occurred in the man-marsh area while higher species evenness, i.e., Pielou's J index E = 0.95 was recorded in the lake area (**Table 3**).

The significant difference of bird diversity (i.e., species diversity, richness and evenness) for man-made marsh and lake area was determined employing ANOVA and Tukey's (HSD) test. Results showed that bird diversity of man-made marsh is not significantly different from the lake area ($F_{1, 4} = 0.53$, p>0.05; **Table 4**).

3.4. Comparison of Feeding Guilds between Man-Made Marsh and Lake Habitats

Ninety eight bird species were categorized into fourteen major feeding guilds based on detected foraging behaviour and food consumption at foraging sites. The feeding guild structure indicated that Insectivore (marsh; 21.13%; 22 bird species and lake area; 1.21%; 9 species) was the most dominant guild in both habitats.

Table 1. List of bird species with relative abundance recorded in man-made marsh and lake area at Putrajaya, Peninsular Malaysia

Family name	Scientific name	Common name	Man-made Marsh Observation	Man-made Marsh % of all detections	Lake Area Observation	Lake Area % of all detections
Sturnidae	*Acridotheres tristis*	Common Myna	2237	6.34	124	0.35
Pycnonotidae	*Pycnonotus goiavier*	Yellow-vented Bulbul	2065	5.85	115	0.33
Sturnidae	*Acridotheres fuscus*	Jungle Myna	1650	4.68	102	0.29
Columbidae	*Treron vernans*	Pink-necked Green Pigeon	1608	4.56	0	0.00
Columbidae	*Geopelia striata*	Peaceful Dove	1493	4.23	102	0.29
Passeridae	*Passer montanus*	Eurasian Tree Sparrow	1342	3.80	145	0.41
Muscicapidae	*Copsychus saularis*	Oriental Magpie Robin	1144	3.24	92	0.26
Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	926	2.63	58	0.16
Columbidae	*Streptopelia chinensis*	Spotted Dove	916	2.60	63	0.18
Hirundinidae	*Hirundo tahitica*	House Swallow	882	2.50	0	0.00
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	839	2.39	85	0.24
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	822	2.33	61	0.17
Aegithinidae	*Aegithina tiphia*	Common Iora	776	2.20	72	0.20
Sturnidae	*Aplonis panayensis*	Asian Glossy Starling	774	2.19	69	0.19
Rhipiduridae	*Rhipidura javanica*	Pied Fantail	682	1.93	43	0.12
Ploceidae	*Ploceus philippinus*	Baya Weaver	655	1.86	69	0.19
Sturnidae	*Hirundo rustica*	Barn Swallow	649	1.84	0	0.00
Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	599	1.70	69	0.19
Estrildidae	*Lonchura maja*	White-headed Munia	573	1.62	0	0.00
Nectariniidae	*Cinnyris jugularis*	Olive-backed Sunbird	568	1.61	0	0.00
Alcidinidae	*Halcyon smyrnensis*	White-throated Kingfisher	525	1.49	37	0.10
Ardeidae	*Egretta garzetta*	Little Egret	513	1.45	0	0.00
Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird	489	1.39	35	0.10
Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	470	1.33	74	0.21
Ardeidae	*Ardea purpurea*	Purple Heron	463	1.31	0	0.00
Meropidae	*Merops leschenaulti*	Chestnut–headed Bee–Eater	458	1.30	0	0.00
Columbidae	*Columba livia*	Rock Pigeon	429	1.22	0	0.00
Ardeidae	*Bubulcus coromandus*	Eastern Cattle Egret	423	1.20	0	0.00
Alcidinidae	*Alcedo atthis*	Common Kingfisher	420	1.19	0	0.00
Meropidae	*Merops philippinus*	Blue-tailed Bee-Eater	405	1.15	0	0.00
Ardeidae	*Nycticorax nycticorax*	Black-crowned Night–Heron	388	1.10	0	0.00
Motacillidae	*Anthus richardi*	Richard's Pipit	361	1.02	43	0.12
Cuculidae	*Cypsiurus balasiensis*	Asian Palm Swift	353	1.00	0	0.00
Nectariniidae	*Anthreptes simplex*	Plain Sunbird	321	0.91	0	0.00
Sturnidae	*Acridotheres grandis*	White-vented Myna	318	0.90	26	0.07
Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia	303	0.86	16	0.05
Ardeidae	*Butorides striata*	Little Heron	302	0.86	39	0.11
Estrildidae	*Lonchura ferruginosa*	White-capped Munia	296	0.84	0	0.00
Ardeidae	*Ixobrychus sinensis*	Yellow Bittern	270	0.77	0	0.00
Rallidae	*Porphyrio porphyrio*	Purple Swamphen	268	0.76	0	0.00
Cisticolidae	*Orthotomus atrogularis*	Dark-necked Tailorbird	266	0.75	0	0.00
Pycnonotidae	*Pycnonotus atriceps*	Black-headed Bulbul	237	0.67	0	0.00
Ciconiidae	*Mycteria leucocephala*	Painted Stork	224	0.64	0	0.00
Nectariniidae	*Arachnothera affinis*	Grey-breasted spiderhunter	205	0.58	0	0.00
Columbidae	*Treron olax*	Little Green–Pigeon	196	0.56	0	0.00
Alcidinidae	*Halcyon pileata*	Black-capped Kingfisher	173	0.49	0	0.00
Cisticolidae	*Orthotomus ruficeps*	Ashy Tailorbird	169	0.48	61	0.17
Alcidinidae	*Todiramphus chloris*	Collared Kingfisher	160	0.46	0	0.00
Dicaeidae	*Dicaeum maculatus*	Yellow-breasted Flowerpecker	158	0.45	0	0.00
Psittacidae	*Loriculus galgulus*	Blue-crowned hanging parrot	148	0.42	0	0.00
Ardeidae	*Ixobrychus cinnamomeus*	Cinnamon Bittern	144	0.41	0	0.00
Laniidae	*Lanius cristatus*	Brown Shrike	134	0.38	0	0.00
Picidae	*Meiglyptes tristis*	Buff–rumped woodpecker	114	0.33	0	0.00
Timaliidae	*Macronus gularis*	Pin-striped tit-babbler	110	0.32	0	0.00

Table 1. Continue

Pycnonotidae	*Pycnonotus simplex*	Cream-vented Bulbul	108	0.31	0	0.00
Corvidae	*Corvus splendens*	House Crow	108	0.31	48	0.14
Ardeidae	*Ardea cinerea*	Grey Heron	107	0.30	0	0.00
Ardeidae	*Ardea alba*	Great Egret	102	0.29	0	0.00
Campephagidae	*Lalage nigra*	Pied Triller	85	0.25	0	0.00
Laniidae	*Lanius tigrinus*	Tiger Shrike	84	0.24	0	0.00
Laniidae	*Hemipus hirundinaceus*	Black-winged Flycatcher Shrike	0	0.00	17	0.05
Turnicidae	*Hemipus picatus*	Bar-winged Flycatcher-Shrike	81	0.23	0	0.00
Cuculidae	*Centropus bengalensis*	Lesser Coucal	81	0.23	0	0.00
Hirundinidae	*Turnix suscitator*	Barred Buttonquail	79	0.22	27	0.08
Dicaeidae	*Dicaeum trigonostigma*	Orange-bellied Flowerpecker	79	0.22	0	0.00
Nectariniidae	*Anthreptes rhodolaema*	Red-throated Sunbird	79	0.22	0	0.00
Muscicapidae	*Ficedula zanthopygia*	Yellow-rumped Flycatcher	79	0.22	0	0.00
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	74	0.21	0	0.00
Picidae	*Micropternus brachyurus*	Rufous Woodpecker	74	0.21	0	0.00
Cuculidae	*Rhinortha chlorophaeus*	Raffle's Malkoha	71	0.20	0	0.00
Columbidae	*Chalcophaps indica*	Emerald Dove	70	0.19	0	0.00
Sturnidae	*Gracupica contra*	Asian Pied Starling	58	0.16	0	0.00
Ardeidae	*Ardeola speciosa*	Javan Pond Heron	54	0.15	0	0.00
Pelecanidae	*Pelecanus onocrotalus*	Great White Pelican	50	0.14	0	0.00
Nectariniidae	*Chalcoparia singalensis*	Ruby-cheeked Sunbird	49	0.13	0	0.00
Falconidae	*Spilornis cheela*	Crested Serpent Eagle	44	0.12	0	0.00
Phasianidae	*Gallus gallus*	Red Junglefowl	41	0.11	0	0.00
Timaliidae	*Malacocincla abbotti*	Abbott's Babbler	40	0.11	0	0.00
Picidae	*Dinopium javanense*	Common Flameback	39	0.11	8	0.02
Cuculidae	*Cacomantis sepulcralis*	Rusty-breasted Cuckoo	38	0.10	0	0.00
Dicaeidae	*Dicaeum thoracicus*	Scarlet-breasted Flowerpecker	35	0.09	0	0.00
Alcidinidae	*Alcedo meninting*	Blue-eared Kingfisher	30	0.08	0	0.00
Timaliidae	*Zosterops palpebrosus*	Oriental White Eye	27	0.07	0	0.00
Dicaeidae	*Dicaeum cruentatum*	Scarlet-backed Flowerpecker	26	0.07	0	0.00
Nectariniidae	*Arachnothera flavigaster*	Spectacled Spiderhunter	24	0.06	0	0.00
Nectariniidae	*Aethopyga nipalensis*	Green-tailed Sunbird	21	0.06	0	0.00
Falconidae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	20	0.05	0	0.00
Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher	19	0.05	0	0.00
Megalaimidae	*Megalaima haemacephala*	Coppersmith Barbet	18	0.05	0	0.00
Cuculidae	*Cuculus micropterus*	Indian Cuckoo	18	0.05	0	0.00
Coraciidae	*Eurystomus orientalis*	Dollar Bird	17	0.04	0	0.00
Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	8	0.02	49	0.14
Muscicapidae	*Ficedula mugimaki*	Mugimaki Flycatcher	6	0.02	0	0.00
Falconidae	*Microhierax fringillarius*	Black-thighed Falconet	4	0.01	0	0.00
Timaliidae	*Turdoides earlei*	Striated Babbler	4	0.01	0	0.00
Cuclidae	*Eudynamys scolpaceus*	Common Asian Koel	0	0.00	24	0.07
Anatidae	*Anas crecca*	Eurasian Teal	0	0.00	24	0.07
Artamidae	*Artamas leucorynchus*	White-breasted Wood Swallow	0	0.00	11	0.03
Total			33,464		1808	

Table 2. Comparison of relative abundance of bird species in man-made marsh and lake area

Habitat name	Mean bird relative abundance
Man-made marsh	341.43a
Lake area	18.45b

Table 3. A comparison of bird species diversity between man-made marsh and lake area

Indices	Man-made marsh	Lake	Overall in both area
Diversity indices			
Shannon's index (N_1)	3.92	3.26	3.94
Richness indices			
Margalef's index (R_1)	8.93	4.00	9.26
Evenness indices			
Pielou's J index (E)	0.86	0.95	0.86

Table 4. Comparison of bird diversity in man-made marsh and lake area

Habitat name	Mean diversity
Man-made marsh	4.57a
Lake area	2.76a

Table 5. Comparison of feeding guilds in marsh and lake areas

Name of guild	Man-made marsh area Total detection (number of species)	(%)	Lake area Total detection (number of species)	(%)
Insectivore	7453 (23 species)	21.13	426 (9 species)	1.21
Frugivore/Insectivore	5691 (7 species)	16.13	371 (4 species)	1.05
Granivore	4499 (7 species)	12.76	226 (3 species)	0.64
Omnivore	3956 (7 species)	11.22	304 (6 species)	0.86
Piscivore/Carnivore/Insectivore	3698 (14 species)	10.48	76 (2 species)	0.22
Granivore/Insectivore	2372 (4 species)	6.72	284 (4 species)	0.81
Nectarivore/Insectivore	2355 (9 species)	6.67	104 (2 species)	0.29
Frugivore	1756 (2 species)	4.98	0	0.00
Insectivore/Nectarivore/Frugivore	452 (7 species)	1.28	0	0.00
Piscivore/Insectivore	450 (2 species)	1.28	0	0.00
Carnivore/Insectivore	440 (7 species)	1.25	17 (one species)	0.05
Piscivore/Carnivore	224 (one species)	0.64	0	0.00
Carnivore	68 (3 species)	0.19	0	0.00
Piscivore	50 (one species)	0.14	0	0.00
Total	33,464 (94 species)		1808 (31 species)	
Grand Total =	35, 272 (98 Species)			

Table 6. Comparison of bird feeding guilds based on number of observation and number of species in man-made marsh and lake area

Habitat name	Mean feeding guild
Based on number of observation	
Man-made marsh	2390.3a
Lake area	129.14b
Based on number of species	
Man-made marsh	6.17a
Lake area	2.21b

In contrast, Piscivore (0.14%) was the rarest guild comprised of only one species in man-made marsh habitat. However, six feeding guilds i.e., Frugivore, Insectivore/Nectarivore/-Frugivore, Piscivore/Insectivore, Piscivore/Carnivore, Carnivore and Piscivore were absent in the lake area (**Table 5**).

Significant difference of feeding guilds based on number of bird observation and number of bird species of man-made marsh and lake area was examined through ANOVA and Tukey's (HSD) test. Results revealed that bird feeding guilds of man-made marsh based on number of observation ($F_{1,26} = 13.4$, p<0.05) and based on number of species ($F_{1,26} = 7.13$, p<0.05) were significantly different from lake area (**Table 6**).

4. DISCUSSION

Monitoring the existing bird species diversity is an important step to describe the avian community structures in order to determine whether the habitats for the birds are suitable. The information obtained can be used for effective conservation and successful management (DeSante *et al.*, 2005).

The man-made marsh is dominated with a wide range of water-loving plants including i.e., *Eleocharis variegation* (Scirpus Variegatus), *E. dulcis* (Chinese Water Chestnut), *Scleria sp.* (Nutrush), *Eriocaulon longifolium* (Pipewort), *Nymphaea* spp. (Water Lilies), *Fimbristylis globulosa* (Globe Fimbry), *F. miliacea* (Grass-like Fimbristylis), *Eichhornia crassipes* (Water

Hyacinth) *Ludwigia adscendens* (Creeping Water Primrose), *Philydrum lanuginosum* (Wooly Frogs Mouth), *Glyceria maxima* (Giant Sweet Grass) *Phragmites australis* (Common Reed), *Typha* spp. (Cattails), *Scirpus* spp. (Bulrushes); fruiting trees such as *Fragraea fragrans* (Heritage Tree), *Ficus fistulosa* (Common Yellow Stem Fig), *F. benjamina* (Weeping Fig), *Caryota mitis* (Fish-tail Palm)*, Eugenia spp.* (Jambu), *Garcinia sp.* (Asam Gelugor) *Dillenia suffruticosa* (Simpoh Air or Shrubby Dillenia) and ornamental plants namely *Delonix regia* (Flame Tree) and *Ixora javanica* (Jungle Flame). Some parts have been modified to provide nesting and roosting habitat for egrets, herons, egrets and storks. In addition, the lake is devoid of aquatic vegetation and contains trees and shrubs only along the edges.

Diversity of herbaceous emergent vegetation has represented a unique complex ecosystem which had significantly changed the landscape, enhanced the biodiversity, hydrology and natural processes that had attracted diverse wildlife species. From the study, the recording of 98 bird species seems to be the most obvious and significant component of man-made marsh and lake areas that had allowed them to perform multiple activities such as foraging, breeding, perching, nesting and roosting. The functions, values and attributes of this man-made marsh and lake areas had benefitted bird communities and compensated to a certain extent the loss of natural wetlands (Zamora-Orozco *et al.*, 2007; Carmona *et al.*, 2011; Rajpar and Zakaria, 2013).

It was observed that the bird species in the marsh and lake areas were extremely diverse in term of relative abundance, feeding guilds and habitat preference. This indicated that both marsh and lake areas have good ecological conditions that offer diverse resources for a wide array of bird species. Bird species often selected the available habitats in different ways depending on their behaviour. The occurring of water, rich food resources (i.e., amphibians, reptiles, small mammals, aquatic as well as terrestrial invertebrates and fishes) and diverse vegetation types had provided ideal habitat for a wide array of water and terrestrial bird individuals. It was observed that avian community structures in the marsh and lake areas were influenced by a number of variables such as water depth, vegetation structure and composition, food resources and foraging behaviour (Chimney and Gawlik, 2007; Michel *et al.*, 2010; Crampton *et al.*, 2011; Carrascal *et al.*, 2012). It was also found that adjacent dry land area dominated by patches of shrubs and fruiting trees had also attracted a number of bird species particularly upland birds i.e., may be only facultative marsh inhabitants (Knight *et al.*, 2001). It has been reported that birds often select habitats that offer specific foraging and nesting sites (Shochat *et al.*, 2005; Kloskowski *et al.*, 2010; Mcnew *et al.*, 2012).

Higher avian species diversity and richness was recorded in man-made marsh than lake area. This could be due to the presence of suitable foraging, safe nesting and chick rearing sites (i.e., islands, shrub and bamboo patches, dense and scattered trees and reedbeds) and diverse fruiting and flowering tree, grass, reed, shrub, herb and aquatic vegetation species that provides heterogeneous habitats.

Availability of food is probably the most crucial factor that influenced the habitat selection and reproductive success. Foraging behaviour is an essential aspect of avian species in which they obtained and consumed their food sources through using a variety of tactics. It is one of the most important characteristics of the avian species, being necessary for their survival and reproduction. The recording of fourteen feeding guilds in the marsh and lake areas indicated that these areas are highly attractive to many avian species.

Finding a suitable prey is a challenge to avian species. For example; Herons, egrets, bitterns and storks, the most common group of birds, foraged in shallow waters to catch a diversity of aquatic animals such as fishes, amphibians and aquatic invertebrates. They preferred open shallow areas due to richness of food resources and excellent view of approaching predators such water monitor lizards and otters. They avoided the dense vegetated area because it interferes with their movement and foraging efficiency (White, 2003; Lantz *et al.*, 2011). When water level increased, they moved to another area, where water was shallower than their length of tarsus, because, in shallow water prey was easier to catch as compared to deep water (Liordos, 2010; Lantz *et al.*, 2011). Likewise, swamphen and moorhens, preferred to utilize patches of emergent vegetation along the water edges which provided major habitat for different fish and aquatic invertebrates. Their distribution is influenced mainly by the richness and diversity of prey and suitable foraging sites and vegetation cover. In addition, water level also play a significant role on waterbird distribution and diversity. The highest waterbirds species richness occurs in the reedbed where water level is shallow (Holm and Clausen, 2006; Kloskowski *et al.*, 2010; Rajpar and Zakaria, 2011b).

Sandpipers and lapwings probed in soft substrates of ditches, mud and wetland edges to feed on aquatic invertebrates. In soft substrate invertebrates are more vulnerable to forage and easy to catch. In addition, pigeons, starlings and bulbuls were often observed foraging on berries and fruits of shrub plants adjacent to

the wetland areas. The vegetation adjacent to wetland is an important factor for avian species in determining foraging site selection and also influences the ability of birds to detect approaching predators (White, 2003; Campell, 2008). Robins, pipits, mynas and sparrows selected open grassy lawn to forage on wide array of invertebrates while doves, quails, munias and weavers feed on grass seeds. Furthermore, the results clearly indicated that habitat selection of bird species may vary from species to species, depending upon avian behaviours such as foraging, nesting, loafing and roosting. Finally, many non habitat-related phenomena also influence the habitat selection in birds such as nest predation (Shochat *et al*., 2005; Marzluff *et al*., 2007), competition for foraging and nesting (Sherry, 2006), intra-specific attraction (Forsman *et al*., 2002; Rajchard, 2007; Sridhar *et al*., 2009) and food limitation (Musil, 2006).

5. CONCLUSION

This study highlighted that artificial wetland habitats i.e., man-made marsh and lake are suitable habitats for a diverse avian species to perform various activities such as foraging, breeding, perching, nesting and roosting. Results also showed that man-made marsh is more capable to attract a higher number of bird species and diversity than the lake habitat.

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