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Density and Diversity of Water Birds and Terrestrial Birds in Man-made Marsh, Malaysia

(Ketumpatan dan Kepelbagaian Burung Air dan Burung Daratan di Rawa Buatan Manusia, Malaysia)

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ABSTRACT

Many bird species are highly dependent on natural marsh habitat. Unfortunately this habitat is rapidly converted to other land uses. Therefore artificial or man-made marsh habitat may become an important alternative habitat for marsh dependent bird species. The main objective of this study was to determine the density and diversity of water and terrestrial birds at man–made marsh habitat at Putrajaya using distance sampling point count technique. A total of 20010 bird individuals of 102 species representing 31.05% water birds and 68.95% terrestrial birds were detected from March 2009 to June 2010. Density analysis showed that bird density is 0.64 + 0.02 birds ha^{-1} and range from 0.60 – 0.68 birds ha^{-1} at 95.0% confidence interval. It was found that terrestrial birds had a higher density 0.74 + 0.02 birds ha^{-1} than water birds 0.54 + 0.09 birds ha^{-1}. For water bird species, the highest density was Black-crowned Nightheron; 2.92 + 1.80 birds ha^{-1} followed by Purple Heron; 1.55 + 0.93 birds ha^{-1} and Grey Heron; 1.05 + 0.13 birds ha^{-1}. The lowest density was recorded in Pintail Snipe; 0.08 + 0.03 birds ha^{-1}, Chinese Egret; 0.08 + 0.02 birds ha^{-1} and Great Egret; 0.07 + 0.08 birds ha^{-1}, respectively. In terrestrial birds, the highest bird density was observed in Rock Pigeon 3.91 + 0.97 birds ha^{-1}, followed by Eurasian Tree Sparrow; 3.72 + 1.03 birds ha^{-1}, House Crow; 3.69 + 0.33 birds ha^{-1} and Philippine Glossy Starling; 3.38 + 0.53 birds ha^{-1}. The lowest bird density was recorded in Brown-capped Woodpecker; 0.07 + 0.02 birds ha^{-1} and Lesser Coucal; 0.09 + 0.03 birds ha^{-1}. The result also shows that terrestrial birds had higher species diversity i.e. Shannon–Wiener index (N1 = 3.10), species richness i.e. Margalef's index (R1= 8.23) and species evenness i.e. Pielou's J index (E = 0.71) as compared with water birds (N1 = 2.04; R1= 8.23 and E = 0.65). This study indicates that man–made marsh is a suitable habitat for diverse avian species and thus should be protected in order to enhance the population of avian species.

Keywords: Density; diversity; marsh; point count; terrestrial birds; vegetation; water birds

ABSTRAK

Banyak spesies burung adalah sangat bergantung kepada habitat paya semula jadi. Malangnya habitat ini ditukar kepada penggunaan tanah lain secara pesat. Oleh itu, habitat paya tiruan atau buatan manusia mungkin boleh menjadi habitat alternatif yang penting bagi spesies burung yang bergantung kepada paya. Objektif utama kajian ini adalah untuk menentukan kepadatan dan kepelbagaian burung air dan daratan di habitat paya buatan manusia di Putrajaya menggunakan teknik kiraan titik melalui pensampelan jarak. Sebanyak 20010 individu daripada 102 spesies burung dengan burung air mewakili 31.05% dan burung daratan mewakili 68.95% telah dikesan dari Mac 2009 hingga Jun 2010. Analisis kepadatan menunjukkan bahawa kepadatan burung ialah 0.64 + 0.02 burung ha^{-1} dan julat dari 0.60 – 0.68 burung ha^{-1} pada selang keyakinan 95.0%. Ia telah mendapati bahawa burung daratan mempunyai kepadatan yang lebih tinggi 0.74 + 0.02 burung ha^{-1} daripada burung air 0.54 + 0.09 burung ha^{-1}. Bagi spesies burung air, kepadatan tertinggi adalah Puchong Kuak; 2.92 + 1.80 burung ha^{-1} diikuti oleh Bangau Paya; 1.55 + 0.93 burung ha^{-1} dan Puchong Seriap; 1.05 + 0.13 burung ha^{-1}. Kepadatan terendah yang dicatatkan adalah masing-masing Berkek Ekor Kipas; 0.08 + 0.03 burung ha^{-1}, Bangau Cina; 0.08 + 0.02 burung ha^{-1} dan Bangau Besar; 0.07 + 0.08 burung ha^{-1}. Untuk burung daratan, kepadatan burung tertinggi diperhatikan adalah Merpati 3.91 + 0.97 burung ha^{-1}, diikuti oleh Ciak Eurasia; 3.72 + 1.03 burung ha^{-1}, Gagak Rumah; 3.69 + 0.33 burung ha^{-1} dan Perling Mata Merah; 3.38 + 0.53 burung ha^{-1}. Kepadatan burung terendah yang dicatatkan adalah Belatuk Sunda; 0.07 + 0.02 burung ha^{-1} dan But-but Kecil; 0.09 + 0.03 burung ha^{-1}. Keputusan itu juga menunjukkan bahawa burung daratan mempunyai kepelbagaian spesies lebih tinggi iaitu Indeks Shannon-Wiener (N1 = 3.10), kelimpahan spesies indeks Margalef (R1 = 8.23) dan kesamaan spesies indeks Pielou's J (E = 0.71) berbanding dengan burung air (N1 = 2.04; R1 = 8.23 dan E = 0.65). Kajian ini menunjukkan bahawa paya buatan manusia adalah habitat yang sesuai untuk pelbagai spesies burung dan dengan itu perlu dilindungi dalam usaha untuk meningkatkan populasi spesies burung.

Kata kunci: Burung air; burung daratan; kepadatan; kepelbagaian; kiraan titik; paya; vegetasi

Introduction

Man–made marsh is a shallow water area constructed artificially to retain water and planted with herbaceous plants (such as grasses, sedges, reeds and cattails) to trap the sediments and to provide alternate habitat for wildlife species. Man-made marshes are considered as the most productive ecosystem on earth due to richness of nutrients. Due to loss and degradation of natural wetland habitats, man–made marshes become increasingly important to wetland–dependent bird species as habitat, shelter, food and water (Ma et al. 2004; Toureq et al. 2001; White & Main 2005). Malaysia is indeed blessed with natural and man–made wetland habitats such as wetlands, lakes, marshes, aquacultural ponds, rice paddy fields and waste water treatment ponds (MNR & E 2009; Rajpar & Zakaria 2011).

Birds are the most conspicuous and significant component of different wetland habitats, i.e. their presence or absence may indicate the ecological conditions of the particular area (Rajpar & Zakaria 2011). This habitat also serves as suitable breeding grounds for other vertebrate species such as frogs, turtles, fishes and invertebrates (Haber 2011; Kushlan 2000; Masero 2003; White 2003). There are about 878 waterbird species representing 33 families which are ecologically dependent on wetland habitats, out of which 815 species occur in Asia followed by the Neo–tropics (554) and Africa (542) (Delany & Scott 2006). These bird species are highly mobile and gregarious in nature i.e. they use a wide array of wetland habitats in search of food, shelter, breeding and chick rearing purposes (George & Zack 2001). Habitat selection in birds may greatly vary from species to species, depending upon the morphology of the bill (i.e. straight, elongated, slender, curved bills), prey availability (i.e. richness and vulnerability to capture) and foraging behaviour such as visual vs. tactile foragers (Gawlik 2002; Kushlan 2000; White & Main 2005).

Out of 815 bird species, 170 water bird species can be found in Malaysia. For example; Sandpipers and allies (Scolopacidae) with 40 species are most dominant group of waterbirds followed by bitterns, herons and egrets (Ardeidae) 21 species, terns (Sternidae) 17 species, rails, crakes, gallinules and coots (Rallidae) 14 species, kingfishers (Alcedinidae) 14 species, plovers (Charadriidae) 13 species, ducks, geese and swans (Anatidae) 11 species and storks (Ciconiidae) 7 species (Wikipedia 2013). It has been reported that around 45 bird species in Malaysia such as Storm's storks (*Ciconia stromi*), Spotted Greenshanks (*Tringa guttifer*), Chinese Egrets (*Egretta eulophotes*), Milky Storks (*Mycteria cinerea*), Lesser Adjutants (*Lepotilos javanicus*), Spoon–billed Sandpipers (*Euryorhynchus pygmeus*) and Hook–billed Bulbuls (*Setornis ciniger*) are threatened and faces the risk of extinction due to habitat loss, invasive species and human interventions (Lepage 2013; Mitsch 2010; MNS–BCC 2005; World Bank Report 2011).

In this study water birds refer to the bird species that entirely depend on wetlands for a variety of activities such as foraging, nesting, loafing and moulting, whereas, terrestrial birds refer to bird species that do not entirely depend on wetland habitat but may visit the wetland occasionally in search of food, shelter and perch (Rajpar & Zakaria 2009, 2010).

In this study, bird density is a population size of each bird species per hectare while diversity is a variation in bird species inhabited man–made marsh. Determining the bird density and diversity provide information on population size, population changes over a specific period across different habitats, the impact of habitat loss and degradation in different habitats (Githiru & Lens 2006; Norvell et al. 2003). For this purpose, distance sampling point count method is a more appropriate technique and extensively used to determine avian density and diversity in different habitats (Buckland et al. 2008; Harrison & Kilgo 2004). This method provides a uniform way of counting birds over time across the locations, reduces bias in estimates of avian populations and each point count station represents an independent data that can generate a large sample size and a robust data set (Thomas et al. 2010; Wilson et al. 2000).

Estimating the bird density and diversity in man–made marsh is an important tool to understand the avian assemblages, population trends and the current status of habitats, for effective conservation and better management in future. Accurate population estimates and detailed information about habitat use of marsh bird species in Malaysia is lacking. No detail study has been carried out in man–made marshes to determine density and diversity of waterbirds and terrestrial birds. Thus the objectives of this study were to determine the density and diversity of terrestrial and water birds in man–made marsh and to understand the ecological importance of the man-made marsh as alternative habitat for avian species.

Materials and Methods

Study Site

Putrajaya man–made marsh and lake is situated about 26 km south of Kuala Lumpur within the quadrant of 2° 57' 43" latitude and 101° 41' 47" longitude (Figure 1). The study area covers an area of 200 ha (i.e. 77.70 ha planted area, 76.80 ha open water bodies, 9.60 ha islands, 23.70 ha inundation area and 9.40 ha tracks) (Sim et al. 2008) and encompasses of five arms (such as upper west arm, upper north arm, upper east arm, lower east arm, upper bisa) and central marsh. Each site has high structural and plant diversity that provides different microhabitat for water birds as well as terrestrial birds. This marsh straddles the water from the catchment areas of Chua River, Bisa River and three tributaries.

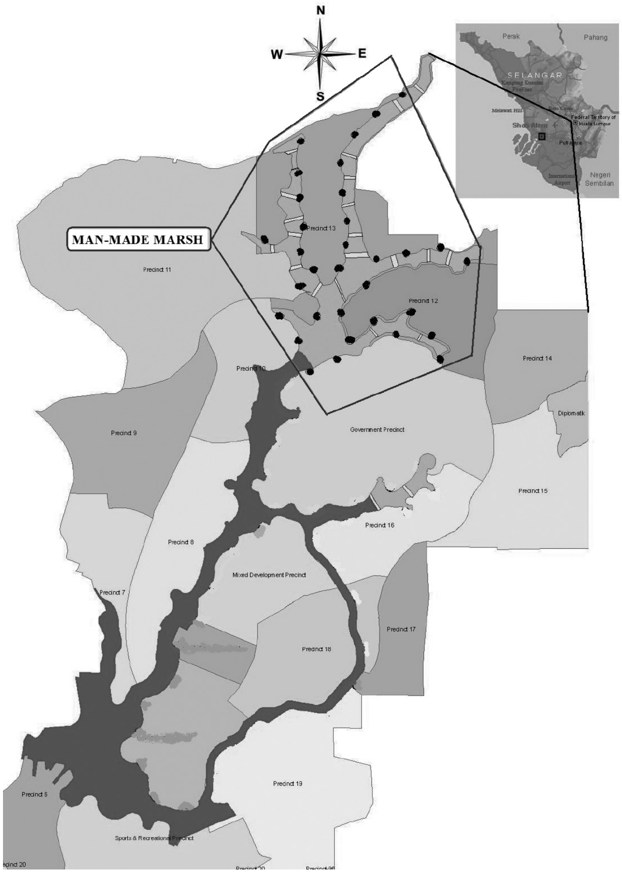

FIGURE 1. Location of the of man–made marsh at Putrajaya, Peninsular Malaysia

BIRD SURVEYS

Avian surveys were carried out in the man–made marsh at Putrajaya using the distance sampling point count method from March 2009 to June 2010. Data were collected for eighteen consecutive months; potentially to increase the number of detections, especially for species that were not frequently detected. Fifty point count stations were systematically placed at 300 m interval apart, to avoid the double counting of the same bird at more than one station. Each point count station was surveyed for 10 min to detect most bird species with minimal efforts and disturbance, in order to obtain reliable results and reduce bias. The survey was carried out from 0730–1100 h. The method was followed as described by Aynalem and Bekele (2008); Buckland et al. (2004); Hosteler (2001); Nadeau et al. (2008) and Zakaria et al. (2009).

DATA ANALYSIS

Bird diversity indices (i.e. Shannon's diversity index, Margalef's Richness Index and McIntosh's Evenness index) were determined employing the Community Analysis Package (PCA) Version 4.0 by Henderson and Seaby (2007). Densities of avian species were analyzed using newly developed Density Estimate Software (Version 6.0) by Buckland et al. (2004).

RESULTS

SPECIES COMPOSITION

A total of 20010 bird individuals of 102 species were detected employing distance sampling method. Out of the total, 6214 bird detections (31.05%) were represented by 23 water bird species and 13796 (68.95%) were belonged to 79 terrestrial bird species.

OVERALL BIRD DENSITY

The result indicated that the bird density of man-made marsh was 0.64 ± 0.02 birds ha^{-1} (n = 20010) and ranged between 0.60 and 0.68 birds ha^{-1} at 95.0% confidence interval. Density analysis showed that terrestrial birds had higher density 0.74 ± 0.02 birds ha^{-1} (n = 13796) than water birds 0.54 ± 0.09 birds ha^{-1} (n = 6214) (Table 1).

WATER BIRD DENSITY

The highest population size for three most dominant water bird species was recorded in Black-crowned Nightheron (*N. nycticorax;* 2.92 ± 1.80 birds ha^{-1} (n = 1677) followed by Purple Heron (*A. purpurea;* 1.55 ± 0.93 birds ha^{-1} (n = 1779) and Grey Heron (*A. cinerea*; 1.05 ± 0.13 birds ha^{-1} (n = 863). On the contrary, the lowest water bird density

TABLE 1. Density estimates of water birds and terrestrial birds in man–made marsh, Putrajaya

Status	No of species	Density (birds ha^{-1}) (*n* =Detection of bird individuals)	Density at 95% confidence interval (birds ha^{-1})
Water Birds	23	0.54 ± 0.09 (*n* = 6,214)	0.41 – 0.72
Terrestrial Bird	79	0.74 ± 0.02 (*n* = 13,796)	0.70 – 0.79
Overall	102	0.64 ± 0.02 (*n* = 20,010)	0.60 – 0.68

of three rarest birds was recorded in Pintail Snipe (*G. stenura*; 0.08 ± 0.03 (*n* = 8), Chinese Egret (*E. eulophotes*; 0.08 ± 0.02 birds ha^{-1} (*n* = 20) and Great Egret (*C. albus*; 0.07 ± 0.08 birds ha^{-1} (*n* = 64), respectively. However, the population of three water bird species namely Lesser Whistling Duck (*D. javanica*; *n* = 2), Black Bittern (*D. flavicollis*; *n* =1) and Cinnamon Bittern (*I. cinnamomeus*; *n* =1) were not analyzed due to small sample size (i.e. < 5 detections) (Table 2).

TERRESTRIAL BIRD DENSITY

The four highest populations of cluster terrestrial birds were observed in Rock Pigeon (*C. livia*; 3.91 ± 0.97 birds ha^{-1} (*n* = 249) followed by Eurasian Tree Sparrow (*P. montanus*; 3.72 ± 1.03 birds ha^{-1} (*n* = 592), House Crow (*C. splendens*; 3.69 ± 0.33 birds ha^{-1} (*n* = 42) and Philippine Glossy Starling (*A. panayensis*; 3.38 ± 0.53 birds ha^{-1} (*n* = 1551). In contrast, the four lowest terrestrial bird density was recorded in Brown-caped Woodpecker (*P. moluccensis*; 0.07 ± 0.02 birds ha^{-1} (*n* = 5), followed by Lesser Coucal (*C. bengalensis*; 0.09 ± 0.03 birds ha^{-1} (*n* = 12), Common Flameback (*D. javanense*; 0.11 ± 0.04 birds ha^{-1} (*n* = 13) and Red-throated Sunbird (*A. rhodolaema*: 0.10 ± 0.04 birds ha^{-1} (*n* = 7). However, the populations of 24 terrestrial bird species were not determined due to low detection (< 5 detections) (Table 3).

TABLE 2. Density estimates of water bird in man-made marsh, Putrajaya

Family	Scientific name	Common name	Density (birds ha^{-1})	Density at 95% confidence interval (birds ha^{-1})
Ardeidae	*Nycticorax nycticorax*	Black-crowned Nightheron	2.92 ± 1.80 (*n* = 1677)	0.95 – 8.93
Ardeidae	*Ardea purpurea*	Purple Heron ©	1.55 ± 0.93 (*n* = 1779)	0.52 – 4.64
Ardeidae	*Ardea cinerea*	Grey Heron ©	1.05 ± 0.13 (*n* = 863)	0.34 – 3.27
Ardeidae	*Bubulcus ibis*	Cattle Egret ©	0.65 ± 0.25 (*n* = 210)	0.30 – 1.39
Ciconiidae	*Mycteria leucocephala*	Painted Stork ©	0.51 ± 0.11 (*n* = 370)	0.14 – 1.93
Ardeidae	*Ixobrychus sinensis*	Yellow Bittern	0.49 ± 0.06 (*n* = 104)	0.38 – 0.63
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	0.43 ± 0.06 (*n* = 35)	0.32 – 0.57
Ardeidae	*Egretta garzetta*	Little Egret	0.42 ± 0.12 (*n* = 202)	0.09 – 2.10
Ardeidae	*Mesophoyz intermedia*	Intermediate Egret	0.40 ± 0.08 (*n* = 25)	0.09 – 2.00
Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	0.23 ± 0.05 (*n* = 413)	0.15 – 0.36
Ardeidae	*Butorides striata*	Little Heron	0.23 ± 0.03 (*n* = 54)	0.17 – 0.32
Ardeidae	*Ardeola speciosa*	Javan Pond Heron	0.22 ± 0.09 (*n* = 9)	0.02 – 2.25
Alcedinidae	*Alcedo atthis*	Common Kingfisher	0.20 ± 0.07 (*n* = 5)	0.08 – 0.52
Rallidae	*Porphyrio porphyrio*	Purple Swamphen	0.19 ± 0.03 (*n* = 204)	0.15 – 0.25
Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	0.19 ± 0.01 (*n* = 139)	0.16 – 0.22
Rallidae	*Gallinule chloropus*	Common Moorhen	0.15 ± 0.09 (*n* = 7)	0.03 – 0.66
Scolopacidae	*Tringa hypoleucos*	Common Sandpiper	0.12 ± 0.02 (*n* = 22)	0.07 – 0.20
Scolopacidae	*Gallinago stenura*	Pintail Snipe	0.08 ± 0.03 (*n* = 8)	0.03 – 0.20
Ardeidae	*Egretta eulophotes*	Chinese Egret	0.08 ± 0.02 (*n* = 20)	0.04 – 0.17
Ardeidae	*Casmerodius albus*	Great Egret	0.07 ± 0.08 (*n* = 64)	0.01 – 0.46
Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck	(*n* = 2)	0
Ardeidae	*Dupetor flavicollis*	Black Bittern	(*n* = 1)	0
Ardeidae	*Ixobrychus cinnamomeus*	Cinnamon Bittern	(*n* = 1)	0

TABLE 3. Density estimates of terrestrial birds in man-made marsh, Putrajaya

Family	Scientific name	Common name	Density (birds ha^{-1})	Density at 95% confidence interval (birds ha^{-1})
Columbidae	*Columba livia*	Rock Pigeon ©	3.91 ± 0.97 (*n* = 249)	2.37 – 6.37
Passeridae	*Passer montanus*	Eurasian Tree Sparrow ©	3.72 ± 1.03 (*n* = 592)	2.17 – 6.38
Corvidae	*Corvus splendens*	House Crow ©	3.69 ± 0.33 (*n* = 42)	1.52 – 8.91
Sturnidae	*Aplonis panayensis*	Philippine Glossy Starling ©	3.38 ± 0.53 (*n* = 1551)	2.49 – 4.60
Sturnidae	*Sturnus sturninus*	Purple-backed Starling	2.44 ± 1.88 (*n* = 17)	0.28 – 21.15
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia ©	1.50 ± 0.37 (*n* = 286)	0.93 – 2.43
Pycnonotidae	*Pycnonotus goiavier*	Yellow-vented Bulbul ©	1.29 ± 0.08 (*n* = 2279)	1.15 – 1.45
Sturnidae	*Acridotheres fuscus*	Jungle Myna ©	1.16 ± 0.12 (*n* = 842)	0.94 – 1.42
Estrildidae	*Lonchura malacca*	Black-headed Munia	1.13 ± 0.36 (*n* = 10)	0.56 – 2.27
Sturnidae	*Sturnus contra*	Asian Pied Starling	1.10 ± 0.30 (*n* = 16)	0.62 – 1.95
Megalaimidae	*Megalaima haemacephala*	Copper-smith Barbet	0.89 ± 0.37 (*n* = 21)	0.37 – 2.10
Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird	0.74 ± 0.06 (*n* = 184)	0.63 – 0.88
Sturnidae	*Acridotheres tristis*	Common Myna ©	0.71 ± 0.11 (*n* = 882)	0.52 – 0.97
Sturnidae	*Acridotheres javanicus*	White-vented Myna ©	0.69 ± 0.09 (*n* = 237)	0.52 – 0.92
Hirundinidae	*Hirundo tahitica*	Pacific Swallow ©	0.68 ± 0.14 (*n* = 164)	0.45 – 1.02
Estrildidae	*Lonchura maja*	White-headed Munia ©	0.67 ± 0.18 (*n* = 195)	0.40 – 1.13
Columbidae	*Treron vernans*	Pink-necked Green Pigeon ©	0.67 ± 0.06 (*n* = 1557)	0.56 – 0.80
Phasianidae	*Turnix suscitator*	Barred Button Quail	0.61 ± 0.03 (*n* = 13)	0.03 – 0.14
Ploceidae	*Ploceus philippinus*	Baya Weaver ©	0.55 ± 0.06 (*n* = 326)	0.46 – 0.69
Nectariniidae	*Nectarinia jugularis*	Olive-backed Sunbird	0.51 ± 0.09 (*n* = 51)	0.35 – 0.74
Columbidae	*Chalcophaps indica*	Emerald Dove	0.50 ± 0.16 (*n* = 11)	0.25 – 1.00
Dicaeidae	*Dicaeum cruentatum*	Scarlet-backed Flowerpecker	0.47 ± 0.13 (*n* = 11)	0.25 – 0.86
Rhipiduridae	*Rhipidura javanica*	Pied Fantail	0.45 ± 0.04 (*n* = 291)	0.38 – 0.54
Chloropseidae	*Aegithina tiphia*	Common Iora	0.41 ± 0.03 (*n* = 326)	0.34 – 0.49
Sylviidae	*Acrocephalus orientalis*	Oriental Reed Warbler	0.37 ± 0.10 (*n* = 29)	0.21 – 0.64
Nectariniidae	*Anthreptes simplex*	Plain Sunbird	0.34 ± 0.08 (*n* = 35)	0.20 – 0.57
Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia	0.34 ± 0.04 (*n* = 136)	0.26 – 0.44
Pycnonotidae	*Pycnonotus plumosus*	Olive-winged Bulbul	0.33 ± 0.07 (*n* = 22)	0.21 – 0.53
Zosteropidae	*Zosterops palpebrosus*	Oriental White-eye	0.32 ± 0.25 (*n* = 15)	0.06 – 1.64
Sylviidae	*Orthotomus sutorius*	Common Tailorbird	0.31 ± 0.10 (*n* = 71)	0.17 – 0.58
Picidae	*Picumnus innominatus*	Speckled Piculet	0.30 ± 0.11 (*n* = 6)	0.12 – 0.73
Cuculidae	*Centropus sinensis*	Greater Coucal	0.30 ± 0.10 (*n* = 6)	0.12 – 0.72
Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher	0.30 ± 0.07 (*n* = 15)	0.18 – 0.51
Columbidae	*Streptopelia chinensis*	Spotted Dove	0.30 ± 0.02 (*n* = 779)	0.26 – 0.35
Turdidae	*Copsychus saularis*	Oriental Magpie Robin	0.28 ± 0.04 (*n* = 505)	0.21 – 0.38
Columbidae	*Geopelia striata*	Peaceful Dove	0.28 ± 0.01 (*n* = 681)	0.25 – 0.30
Cisticolidae	*Cisticola juncidis*	Zitting Cisticola	0.27 ± 0.13 (*n* = 16)	0.10 – 0.72
Sylviidae	*Orthotomus ruficeps*	Ashy Tailorbird	0.27 ± 0.03 (*n* = 115)	0.23 – 0.33
Motacillidae	*Anthus novaeseelandiae*	Richard's Pipit	0.26 ± 0.05 (*n* = 127)	0.18 – 0.38
Cuculidae	*Eudynamys scolopacea*	Common Asian Koel	0.26 ± 0.04 (*n* = 31)	0.20 – 0.36
Phasianidae	*Gallus gallus*	Red Junglefowl	0.26 ± 0.02 (*n* = 243)	0.20 – 0.39
Chloropseidae	*Aegithina viridissima*	Green Iora	0.24 ± 0.04 (*n* = 32)	0.17 – 0.34
Meropidae	*Merops viridis*	Blue-throated Bee-eater	0. 23 ± 0.06 (*n* = 28)	0.14 – 0.39
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	0. 22 ± 0.01 (*n* = 337)	0.20 – 0.24
Laniidae	*Lanius cristatus*	Brown Shrike	0. 21 ± 0.02 (*n* = 69)	0.17 – 0.26
Meropidae	*Merops philippinus*	Blue-tailed Bee-eater	0. 21 ± 0.02 (*n* = 178)	0.18 – 0.24
Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	0.19 ± 0.10 (*n* = 7)	0.05 – 0.67

(continue)

Continued (TABLE 3)

Family	Scientific name	Common name	Density (birds ha^{-1})	Density at 95% confidence interval (birds ha^{-1})
Picidae	*Celeus brachyurus*	Rufous Woodpecker	0.19 ± 0.04 (*n* = 17)	0.12 – 0.30
Campephagidae	*Lalage nigra*	Pied Triller	0.15 ± 0.09 (*n* = 19)	0.04 – 0.49
Cuculidae	*Cacomantis merulinus*	Plaintive Cuckoo	0.13 ± 0.09 (*n* = 7)	0.03 – 0.65
Corvidae	*Corvus macrohynchos*	Large-billed Crow	0.13 ± 0.06 (*n* = 10)	0.04 – 0.40
Picidae	*Dinopium javanense*	Common Flameback	0.11 ± 0.04 (*n* = 13)	0.05 – 0.24
Nectariniidae	*Anthreptes rhodolaema*	Red-throated Sunbird	0.10 ± 0.04 (*n* = 7)	0.03 – 0.30
Cuculidae	*Centropus bengalensis*	Lesser Coucal	0.09 ± 0.03 (*n* = 12)	0.04 – 0.21
Picidae	*Picoides moluccensis*	Brown-caped Woodpecker	0.07 ± 0.02 (*n* = 5)	0.02 – 0.29
Cuculidae	*Cacomantis solleratii*	Banded Bay Cuckoo	(*n* = 4)	0
Passeridae	*Passer domesticus*	House Sparrow	(*n* = 4)	0
Pycnonotidae	*Pycnonotus jocosus*	Red-whiskered Bulbul	(*n* = 4)	0
Timaliidae	*Macrnous gulais*	Striated Babbler	(*n* = 4)	0
Dicruridae	*Dicrurus macrocercus*	Black Drongo	(*n* = 3)	0
Accipitridae	*Elanus caeruleus*	Black-shouldered Kite	(*n* = 3)	0
Nectariniidae	*Arachnothera flavigaster*	Spectacled Spiderhunter	(*n* = 3)	0
Accipitridae	*Aviceda leuphotes*	Black Baza	(*n* = 2)	0
Cuculidae	*Cuculus micropterus*	Indian Cuckoo	(*n* = 2)	0
Accipitridae	*Accipiter gularis*	Japanese Sparrow Hawk	(*n* = 2)	0
Estrildidae	*Lonchura leucogastroides*	Javan Munia	(*n* = 2)	0
Caprimulgidae	*Caprimulgus macrurus*	Large-tailed Nightjar	(*n* = 2)	0
Laniidae	*Lanius schach*	Long-tailed Shrike	(*n* = 2)	0
Columbidae	*Treron curvirostra*	Thick-billed Green Pigeon	(*n* = 2)	0
Cuculidae	*Chrysococcyx xanthorhynchus*	Violet Cuckoo	(*n* = 2)	0
Nectariniidae	*Arachnothera chrysogenys*	Yellow-eared Spiderhunter	(*n* = 2)	0
Sylviidae	*Phylloscopus borealis*	Arctic Warbler	(*n* = 1)	0
Strigidae	*Ketupa ketupu*	Buffy-fish Owl	(*n* = 1)	0
Coraciidae	*Eurystomus orientalis*	Dollar Bird	(*n* = 1)	0
Psittacidae	*Psittacula longicauda*	Long-tailed Parakeet	(*n* = 1)	0
Caprimulgidae	*Eurostopodus temminckii*	Malaysian Nightjar	(*n* = 1)	0
Accipitridae	*Spilornis cheela*	Serpent Eagle	(*n* = 1)	0
Accipitridae	*Haliaeetus leucogaster*	White-bellied Fish Eagle	(*n* = 1)	0
Megalaimidae	*Megalaima henricli*	Yellow-crowned Barbet	(*n* = 1)	0

DIVERSITY OF WATER BIRDS AND TERRESTRIAL BIRDS

Determining the species diversity, richness and evenness are major aspects of bird species, as it indicates the variation, richness and distribution of different bird species in a particular habitat. Principal Community Analysis Software was used to determine the diversity indices of water birds and terrestrial birds in man–made marsh. The result showed that terrestrial birds had higher species diversity i.e. Shannon–Wiener index (N_1 = 3.10), species richness i.e., Margalef's index (R_1= 8.23) and species evenness i.e. Pielou's J index (E = 0.71) as compared with water birds (N_1 = 2.04; R_1= 8.23 and E = 0.65) (Table 4).

TABLE 4. A comparison of bird diversity indices between terrestrial and water birds detected in Putrajaya man–made marsh habitat

Indices	Terrestrial birds	Water birds	Overall
Diversity indices Shannon's index (N_1)	3.10	2.04	3.38
Richness indices Margalef's index (R_1)	8.23	2.52	10.22
Evenness indices Pielou's J index (E)	0.71	0.65	0.73
She analysis	3.10	3.38	

Discussion

Determining the density and diversity of water bird and terrestrial bird species inhabiting man–made marshes are highly important in order to understand the bird community structure, the health of wetland habitats and to provide a robust and appropriate index to develop an effective bird conservation strategy within the context of ecological and spatial parameters for future management. This man–made marsh encompassed of five arms and extremely varied in term of habitat such as shallow water, deep water, islands and adjacent planted vegetated areas. This habitat straddles water from the catchment areas of Chua and Bisa Rivers that flourished along and finally seeps into the lake before stored into a dam. Water is a major driven factor that affected aquatic vegetation composition and food resources that influenced bird density, diversity and distribution (Colwell & Taft 2000; Quinn 2002; Wilcox et al. 2002). The recording of bird species indicated that this man–made freshwater marsh is extensively utilized by water birds and land birds to acquire their daily requirements such as habitat, food, shelter and water.

Furthermore, recording of twenty three water bird species indicated that this man–made habitat is utilized by a wide array of water bird species for food, perch, roost and breed. This man–made marsh is rich in emergent vegetation such as Spike Rush – *Eleocharis varigata*, Water Chestnut – *E. dulcis*, Common reed – *Fragmites karaka*, Blue Sedge – *Lepirona articulata*, Bog Bulrush – *Scirpus mucronatus*, Dwarf Papyrus Sedge – *Cyperus haspan*, Common Susum – *Hanguana malayana*, Globe Fimbry – *Fimbristylis globulosa*, Nutrush – *Scleria sumatrensis* and Cattail – *Typha angustifolia*. The emergent vegetation composition of this habitat is quite heterogeneous and variable from site to site depending upon the frequency and duration of water flow. Emergent vegetation is ideal habitats for numerous macro invertebrates. They preferred emergent vegetation during the juvenile stages to complete their life cycle and are major source of food for birds, turtles, snakes, frogs and fishes (Meyer et al. 2010).

It was observed that diversity of wetland habitats such as shallow waters, emergent vegetation patches, marsh edges and adjacent vegetated areas had attracted different waterbird species such as wading birds (heron, egret, storks, bitterns), surface foragers (ducks, swamphen, moorhens) and edge foragers (waterhens, crakes, bittern). The highest waterbird density was recorded for Black–crowned Nightheron followed by Purple Heron, Grey Heron, Cattle Egret and Painted Stork. This was due to the shallow water and richness of food resources such as fishes, amphibians, reptiles and aquatic insects. The shallow water offers crucial foraging sites for wading birds such as herons, egrets, bitterns, storks because obtaining food is easily accessible. It has been reported that water depth is an important variable affecting the habitat selection in waterbirds (Colwell & Taft 2000; Isola et al. 2002), because it directly determines the accessibility of prey while foraging (Collazo et al. 2002; Darnell & Smith 2004). Wading birds prefer shallow water depth, because foraging efficiency decreased with increasing water depth. This indicated that water birds obtain higher net energy intake in shallower than deep water as reported by Kushlan (2007) and Ma et al. (2010). It was observed that water level fluctuation creates different foraging habitats from time to time depending on inflow of water from catchment areas and rainfall pattern. When water level reduced, the food resources such as fishes and tadpole were concentrated in low–lying sites that attracted a higher number of wading birds due to visibility of prey resources and increased foraging success. In addition, nine islands also occur within the middle of the marsh that provides safe roosting and breeding sites particularly for heron, egret and storks. Island habitats have become focal areas for breeding by colonial birds (Elbin & Tsipoura 2010) and can be used as resting, roosting, preening and even nesting and molting sites by water birds (Erwin & Beck 2007; Warnock et al. 2002). These species heavily utilized islands for loafing, nesting, roosting and chick rearing purposes. The reason is that, these vegetated island provide safe nesting and chick rearing sites, due to reduce ground predators access to their breeding sites and are within the vicinity of ideal foraging sites and shallow waters.

Lowest water bird density was determined for Lesser Whistling Duck, Black Bittern and Cinnamon Bittern. The reason is that, this marsh is shallow and devoid of submerged and floating vegetation such as pond weed – *Potamogeton* sp., Watermilfoils – *Myriophyllum* sp., bladderworts – *Utricularia* sp., rushes – *Sciropus* sp., coontails – *Ceratophyllum* sp. and waterweed or hydrillas – *Hydrilla* sp.. It has been reported that habitats with deeper water support the greatest density of water birds such as ducks (Hattori & Mae 2001). Ducks preferred deep open water bodies rich in submerged vegetation for foraging and loafing as reported by Rajpar and Zakaria (2011). This might be due to higher diversity and richness of food resources such as aquatic insects, fishes and amphibians that occur in submerged vegetation as found by Meerhoff et al. (2003). Likewise, the lowest density was detected in Black Bittern and Cinnamon Bittern. These water birds are migratory, secretive and shy in nature i.e. they avoided human presence and most often seen in reedbeds of emergent vegetation. The waterbird community structures (i.e. species richness, distribution, diversity and density) is influenced by different factors such as availability and richness of food resources, water depth, size of the effective foraging area (Burkert et al. 2004; Gillis et al. 2008; Lentz-Cipollini & Dunson 2006) and the abiotic changes in the wetlands (Jaksic 2004; Lagos et al. 2008; Wrona et al. 2006).

Likewise, the recording of 79 terrestrial bird species indicated that this habitat is not only preferred by water birds but are also utilized by land bird species for food and shelter. The occurring of higher number of terrestrial bird species could also be due to the diversity of fruiting such as brush cherries – *Syzygium* sp., weeping Fig

– *Ficus benjamina*, golden fig – *Ficus microcarpa*, tembusu – *Fragrea fragans*, fish-tailed palm – *Caryota mitis*, island lychee – *Pometia pinnata*, *simpoh air – Dillenia suffruticosa* and flowering trees such as flame tree – *Flamboyant* sp., beach hibiscus – *Hibiscus tiliaceus*, gelam – *Melaleuca cajuputi* – *Cratoxylon* sp., cicada Tree – *Ploiarium alternifolium*, ixora plant – *Ixora javanica*, sunflower plant – *I. umbellata*, wild orchid – *Arundina* sp., aquatic orchid – *Vanda hookeriana*, carolena dayflower – *Commelina nudiflora*, spider lily – *Crinum defixum* and knot grass – *Polygonium* sp. Fruiting trees provided a wide array of berries throughout the year that had attracted different insect species and fruit eating birds. Similarly, flowering trees also produced diverse flowers that attracted nectarivore bird species to nip the nectar and prey on insects.

Among the highest density for terrestrial birds were recorded for Rock Pigeon, Eurasian Tree Sparrow, House Crow and Philippine Glossy Starling. It was observed that food is provided to pigeons, sparrows and crows in some parts of the marsh. The other reason could be that these bird species are habituated to human and non–shy species. They utilized wetland areas, adjacent plantations and also human settlements for foraging, loafing and breeding purposes. In addition, food for Glossy Starling is abundant due to availability of diverse fruiting trees such *Eugenia* sp., *Ficus benjamina*, *F. microcarpa*, *Elaeis guineensis, Fragrea fragans*, *Caryota mitis*, *Pometia pinnata* and *Dillenia suffruticosa* that frequently bear fruits throughout the year.

The lowest terrestrial bird density was recorded in Brown–capped Woodpecker, Common Flameback and Lesser Coucal. This could be due to non–availability or suitable dead dying mature trees for the woodpeckers nesting and foraging sites. Likewise, the low density in lesser coucal could be due to lack of dense and tall grassy beds and shrub patches. Lesser Coucal is a ground forager with secretive and shy nature which often prefers to use dense grassy beds and shrub patches for foraging and nesting.

The results of the CAP analysis revealed that terrestrial birds had the highest bird diversity than water birds. The vegetation diversity and richness directly affect the species diversity and richness of birds (Canterbury et al. 2000; Martin 2001; Soderstrom & Part 1999). In addition, the occurrence and richness of food resources such as fruits, seeds, insects (locus, moths, butterflies, crickets, flies, termites and beetles), nectar, reptiles (lizards, snakes), mammals (mice and rats), amphibians and birds is also a key factor that affects diversity and richness of bird species (van Heezik & Seddon 2012). Water bird species are specialized in food type and habitat i.e. their diversity is influenced by microhabitat variables such as water depth, water level fluctuation, aquatic vegetation composition, wetland size, availability of food resources and wetland connectivity. On the other hand, terrestrial birds are capable to use various habitats such as water bodies, open areas, vegetated lands and human settlements for foraging, perching, roosting and breeding purposes. Therefore, it is concluded that this man–made marsh is a crucial alternative habitat for diverse population of water and terrestrial birds.

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