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ORIGINAL PAPER

Effects of anthropogenic disturbance on the species assemblages of birds in the back mangrove forests

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Abstract Around the world, mangrove ecosystem has faced major threats from human activities, and birds were unexceptionally impacted. Mangrove fringe a large extent of the east and west coast of Peninsular Malaysia. The intertidal gradients along the coastline, has formed a brackish zone (back-mangrove), which exhibited different pattern of mangrove species, but received much less attention. In this study, we compare species assemblages of birds based on different level of anthropogenic pressures at different back-mangroves sites; KY; KD and KST which is measured by analysis of land use change for 15 years using ERDAS Imagine. 97 species from 36 families of birds were recorded from all sites, dominated by family Alcedinidae (kingfishers), Ardeidae (egrets, herons) and Coraciidae (dollarbirds). Anthropogenic disturbance changes the landscape structure, with reduction of mangrove cover, other than increasing horticulture, urbanization, and monoculture plantation activities. This is most apparent at KY, followed by KD and lowest at KST, which also showed reducing in species abundance and richness of birds. Species assemblages of birds also differ, as highly disturbed sites exhibited a poorer representation of mangroves-specialist, compared to less disturbed sites as illustrated by the nMDS ordination. Finally, PERMANOVA analysis showed significant effect of the bird family and their ecological niches towards the species assemblages at different back-mangrove sites. The high abundance of open country species such as mynas, crows and doves at all sites indicate the influence of anthropogenic activities. Presence of several highly protected species indicates high conservation value of the back-mangrove zone, apart from their true-mangrove counterparts.

Keywords Avian · Diversity · Functional niche · Feeding guild · Brackish zone

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Introduction

Mangrove forests play a significant role in the management of coastal ecosystem in Malaysia as it serves as crucial habitat for variety of marine life as well as flora and fauna (Jusoff 2013). Mangroves are not only important to flora and fauna, but also important to human for their livelihood and recreation (Norhayati et al. 2009). However, these unique coastal tropical forest environments are among the major threatened habitat in the world (Luther and Greenberg 2009). Mangrove ecosystem around the world, faced serious degradation from anthropogenic activities such as deforestation, tin mining, salt production, coastal development, urbanization, over-harvesting of timber and fuel wood and pollution from crude oil excavation and dumping of domestic sewage (Gracia and Rosenberg 2010; Rajpar and Zakaria 2014). Land use changes can be measured through spatio-temporal analysis using satellite imagery (Etemadi et al. 2018), to distinguish the level of change of particular habitat, due to natural events or anthropogenic disturbance (Maryantika and Lin 2017). Olaniyi et al. (2012) stated that agricultural expansion is the main driver of coastal lands disruption in Malaysia, due to their accessibility, suitable slope and favourable climatic condition of the areas, apart from urbanization.

Mangrove forests which inhabited by uniquely adapted flora and fauna are important habitat, nursery and feeding grounds, not only for aquatic, but also for many terrestrial animals (Jawardi 2016). Presence of various types of niches in mangrove forest does provide sufficient and suitable habitat for foraging, roosting and nesting sites for many avian species in mangroves (Mohd-Azlan et al. 2015) including roosting sites for migratory birds, during wintering in this region (Othman et al. 2004). Noske (1995) elaborate on the feeding ecology of mangrove birds, particularly the abundance of insectivorous and nectarivores, indicating the important role of these species in mangrove ecosystem such as pollination and seed dispersal. Insectivorous would be the main feeding choice as mangrove habitat does provide a wide niche for variety of insects at many trophic level (Norhayati et al. 2009). Bird's species are also important bio-indicator of mangrove ecosystem and play a substantial role in the vegetation management for their ability to control the population of insect pest that causes impairment to the seeds, the defoliation among trees and reduces their growth (Rajpar and Zakaria 2014). Little information is available on the assemblages of birds in Malaysian mangrove forests (Noske 1995). Norhayati et al. (2009) and Zakaria and Rajpar (2015) listed a total of 57 and 69 bird species respectively in Klang mangrove forests meanwhile Zakaria and Rajpar (2009) found 74 bird species in Marudu Bay mangrove forest in Sabah, Malaysia.

Mangrove ecosystem can be separated into different zones. According to FAO (2005), zonation pattern of mangrove forest in Malaysia can be categorized in three clear zones following the vegetation composition as well as salinity and sediment types in the area. First zone is the open zone or seawards zone in which *Avicennia-Sonneratia* spp. dominate in this muddy area. Following seawards zone is the middle zone which is the more inland area where variety of mangrove species present and dominated with *Brugeira-Rhizophora* spp. (Jusoff 2013). Lastly, the thirds zone is the riverine zone or back mangrove zone (Tomlinson 1986) where salinity in this area changes due to freshwater influences from the upstream, whereby swamp palm such as *Nypa fructicans* dominated the area (Jusoff 2013). According to Jusoff (2013), back mangrove constitute of less favourable habitat condition for mangrove vegetation because of its habitat's structure which provide less support for most of mangrove flora. This is due to the soft, silty and shallow habitat, coupled with the endless ebb and flow of water providing very little support for most mangrove plants, which have aerial or prop roots and buttressed trunks. Apart from timing of mangrove flowering and the nature of the matrix surrounding mangroves, Mohd-Azlan et al. (2012) indicated that birds diversity and assemblages differ according to mangrove zonation. In addition, each zonation could be represented by certain indicator species, thus influences the birds assemblages. The back mangrove zone is also important habitat for fireflies, a light-emitting insect, which can be found in groups on trees and shrubs along the estuarine mangrove swamps (Motuyang 1995). This has boosted tourism activities at the mangroves, for the firefly watching as well as bird watching.

In this study, we classify the birds into specific functional groups (feeding guild and ecological niche). The aim of the study is to distinguish the birds assemblages and composition in the back mangroves, based on the anthropogenic pressures, at different coastal line of Peninsular Malaysia. This include Yakyah river (river = sungai, sg.) located on the east coast, and sg. Timun and sg. Dew on the west-coast. These sites were located inland of the true mangroves, but differ in the intensity of anthropogenic disturbance. Information on the current state of the mangrove areas, as demonstrated by the bird species composition would informed us on the habitat condition of each mangrove sites. Coupled with the anthropogenic disturbance obtained from the land-use assessment, these information are important for prioritising the mangrove conservation and rehabilitation before further habitat degradation took place. A complete bird checklist in each mangrove forest is also essential in promoting the river-based eco-tourism in the mangrove sites.

Materials and methods

Study areas

The study sites were located in mangrove forest in three states of Peninsular Malaysia; Terengganu (Kampung Yakyah, KY) (kampung, Kg.), Negeri Sembilan (Kg. Sungai Timun, KST), and Perak (Kg. Dew, KD) (Fig. 1). KST and KD is located on the west-coast, whereby KY is located on the east-coast of Peninsular Malaysia and all the three habitats exhibit the back-mangrove zone, due to the vegetation types and further distance from the sea. Sampling was conducted in four stations at each site (n = 4), along 1 km from the jetty, between December 2017 and February 2018. Description of the study areas were pointed in Table 1.

Field sampling

Birds were surveyed for six days at each sampling site using point count and mist netting methods. Point count method was conducted along the river in two sessions; early morning (from 08:00 to 10:00) and late afternoon (from 16:00 to 18:00) using a boat, by three observers (FSMT, WMS and MSM) to document species and abundance of birds. Birds were observed at each station and distance between stations were not less than 300 m to avoid multiple counting (Zakaria and Rajpar 2013). Birds that can be seen or heard within 40 m radius in 10 min observation period were observed, identified and recorded (Kwok and Corlett 2000). All bird counts were carried out by the same observer. Mist netting technique was conducted in two sessions, from 07:00 to 12.00 and 16:00 to 19:00 every day. Two mist nets (2.5 m × 9 m × 4 m) were deployed and installed about 0.5 m above the ground randomly in each station. Nets were open from 07:00 and close at 19:00. Mist nets were inspected every two hours to extract the captured birds. The captured individuals were measured, identified and ringed before released. Bird's identification was aided by Robson (2008). Birds were assigned to specific functional groups; (1) ecological niche (i.e. mangrove-specialist, forest-specialist, and open-country), and (2) feeding guild (i.e. carnivore, frugivore, granivore, insectivore, omnivore), following Kati and Sekercioglu (2006), Robson (2008), Jeyarajasingam and Pearson (2012), and Mohd-Azlan et al. (2015).

Land use analysis

To distinguish the anthropogenic pressures, land use and land cover types surrounding the three mangrove sites for year 2002 and 2017 were identified using satellite imageries. The area of each site analysed was 5218 hectares (KY), 4070 hectares (KST) and 7169 hectares (KD). LANDSAT 7 and 8 imageries were downloaded from https://earthexplorer.usgs.gov/ and then analysed using ERDAS Imagine. Unsupervised classification is the process of clustering pattern recognition. Classification was conducted using the Interactive Self Organizing Data Analysis Technique (ISODATA). Generated spectral classes from the unsupervised classification were used for verification during ground-truthing. In supervised classification the images were further analysed using the Maximum Likelihood Classification algorithm. Ground-truth data were used to aid the supervised classification process. Ground-truth data were collected during field observation where location of different land use and land cover types were recorded. A total of 300 locations were identified (100 for each site). Signature of different land use and land cover were selected as training data. Spectral properties of the training sets (a total of 30 training points for each land use and land cover types from each site) and data from field observations were all combined to perform the supervised classification (Veerendra and Latha 2014). Overall accuracy of the classified maps was calculated. A confusion matrix was used as the quantitative method of characterising image classification accuracy (Story and Congalton 1986). The classified images of 2002 and 2017 were then overlaid to determine the land use and land cover area changes. Change

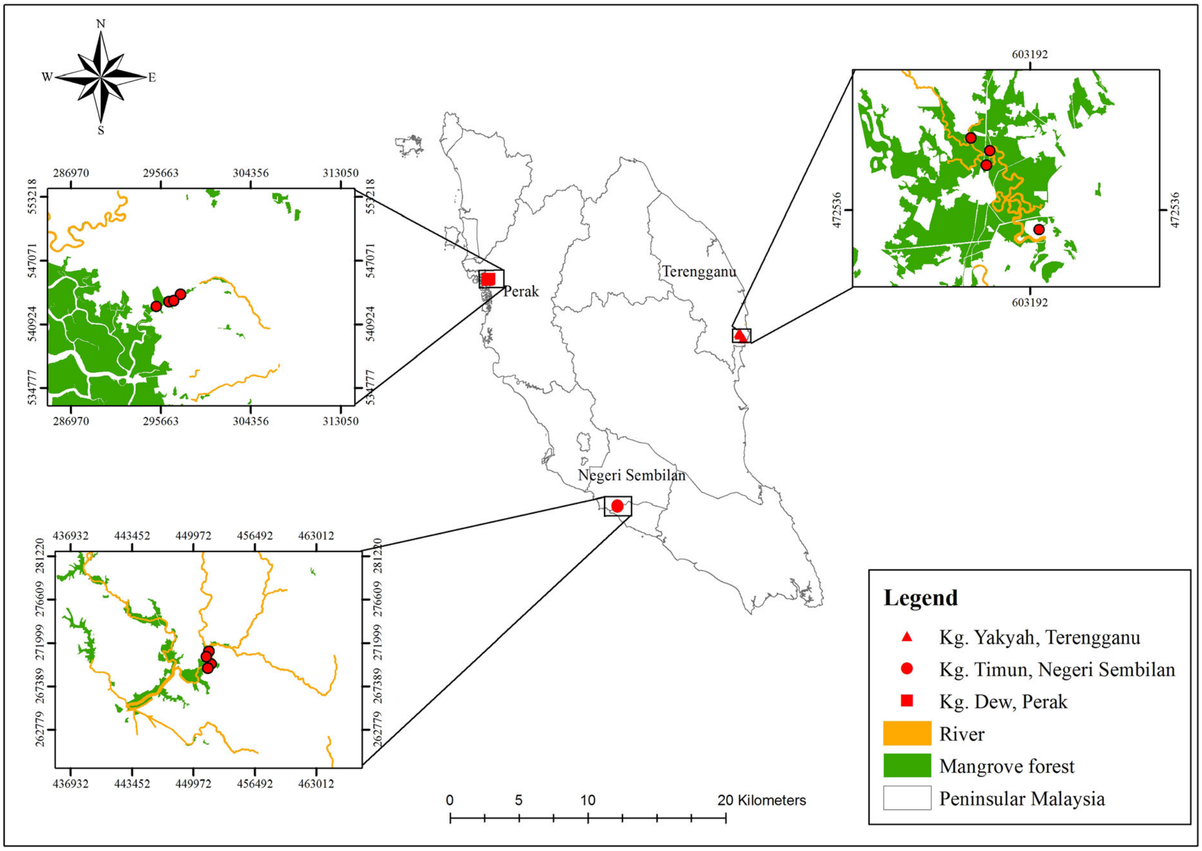


Fig. 1 Map of mangrove sites at Kg. Dew, Perak, Kg. Yakyah, Terengganu and Kg. Timun, Negeri Sembilan in Peninsular Malaysia

detection was assessed using pixel-by-pixel comparison of the images. This analysis enables the identification of the level of anthropogenic disturbance in each sites, based on the land-use changes in 15 years.

Data analysis

Biodiversity indices including species richness, dominance (D), diversity (Shannon, H'), evenness, and species richness estimator (Chao-1) were calculated using Paleontological Statistics (PAST) Software version 2.17c (Palaeontological Association 2001). Chao-1 estimator index provide most robust method in prediction of the species number in a community when sampling is prolonged (Chao 1984). Next, individual-based rarefaction curves was constructed separately for each sampling techniques to compare species richness in each sampling location with different sample sizes (Magurran (2004) using Ecosim software version 7.71 (Acquired Intelligence Inc. 2018). This curve provides a useful information in comparing samples sets with different size due to incomplete inventories (Yusof et al. 2019). Kruskal–Wallis test was used in order to measure the differences of species abundance based on functional groups (ecological niches and feeding guild) for each site using SPSS version 23 (IBM Corporation 2017).

Non-metric multidimensional scaling (nMDS), produces an ordination based on a distance or dissimilarity matrix, was presented based on Bray–Curtis index to demonstrate the pattern of species assemblages with functional groups (feeding guild and ecological niche) as factors, at different mangrove sites. Prior to this analysis, abundance data were square-root transformed. Permutational analysis of variance (PERMANOVA) was adopted to calculate the effect of different functional groups (bird family, feeding guild, and ecological niche) and their interactions in shaping the distribution of the species in each back-mangrove sites. This analysis was performed

Table 1 List of study areas with its GPS reading and description

Study areas	GPS reading Latitude (N°)	GPS reading Longitude (E°)	Study areas description
KY			Some part of the river channel was re-channelled (straightened) to increase water flow to the sea for flood control during monsoon season Distance from the sea: 21.5KM
Station 1	4.261111	103.429722	
Station 2	4.321388	103.385000	
Station 3	4.303333	103.395277	
Station 4	4.312777	103.397500	
KST			Undergoing anthropogenic disturbance from oil palm plantation and aquaculture ponds, as well as pollution from domestic dumps into the river Distance from the sea: 16.2KM
Station 1	2.450000	102.061666	
Station 2	2.437777	102.063611	
Station 3	2.433888	102.060555	
Station 4	2.445000	102.059166	
KD			Undergoing pollution from surface run-off of adjacent oil palm plantation, as well air pollution from charcoal factories nearby. This river also act as main transport of charcoal woods to the factories Distance from the sea: 18.5KM
Station 1	4.912500	100.667500	
Station 2	4.906111	100.657500	
Station 3	4.901666	100.646388	
Station 4	4.906944	100.661666	

using PRIMER v6.1.9 (Primer-E Ltd, Plymouth, UK) with PERMANOVA + V1 (Clarke and Gorley 2006).

Results

Land use changes and level of anthropogenic disturbance

Table 2 listed the area of change of the land cover surrounding each back mangrove sites from year 2002 to 2017. There were 14 land cover types depicted from these mangroves. Overall, land cover change was highest for mangroves coverage, which shows significant reduction from 2002 to 2017 at all sites. Mangrove coverage has the highest reduction at all sites, with average change of 48.8%, and especially highest reduction at KY. This is followed by water body, with average of 43.5%, and especially increased at KY and KST. Water body is referred to aquaculture, river and ponds, and the increase in their coverage indicate high anthropogenic disturbance due to the opening of land for aquaculture activities which posed disturbance to the mangrove environment. Next were swamp and horticulture coverage, with average of 35.9 and 34.5% respectively. Increase in swamp covers at all sites especially at KY, was due to flooding events that took place annually, as well as land burning which caused part of the area to become swamped. Horticulture activities was especially intense at KD and KY. Both these land covers were partly due to anthropogenic disturbance. Finally, urban land use was also contributed to the land use change in the back-mangrove sites with an average of 32.2%, and especially high at KD and KY, but very low at KST. From these analysis, KY was shown to exhibit the highest level of anthropogenic disturbance, followed by KD and least disturbed at KST.

Species distribution, richness and diversity of birds at back-mangrove sites

A total of 97 bird species from 36 families has been recorded from all mangrove sites, with both sampling techniques. Table 3 listed the abundance and distribution of birds recorded from each mangrove sites based on different sampling methods. Altogether, KST recorded the highest abundance and species richness, with 884 individuals from 53 species, followed by KD with 467 individuals from 51 species, whereby the

Table 2 Area and percentage of land use change from 2002 to 2017 in all back-mangrove sites, and the average of all sites

	KD		KST		KY		Average of change %
	Area of change (ha)	% of change	Area of change (ha)	% of change	Area of change (ha)	% of change	
Barren Land	− 105.58	19.92	68.73	31.33	− 46.78	25.84	25.7
Swamp	27.94	29.39	19.6	22.24	1348.55	**55.98**	**35.9**
Forest	278.22	11.25	199.43	25.72	899.16	36.27	24.4
Rubber	0	0	− 453.65	24.22	− 163.66	**65.24**	29.8
Horticulture	− 534.8	**77.18**	1.53	1.82	24.28	24.48	**34.5**
Infrastructure	0	0	− 0.1	0.6	1.62	0.72	0.4
Mangrove	− 295.65	**42.3**	− 97.53	12.82	− 2302.1	**91.41**	**48.8**
River	− 1.45	2.3	− 1.15	0.95	− 26.5	15.97	6.4
Water body	14.15	0	4.24	**63.28**	5.21	**67.29**	**43.5**
Road	60.81	27.34	8.72	5.32	− 3.27	5.6	12.8
Settlement	11.16	3.66	54.3	5.03	23.39	6.18	5.0
Oil Palm	442.06	5.87	236.06	8.31	203.65	12.67	9.0
Urban	114.8	**69.91**	− 0.98	0.9	36.46	25.84	**32.2**
Paddy	11.67	0.89	0	0	0	0	0.9

Note: Highlighted percentage (%) of change refers to the high land use change from 2002 to 2017 at different sites and averaged (increase or reduction)

lowest was recorded in KY, with 249 individuals from 44 species. The most dominant family were Alcedinidae (kingfishers) and Ardeidae (egrets, herons) with both eight species. These mangroves sites shared only nine species, particularly dominant with Crested serpent eagle (*Spilornis cheela*), Little heron (*Butorides striata*), Little egret (*Egretta garzetta*), Pink-necked green pigeon (*Treron vernans*), Asian dollarbird (*Eurystomus orientalis*), and Asian glossy starling (*Aplonis panayensis*).

Shannon diversity index was slightly higher at KD (3.208), followed by KY (3.12), and lowest at KST (2.943). In contrast, evenness index was highest at KY (0.515), and lowest in KST. Although KST composed of the highest richness and abundance, it exhibited a highly dominant species particularly the Pacific swallow (*Hirundo tahitica*), and Blue-tailed bee-eater (*Merops philippinus).* Chao-1 index estimated that species richness in KD could increase 11 species, compared to KST with 7 species and least at KY at only 5 species. Table 4 summarizes the result of this analysis.

Rarefaction curve of different mangrove sites were illustrated in Fig. 2. From these curves, all three sites show steady increase in species in relation to abundance, indicating that more species are expected to be discovered in these areas. However, KD is closer to reaching asymptote from the decreasing steepness of the curve. Interpolation at the site with the lowest species abundance (KY), which is at 243 number of individuals, indicate KY site as having the highest number of species (43.7 ± 0.3), followed by KD (42.1 ± 4.9) and lowest at KST (34.9 ± 5.1). There was significant difference in species richness between KY and KST, but no significant difference in species richness between KY and KD, as well as KD and KST due to the overlap in confidence interval at 95%.

Species assemblages based on functional groups and anthropogenic intensity

From 97 species recorded in our study sites, 84 species were resident (R), 12 were migrants (M) and 10 species were both resident and migrant (R&M) (Appendix in Table 5). Among the migrant species recorded, there were two species that were frequently sighted which were Black-capped kingfisher (*Halcyon pileata*) and Barn swallow (*Hirundo rustica*). Two species were listed as Vulnerable according to IUCN red list, namely the Wallace's hawk-eagle (*Nisaetus nanus*) which was sighted only once in KD, while

Table 3 Species abundance and distribution of birds in each mangrove sites

Method	Study areas		
	KY, Terengganu	KST, Negeri Sembilan	KD, Perak
Point count			
No. of species	34	46	47
No. of family	18	21	22
No. of individual	231	862	455
Mist netting			
No. of species	12	14	10
No. of family	9	11	9
No. of individual	18	22	12

Lesser adjutant (*Leptoptilos javanicus*) was sighted twice in KY.

Feeding guild assemblages indicate insectivore were the most abundant feeding guilds (36%), followed by carnivore (30%), omnivore (16%), frugivore (16%) and the least abundant group was granivore (2%). Dollarbird (*Eurystomus orientalis*), Pacific swallow (*Hirundo tahitica*), and Blue-tailed bee-eater (*Merops philippinus*) were the most abundant insectivores recorded, while Little egret (*Egretta garzetta*) and Great egret (*Ardea alba*) were the dominant carnivores recorded. Omnivores species were represented by hornbills, malkoha, waterhen and myna. There was no significant difference of any of the feeding guild types at different mangrove sites ($p > 0.05$). Based on ecological niche, there were no significant difference in mangrove-specialist and forest birds among the study sites ($p > 0.05$), but there were significant difference of the open-country birds among the mangrove sites (Kruskal–Wallis, $\chi^2 = 6.87$, df = 2, $p = 0.032$), with high mean abundance in KST (37.28), and KD (30.15), compared to KY (24.08).

Table 4 Bird diversity indices at different mangroves sites

	KY	KST	KD
Number of species	44	53	51
Number of individuals	249	884	467
Dominance (D)	0.0686	0.08262	0.06391
Simpson (1-D)	0.9314	0.9174	0.9361
Shannon (H’)	3.12	2.943	3.208
Evenness	0.5147	0.3581	0.4849
Chao-1	49.5	60.09	62.38

The nMDS ordination separated the back-mangroves into several groups based on feeding guild (Fig. 3a, stress value = 0.12), with KD and KST resemble closer species composition compared to KY. KD and KST were represented by many carnivores such as kingfishers (Alcedinidae) and waterbirds (Ardeidae), other than frugivores such as bulbuls (Pycnonotidae). KY on the other hand dominated by omnivorous feeding guild such as crows (Corvidae) and hornbills (Bucerotidae). In addition, this analysis also revealed that majority of the insectivorous are not specific to the back-mangroves sites, as only small number of them falls within the perfection correlation circle, such as dfollarbirds, and fantails. Amongst the common species shared between KD and KST were Great egret (*Ardea alba*), Spotted dove (*Spilopelia chinensis*), Greater coucal (*Centropus sinensis*), Chestnut-winged cuckoo (*Clamator coromandus*), and Yellow-vented bulbul (*Pycnonotus goiavier*). KY shows different assemblages with the presence of Chinese pond-heron (*Ardeola bacchus*), Lesser adjutant (*Leptoptilos javanicus*), majority of sunbirds, flowerpecker, and nightjars.

Similarly, ecological niche also exhibits similar pattern with feeding guilds, as KST and KD resemble closer species composition compared to KY (Fig. 3b, stress value = 0.12). KD and KST were highly exhibited by mangrove-specialist species, unlike KY. Mangrove-specialist was very less at KY, with domination of Black-capped kingfisher (*Halcyon pileate*), Little heron (*Butorides striata*) and Stork-billed kingfisher (*Pelargopsis capensis*). The higher abundance of forest-specialist species at KY were due to the high forest coverage at this sites, compared to KD and KST.

However, distribution of the open-country species was not restricted to the sites with higher anthropogenic pressure, but were fairly distributed in all areas, indicating the influence of anthropogenic factors at all sites. In addition, mangrove specialist were particularly confined within the perfection correlation circle, with several species falls outside the circle such as Jungle myna *(Acridotheres fuscus),* Long-tailed parakeet (*Psittacula langicauda),* Grey heron (*Ardea cinerea)* and Black-crowned night-heron *(Nycticorax nyxticorax)* as these species could utilize other water bodies such as nearby river, and ponds surrounding the back-mangrove sites. PERMANOVA analyses showed that the species distribution in different back-mangrove sites were significantly affected by the bird family factors (n = 36) (PERMANOVA, F = 0.964, p = 0.036), and interaction of family × ecological niche (PERMANOVA, F = 1.74, p = 0.046), but not feeding guild ($p > 0.05$). Therefore, distribution and assemblages of bird species in back mangroves sites can be associated with the different level of anthropogenic pressures, as exhibited by each sites.

Fig. 3 Non-metric multidimensional scaling (nMDS) ordinations of birds community at back-mangrove sites based on **a** feeding guild and **b** ecological niche. The direction and length of the arrow is proportional to the strength of Pearson correlation between three mangrove forest sites and species assemblages. The circle represents a perfect correlation (r) of 1. The nMDS generates by PRIMER software does not have axis scale (i.e. its scale is arbitrary) thus the circle does not need to be centred/ middle of the ordination ▶

Discussion

Our study indicates that anthropogenic disturbance significantly affect the species richness and assemblages of birds in the back-mangrove forest. These back-mangrove habitats were dominated with Alcedinidae (kingfishers) and Ardeidae (egrets, herons) family. Family Ardeidae mostly spent lots of their time in wetlands for feeding and roosting, even for nesting. Open water area and shrimp pond in mangrove habitat provide food sources for many mangrove visitors such as Ardeidae and Alcedinidae (Rajpar and Zakaria 2012; Vijaya Kumar and Kumara 2014). The Great egret (*Ardea alba*) was the most abundant waterbirds species recorded in KST and KD, while Little heron (*Butorides striata*) dominated at KY site. The presence of shallow-water areas (Zakaria and Rajpar 2013) potentially contributes to the presence of

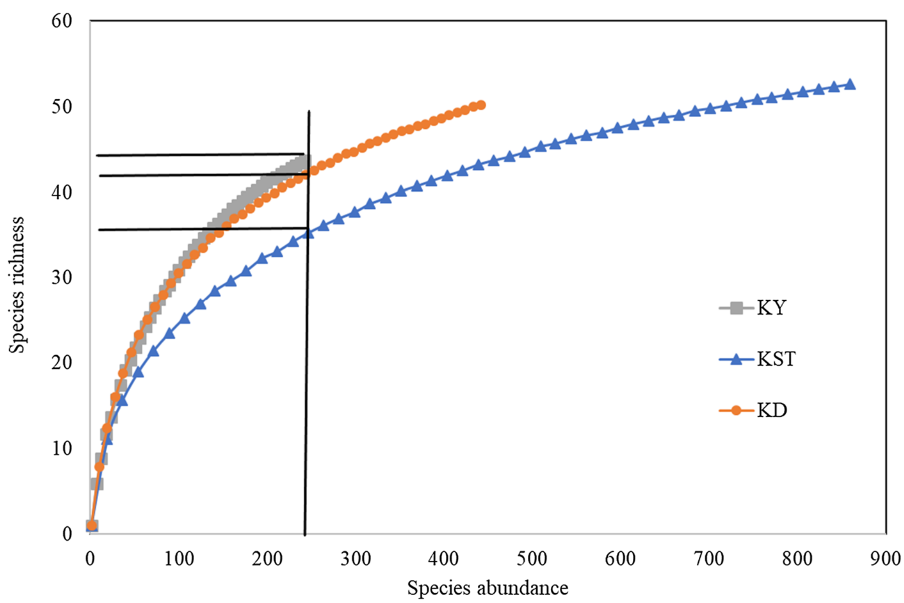
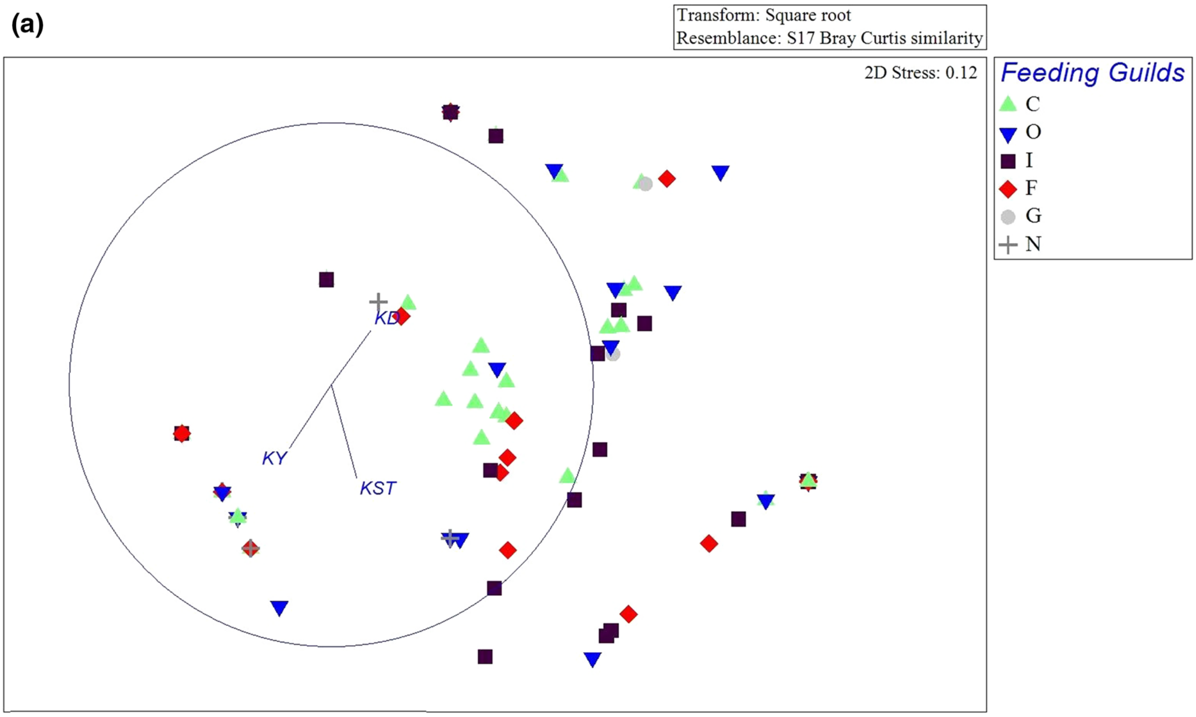


Fig. 2 Rarefaction curve based on the species richness and abundance of birds in each mangrove sites, with interpolation line at 243 individual

(a)


Transform: Square root
Resemblance: S17 Bray Curtis similarity
2D Stress: 0.12
Feeding Guilds
C
O
I
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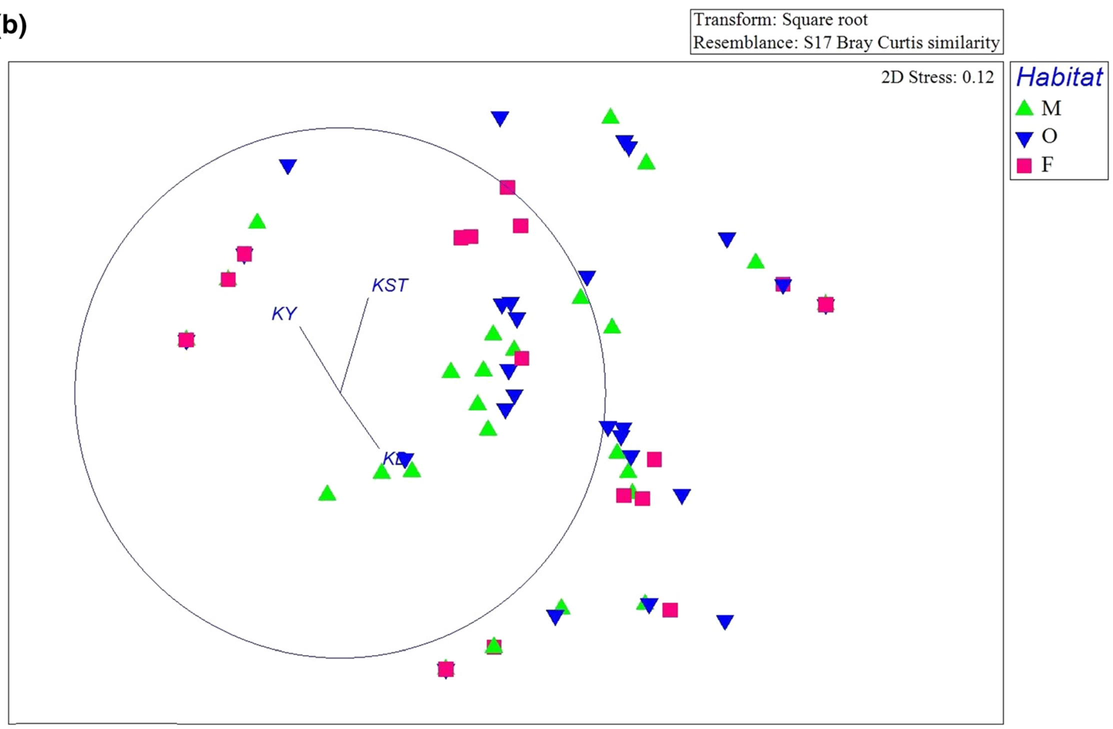
N
KD
KY
KST

(b)


Transform: Square root
Resemblance: S17 Bray Curtis similarity
2D Stress: 0.12
Habitat
M
O
F
KST
KY
KD

egrets, herons, and bittern in the present study. Water depth is known to play a crucial role in attracting waterbird communities (Zakaria and Rajpar 2013; Aboushiba et al. 2013; Clipp et al. 2017). Water depth affects waterbirds in terms of its physical morphology and feeding habits (Isola et al. 2000). Alcedinidae, consist of kingfisher, mostly can be found in the forest or open area near the water bodies (Kirschbaum 2004; Rajpar and Zakaria 2012) such as in mangrove habitat. Besides Ardeidae and Alcedinidae, there were also other waterbird families recorded in the study areas, such as Ciconiidae (storks), Rallidae (waterhen) and Scolopacidae (sandpiper). Hence, indicate that wetlands particularly mangrove habitat, are very important as they harbour various avian species from waterbird family and mangrove-specialists.

As mentioned earlier, mangrove habitats are classified into three zonation; seawards, middle and riverine zone or back mangrove, which differ in the flora species composition, salinity, distance from the sea and soil types. Wang et al. (2011) elaborate that true-mangroves can be found in seawards and middle zones, whereby mangroves-associates which dominated the riverine zone (back-mangroves) were characterized by their leaf characteristics and salt-tolerant features. True-mangrove plants consist of halophyte plants with higher salt tolerance and have several mechanisms that allow them to optimally grow in high salinity condition (Parida and Das 2005), thus they usually located near the river mouth and facing seaward. Present study found that the back mangroves (KY, KST and KD), which consist of glycophytic plants and brackish water with low salinity and higher vegetation density, exhibited lower bird species richness and diversity compared to their true-mangrove counterparts such as the Klang mangrove forest reserve (Rajpar and Zakaria 2009). Compared to studies in the seawards mangroves, their birds assemblages were dominant with mangrove-specialist (Noske 1995), as opposed to our study, which recorded a mixture of forest-specialist, open-country as well as mangrove-specialist species. The inland or back mangrove composed of brackish water vegetation forms, and the soils are predominantly heavy alluvial clay (Saw 2010). These features, apart from the distance from the seaward, making vegetation covers differ from that of the true mangrove counterparts, with a mixture of middle and landward zones mangrove forest (Turner 1977), including Rhizophoracea, Palmae, Moraceae and Euphorbacea (Saw 2010). This could explain the mixture of species assemblages between mangrove-specialists and other functional groups in the back mangrove sites.

The anthropogenic disturbance due to unsustainable mangroves resource use, such as exploitation for firewood, charcoal and timber, land reclamation for urban and industrial development, shrimp farming and dumping of pollutants has caused serious threat to this habitats (Upadhyay et al. 2002). This scenario undeniably has huge implication to the faunal diversity such as fishes, insects, plankton which are part of the food web in the mangrove ecosystem, and subsequently affects the bird community. In our study, different mangrove sites exhibit different level of anthropogenic disturbance, with KY exhibited the highest anthropogenic pressure, followed by KD and lowest was KST. KY faced highest anthropogenic pressure from massive reduction of mangrove coverage, increasing intensity of horticulture and oil palm plantation, new emergence of swamps from land burning and flooding, apart from urbanization. Similarly, KD also exhibited fairly high reduction of mangrove coverage, apart from intense horticulture and urbanization. KST on the other hand, was less impacted by urbanization, but there were intense aquaculture activities. In addition, the back-mangrove habitat were highly threatened by development especially areas that are close to urban centers (Jusoh and Hashim 2012), which also affect the population of fireflies in this areas. Carugati et al. (2018) found that meiofaunal diversity was significantly lower in the disturbed mangroves, which were likely linked to the extreme conditions (higher temperature and irradiation) characterizing the disturbed habitats, as well as lower organic matter availability. On another note, the high abundance of open-country birds explained high influence of anthropogenic activities and development surround the mangroves.

Mangrove habitat serves as important nursery ground for crustaceans and fishes (Lee et al. 2014), other than insects, which provides abundant food resources to birds and other higher vertebrate taxa. However, disruption of the mangrove ecosystem through anthropogenic activities, caused significant impact on the food resources, as demonstrated by the differences in species assemblages of birds in our study. KST, the less impacted sites with anthropogenic activities shows higher species richness, compared to KY and KD. However, the influenced of anthropogenic factors through urbanization, shrimp pond, garbage disposal, as well as oil palm plantation in these sites, was manifested by the high abundance of open country birds such as *Treron vernans*, *Hirundo tahitica,* and *Merops philippinus,* compared to the mangrove-dependent birds. In addition, patch quality and plant species richness were found to correlated with increase in forest-specialist species (Raman 2006; Lees and Peres 2006). Mangrove-dependent species were shown to prefer higher understorey vegetation density, due to the availability of arthropods and crustaceas (Mohd-Azlan et al, 2015). Therefore, habitat destruction due to anthropogenic activities clearly reduce the quality of the remaining patch and subsequently the bird richness. The high abundance of forest-specialist at KY was likely due to the high forest coverage as indicated in the land use analysis. Apart from that, KD and KST exhibit higher abundance of several feeding guild types such as carnivores, and frugivores, whereas, KY was higher in omnivores species. Rainforest patches provide a more heterogeneous vegetation structure as compared to relatively homogeneous mangrove stands, which in turn provide additional foraging niches that potentially enable birds from within the mangroves and the adjacent matrix to coexist (Raman 2006; Mohd-Azlan and Lawes 2011). However, according to the perfection correlation circle from the nMDS analysis, insectivores species were not restricted at the back-mangrove habitats, but more likely to be more general in distribution, although this feeding guild make up the biggest proportion of feeding guild among the study sites. On the other hand, Mohd-Azlan et al. (2015) found two-third of the species composition in the true-mangroves forests are insectivorous, which explain the dominance of this feeding guild in mangroves ecosystem. In addition, high abundance of nectarivores in the both areas serve as pollinators of the mangrove vegetations.

On another instance, both KD and KST are located on the located on the west coast of the Peninsular Malaysia, whereby KY on the east coast. The higher species richness, diversity and similarity in species assemblages shown in the west coast sites, compared to east-coast could also be due to the location of these sites on different coastal areas of the peninsular. The west-coast mangroves exhibit especially higher abundance of mangroves-specialist and open country species than east-coast mangroves, which were highly dominant with forest-specialist species. According to Saw (2010), at the east coast of Peninsular Malaysia, the annual monsoons prevent development of large muddy shores in many of the rivers draining out to the South China Sea. The mangroves here are confined to sheltered river mouths and estuaries, thus explain the low abundance of the mangrove-specialist, particularly from family Alcedinidae (kingfishers) and Ardeidae (egrets, herons) of carnivorous group. In contrast, muddy shores, lagoons and muddy estuaries of tidal rivers fringe a large extent of the west-coast coastline, therefore securing habitat for a lot of mangrove-dependent species, as shown in our study. West coast regions composed more areas of wetland, shoreline, marshes, mangrove and agriculture (paddy) compared to the east coast region (Zainul-Abidin et al. 2017), thus sustains the habitat and flyway route of water bird species, particularly along Peninsular Malaysia (Li et al. 2007). This explains the high abundance and species assemblages of carnivorous feeding guild, especially referred to water birds, on the west-coast of peninsular.

Conclusion

The presence of various bird species in mangrove habitat, which currently threatened worldwide, has the potential to attract tourists, as well as highlighting the need to promote mangrove conservation and restoration. An understanding of bird's functional groups, coupled with the level of anthropogenic disturbance in an area are important for distinguishing the habitat quality and level of habitat degradation, subsequently could aid in decision making and conservation planning (Kati and Sekercioglu 2006). Continuous degradation of the mangrove forest due to agricultural expansion, and overexploitation for charcoal industries as well as pollution will certainly affect the bird communities particular mangrove-specialist and mangrove-dependents. The presence of several highly protected species indicates the high conservation value of mangrove habitat. Retaining dense understorey vegetation and the diversity of mangrove zones, as well as limiting the anthropogenic disturbance are critical for maximizing the ecological balance of this habitat. This study is important as baseline information for mangrove restoration and eco-tourism in the mangrove ecosystem. Future study could incorporate the effects of other environmental parameters such as vegetation composition, insect abundance and diversity, and water quality.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by FSM-T, WM-S, RA, MSM, MA-M, and NA M-B. The first draft of the manuscript was written by FSM-T and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.Code availability: Software application or custom code.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Appendix

See Appendix in Table 5

Table 5 List of species and their abundance in different back-mangroves sites, based on residency status, IUCN status, feeding guilds and ecological niches

Family	Scientific name	Common name	Mangrove sites			Residency status	IUCN status	Feeding guilds	Ecological niches
			KY	KST	KD				
Accipitridae	*Spilornis cheela*	Crested serpent eagle	5	21	10	R	LC	C	M
	Haliastur indus	Brahminy Kite	2	0	12	R	LC	C	M
	Haliaeetus leucogaster	White-bellied Sea Eagle	2	5	3	R	LC	C	O
	Aviceda leuphotes	Black Baza	0	0	1	M	LC	C	F
	Nisaetus nanus	Wallace's Hawk-eagle	0	0	1	R	VU	C	F
	Elanus axillaris	Black-shouldered Kite	0	2	0	R	LC	C	O
	Milvus migrans	Black Kite	0	1	0	M	LC	C	O
Alcedinidae	*Halcyon pileata*	Black-capped Kingfisher	29	2	2	M	LC	C	M
	Pelargopsis capensis	Stork-billed Kingfisher	15	2	8	R	LC	C	M
	Alcedo atthis	Common Kingfisher	1	0	0	M	LC	C	M
	Halicyon smyrnensis	White Throated Kingfisher	2	6	1	R	LC	C	O
	Todiramphus chloris	Collared Kingfisher	3	1	8	R	LC	C	M
	Ceyx erithaca	Oriental Dwarf-kingfisher	1	0	1	M	LC	C	M
	Alcedo meninting	Blue-eared Kingfisher	0	1	4	R	LC	C	M
	Halcyon coromanda	Ruddy Kingfisher	1	0	0	R	LC	C	M
Ardeidae	*Butorides striata*	Little Heron	18	6	31	R&M	LC	C	M
	Egretta garzetta	Little Egret	8	17	63	R&M	LC	C	M
	Ardeola bacchus	Chinese Pond-heron	4	0	0	M	LC	C	M
	Ardea cinerea	Grey Heron	0	4	9	R	LC	C	M
	Nycticorax nycticorax	Black-crowned Night-heron	0	0	5	R	LC	C	M
	Ardea alba	Great Egret	0	98	17	R&M	LC	C	M
	Ardea purpurea	Purple Heron	0	0	16	R&M	LC	C	M
	Ixobrychus cinnamomeus	Cinnamon Bittern	1	0	0	R&M	LC	C	O

Table 5 continued

Family	Scientific name	Common name	Mangrove sites			Residency status	IUCN status	Feeding guilds	Ecological niches
			KY	KST	KD				
Bucerotidae	*Anthracoceros malayanus*	Black Hornbill	3	4	0	R	NT	O	F
	Anthracoceros albirostris	Oriental Pied Hornbill	2	2	0	R	LC	O	F
Campephagidae	*Lalage nigra*	Pied Triller	0	1	0	R	LC	I	M
Caprimulgidae	*Lyncornis temminckii*	Malaysian Eared Nightjar	1	0	0	R	LC	I	F
	Caprimulgus affinis	Savanna Nightjar	1	0	0	R	LC	I	O
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	0	2	0	R	LC	O	O
Ciconiidae	*Leptoptilos javanicus*	Lesser Adjutant	2	0	0	R	VU	C	M
Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia	0	0	1	R	LC	I	O
Columbidae	*Treron vernans*	Pink-necked Green Pigeon	17	55	10	R	LC	F	O
	Treron curvirostra	Thick-billed Green Pigeon	0	0	24	R	LC	F	F
	Spilopelia chinensis	Spotted Dove	0	7	4	R	LC	G	O
	Geopelia striata	Zebra Dove	0	0	17	R	LC	G	O
	Chalcophaps indica	Emerald Dove	0	1	0	R	LC	G	F
Coraciidae	*Eurystomus orientalis*	Dollarbird	33	35	27	R	LC	I	O
Corvidae	*Corvus macrorhynchos*	Large-billed Crow	3	0	0	R	LC	O	O
	Corvus splendens Vieillot	House Crow	0	0	4	R	LC	O	O
Cuculidae	*Eudynamys scolopaceus*	Asian Koel	4	0	12	R&M	LC	F	O
	Centropus sinensis	Greater Coucal	0	6	4	R	LC	O	O
	Phaenicophaeus diardi	Black-bellied Malkoha	0	1	8	R	NT	O	F
	Clamator coromandus	Chestnut-winged Cuckoo	0	2	6	M	LC	I	M
	Rhinortha chlorophaea	Raffles's Malkoha	0	1	0	R	LC	O	F
	Centropus bengalensis	Lesser Coucal	0	0	1	R	LC	O	O
Dicaeidae	*Dicaeum trigonostigma*	Orange-bellied Flowerpecker	1	0	0	R	LC	F	O
	Dicaeum cruentatum	Scarlet-backed Flowerpecker	4	0	0	R	LC	F	M
Dicruridae	*Dicrurus paradiseus*	Greater Racquet-tailed Drongo	9	28	0	R	LC	I	F
Falconidae	*Microhierax fringillarius*	Black-thighed Falconet	0	0	2	R	LC	C	F
Hirundinidae	*Hirundo tahitica*	Pacific Swallow	32	159	0	R	LC	I	O
	Hirundo rustica	Barn Swallow	0	34	0	M	LC	I	O
Laniidae	*Lanius cristatus*	Brown Shrike	0	3	4	R	LC	C	O
	Lanius tigrinus	Tiger Shrike	0	1	2	R	LC	C	F

Table 5 continued

Family	Scientific name	Common name	Mangrove sites			Residency status	IUCN status	Feeding guilds	Ecological niches
			KY	KST	KD				
Megalaimidae	*Psilopogon haemacephalus*	Coppersmith Barbet	0	0	1	R	LC	F	O
Meropidae	*Merops philippinus*	Blue-tailed Bee-eater	0	110	3	R&M	LC	I	O
	Merops viridis	Blue-throated Bee-eater	0	40	0	R&M	LC	I	O
Muscicapidae	*Kittacincla malabarica*	White-rumped Shama	1	0	0	R	LC	I	F
	Muscicapa dauurica	Asian Brown Flycatcher	0	0	1	M	LC	I	F
	Cyornis rubeculoides	Blue-throated Blue-flycatcher	0	0	1	M	LC	I	F
	Cyornis rufigastra	Mangrove Blue-flycatcher	0	0	1	R	LC	I	M
Nectariniidae	*Chalcoparia singalensis*	Ruby-cheeked Sunbird	3	0	0	R	LC	N	F
	Leptocoma calcostetha	Copper-throated Sunbird	4	0	0	R	LC	N	M
	Anthreptes rhodolaemus	Red-throated Sunbird	2	0	0	R	NT	N	F
	Aethopyga siparaja	Crimson Sunbird	2	2	0	R	LC	N	F
	Anthreptes malacensis	Brown-throated Sunbird	2	0	4	R	LC	N	M
	Arachnothera hypogrammica	Purple-naped Sunbird	0	1	0	R	LC	N	F
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	0	5	0	R&M	LC	F	O
Passeridae	*Passer flaveolus*	Plain-backed Sparrow	0	0	1	R	LC	G	O
Picidae	*Picoides moluccensis*	Sunda Pygmy Woodpecker	1	0	0	R	LC	I	M
	Dinopium javanense	Common Flameback	0	24	1	R	LC	I	M
	Micropternus brachyurus	Rufous Woodpecker	0	0	1	R	LC	I	F
	Chrysophlegma miniaceum	Banded Woodpecker	0	2	2	R	LC	I	F
	Picus puniceus	Crimson-winged Woodpecker	0	1	0	R	LC	I	F
	Picus vittatus	Laced Woodpecker	0	3	0	R	LC	I	M
Pittidae	*Pitta moluccensis*	Blue-winged Pitta	0	2	0	R&M	LC	C	F
Psittacidae	*Psittacula longicauda*	Long-tailed Parakeet	0	21	0	R	NT	F	M
Pycnonotidae	*Pycnonotus brunneus*	Red-eyed Bulbul	2	14	2	R	LC	F	F
	Brachypodius atriceps	Black-headed Bulbul	1	0	0	R	LC	F	F
	Pycnonotus plumosus	Olive-winged Bulbul	1	7	0	R	LC	F	F
	Pycnonotus erythropthalmos	Spectacled Bulbul	0	1	0	R	LC	F	F
	Pycnonotus goiavier	Yellow-vented Bulbul	0	4	32	R	LC	O	O
	Pycnonotus blanfordi	Streak-eared Bulbul	0	5	0	R	LC	F	O
	Pycnonotus simplex	Cream-vented Bulbul	2	0	0	R	LC	F	F
Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	3	3	6	R	LC	O	O
Rhipiduridae	*Rhipidura javanica*	Sunda Pied Fantail	1	0	1	R	LC	I	M
Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	0	2	0	M	LC	O	O

Table 5 continued

Family	Scientific name	Common name	Mangrove sites			Residency status	IUCN status	Feeding guilds	Ecological niches
			KY	KST	KD				
Strigidae	*Ketupa ketupu*	Buffy Fish-owl	0	0	2	R	LC	C	M
	Otus lettia	Collared Scops-owl	3	0	0	R	LC	C	F
	Otus rufescens	Reddish Scops-owl	0	1	0	R	NT	C	F
	Otus sunia	Oriental Scops-owl	0	1	0	M	LC	C	F
Sturnidae	*Aplonis panayensis*	Asian glossy starling	6	45	12	R	LC	F	O
	Gracula regiliosa	Common Hill Myna	2	0	0	R	LC	O	F
	Acridotheres tristis	Common Myna	0	0	68	R	LC	O	O
	Acridotheres fuscus	Jungle Myna	0	73	0	R	LC	O	M
Sylviidae	*Orthotomus ruficeps*	Ashy Tailorbird	0	0	2	R	LC	I	M
Turdidae	*Copsychus saularis*	Oriental Magpie-robin	0	9	8	R	LC	I	O
Tytonidae	*Tyto alba*	Common Barn-owl	9	0	0	R	LC	O	O

Location: *KY* Kg. Yakyah, *KST* Kg. Sungai Timun, *KD* Kg. Dew

Residency status: *R* resident, *M* migrant

Feeding guilds: *I* insectivore, *C* carnivore, *O* omnivore, *F* frugivore, *G* granivore

IUCN Status: *LC* least concern, *VU* vulnerable, *NT* near threatened

Ecological niches*:* *M* mangrove, *F* forest, *O* open

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