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IMPLICATIONS OF PATCH SIZE AND LANDSCAPE MATRIX TOWARDS NATIVE-FOREST BIRD SPECIES IN FRAGMENTED FORESTS

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ABSTRACT

Forest fragmentation has been one of the major issues in urban landscape due to anthropogenic activities. It produces remnants of forest patches, which were originally large and continuous forest. Forest fragmentation will adversely impact on forest fauna diversity. However, the impacts are dependent on the type and characteristic of the forest remnants itself. This study therefore investigated species composition of birds within fragmented forest in the state of Selangor. Six remnants of forest reserves located in the midst of urban landscape that vary in size and landscape matrix were chosen. Methods used were mist-netting and direct observation. A total of 83 species of birds have been recorded in all sites. Native-forest species are species that depends solely on forest for their livelihood. Larger percentage of native-forest species were found in the larger forest compared to smaller forest suggesting that smaller forest are more vulnerable towards invasion of non-forest species. This however is highly supported by the landscape matrix that surrounds the forest. In conclusion, landscape matrix other than forest size were found to be the major factor that influenced the capacity of the forest to maintain more native-forest species. However,further studies need to be carried out at a larger experimental scale to test this theory.

Key words: forest fragmentation, native-forest birds, species richness, urban landscape and Selangor

INTRODUCTION

Forest fragmentation occurs when a large continuous forest is reduced into smaller fragments which are isolated by surroundings resulting from anthropogenic activities. It also includes a subdivision of forest patches into more isolated fragments by expanding urban areas, agriculture and other types of land uses (Sodhi *et al.*, 2011). Area effect in conjunction to the island biogeographic theory (IBT) has spurred the traditional knowledge that larger fragments always holds more species than smaller ones. However, this has been argued by Simberloff and Abele (1976) through the SLOSS debate (Single Large or Several Small) which centered on whether single large or several small would be more effective in preserving species. There are a number of study supporting larger continuous forests are better at preserving tropical forest birds throughout the world such as Watson *et al.* (2004) in Madagascar, and Van Balen (1999) in Java island. This was also further supported by Ramli (2004) in his study of diversity of birds in fragmented forests in Kuala Lumpur, Malaysia where larger forest composed of higher species richness and diversity compared to the smaller ones.

Fragmented forest carries an edge-effect which dependent upon the size and shape of the fragment. Smaller fragments were proven to be greatly influenced by edge-effect and smaller internal size core is less suitable as habitat and shelter for forest specialist birds (Saunders *et al.,* 1991). In contrast, larger fragments have better quality of internal core therefore not influenced by environmental disturbance and abiotic factors related to edge-effect (Laurrence, 1991). However, Fischer and Lindenmayer (2002) in their study on the value of small fragments towards birds in South Australia discovered that, majority of bird species are not confined to large fragments alone, as small fragments compliment the larger fragments efficiently in conservation.

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Native-forest species generally depends on primary forests, but disturbance and changes in the forests structure has resulted in loss of these species and increase in generalist or non-forest species (Sodhi *et al.*, 2011). Higher edge-effect will contribute to higher disturbance of the forest and forest bird community by increasing the number of 'forest-avoiding' generalist predator. Surrounding matrix could play an important role in buffering edge effects, and protecting fragments from the most extreme conditions of the matrix. A more favorable matrix can help buffer against species loss (Watson *et al.,* 2005) and allow movement of birds and other fauna by connecting one fragment to another. A study carried out in Andean forest, 20% of the forest species that declined in fragments surrounded by cattle pasture persisted in the fragments surrounded by tree plantations (Renjifo, 2001). In order to test these fragmentation theories in our local environment, this study is thus conducted to investigate the implications of forest size and their surrounding matrix towards native-forest bird species. This study is performed in several forest fragments in the state of Selangor.

MATERIALS AND METHODS

The study was conducted from December 2010 to June 2011. This study was carried out in 6 forest fragments of different sizes and intensity of disturbance, located within the state of Selangor (Fig. 1); Bukit Nanas Forest Reserve (BN), Sungai Puteh FR (SP), Sungai Besi FR (SB), Bangi FR (Bangi), Kota Damansara FR (KD) and Ayer Hitam FR (AH). The study area were primarily large and continuous forests, shrunk from their original size and some were even subdivided to several remnants resulting from development processes. The area of the forests ranged from 10 ha to 1200 ha. Table 1 listed general description of each study sites.

Landscape matrixes were measured according to the land use types obtained from land use map of year 2008. A 1 km buffer was constructed surrounding each fragment (Fig. 2), using the ArcGIS software. Percentage of each land use types were then generated from the 1 km buffer, which was referred as the landscape matrix.

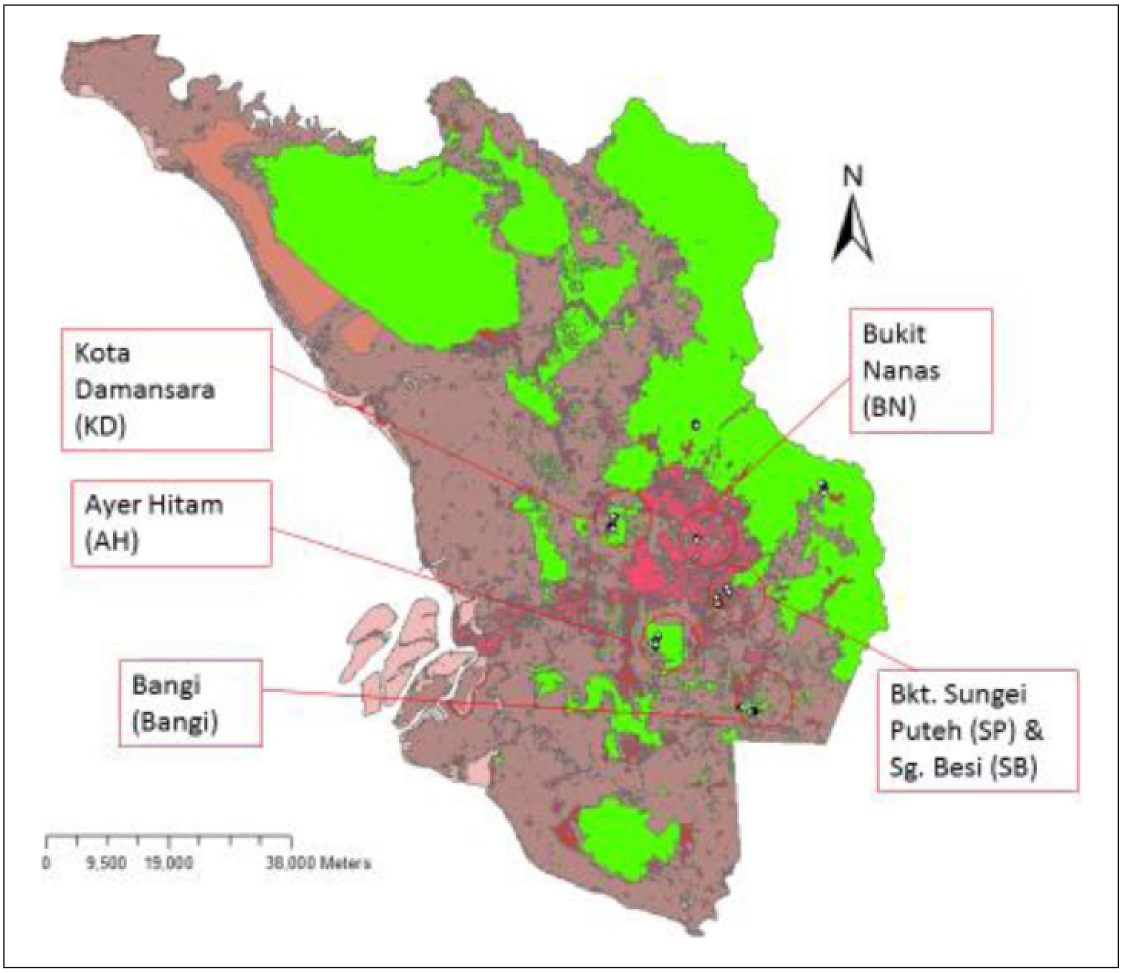

Fig. 1. Location of the study areas in Selangor State and Kuala Lumpur.

Table 1. General description size and landscape matrix of selected forest fragments in Selangor

Forest fragment	Size (ha)	Matrix
Bukit Sungai Puteh (SP)	7.4	Roads, urbanized areas, residential areas. Reforestation was carried out in some part by the forest department.
Bukit Nanas (BN)	10.52	Rapid urban in the heart of Kuala Lumpur metropolitan city.
Sungai Besi (SB)	42.11	Located at the hill terrain. Army camp and electrical substation.
Bangi (Bangi)	100	Moderate urbanized areas, residential villages, some oil palm plantation.
Kota Damansara (KD)	321.7	Residential areas, water reservoir, urbanized areas.
Ayer Hitam (AH)	1217.9	High density residential areas, urbanized areas.

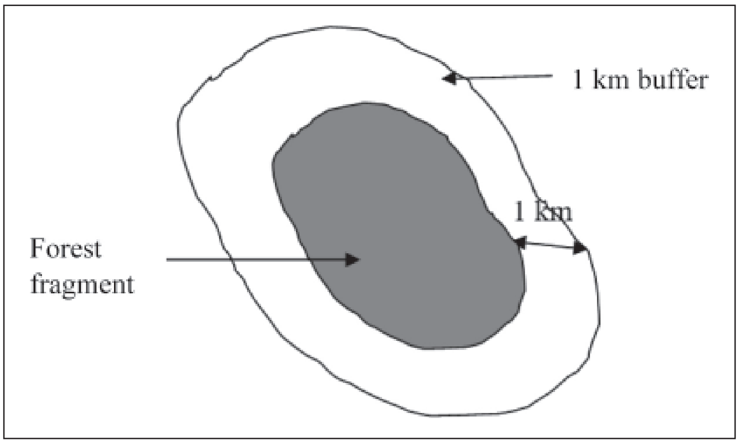

Fig. 2. Illustration of buffer zones surrounding the fragments.

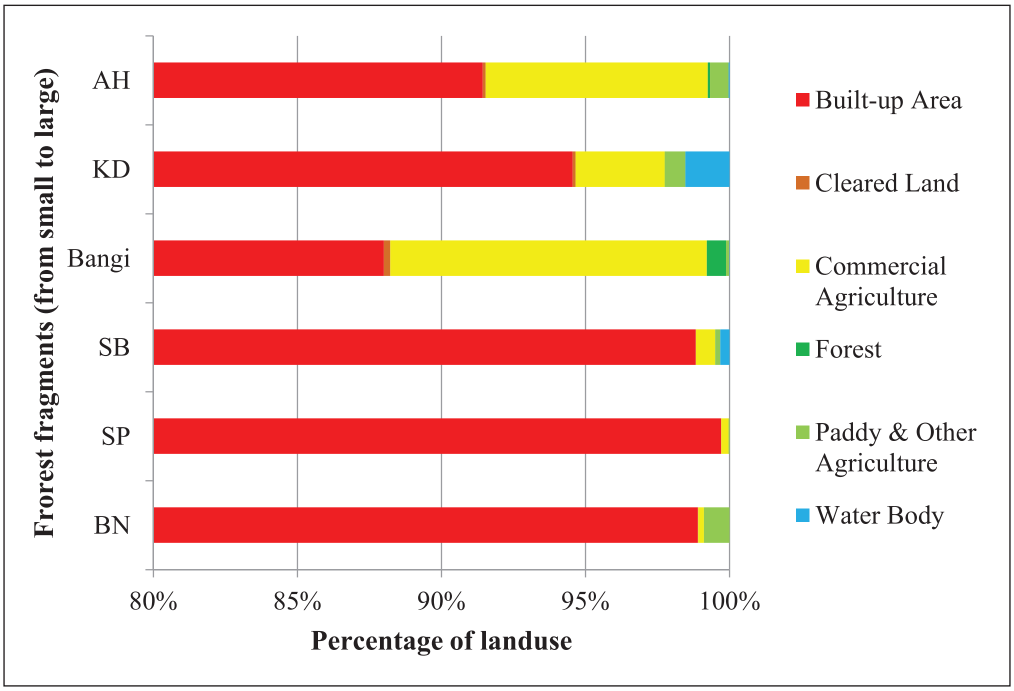

Fig. 3. Percentage of land use types in 1km buffer zones of each forest fragments.

In each fragment, two established trail, chosen randomly were represented as 1 km transect-line. The sampling was carried out for 10 continuous days in every sites but not in one year cycle due to limited capacity of sampling time. A total of 20 mist-nets with a dimension of 2.5x12 m and a distance of 100 m from one another were set up along the transect line. These nets were set up at understorey level and opened at dawn (0700 h) and closed at dusk (1900 h). There were checked every hour. All captured birds were weighed, measured and ringed with a numbered aluminium tag (provided by Department of Wildlife and National Park) and then released at the site of capture. Point-count observation with 10 minutes time allocated at each point was also carried out along the transect line in the morning (0700 to 1000 hour) and evening (1600 to 1800 hour) throughout the study period. Identification and classification of native and non-native forest species were made based on Jeyarajasingam (2012). Data analysis only involves species occurrence, but not abundance.

To understand relationship between communities among study sites, similarity and composition of species were performed by Cluster Analysis based on the Jaccard Coeffision of Similarity with unweighted pair-group method (UPGMA) and dendrogram by using Multi-variate Statistical Package (MVSP) version 3.13d.

RESULTS

Landscape matrix

Fig. 4 shows percentage of land use in buffer zones for each study sites in 2005. From this analysis, almost 100% of the landscape matrix were surrounded with built-up areas, especially the small fragments BN, SP and SB. Built-up areas may consists of urban areas, as well as residential areas. The larger fragments on the other hand, consist of commercial and other agriculture such as oil palm plantation, rubber plantations and orchards in their matrix. Bangi, unlike other fragments was buffered with about 1% of forest. KD the second largest fragment, even though having higher percentage of built-up areas, compared to the largest fragment, AH, it has 2 large water reservoir within the landscape matrix. This contribute to higher species richness of birds due to the additional food resources provided by the water reservoir. AH on the other hand dominated mainly by residential as well as urban areas.

Species composition

A total of 83 bird species were recorded in all six forest fragments, with 71 species categorized as native-forest species (Table 2). Family Pyncnonotidae is the dominant family comprised of 7 species. KD has the highest species richness with 53 species, followed by Bangi with 42 species and SB with 29 species whereby the least bird species recorded in BN with only 17 species, followed by SP with 24 species. Result from this study generally account for more species in larger forest. This trend is almost similar to the number of native forest species, where KD recorded the higher proportion of native forest species with 42 out of 53 species, followed by Bangi with 34 out of 42 species and SB with 23 out of 29 species. In contrast, AH, consists of lower proportion of native forest species where only 21 out of 28 species are native forest species. BN and SP the two smallest fragments as expected composed of lower proportion of native forest species and higher proportion of non-forest species. Fig. 4 summarized the number of species recorded in all study sites.

In terms of native forest species, Bangi composed of the highest composition of native-forest species with 81% from total number of species captured in the site. This is followed by KD and SB with 79% both and AH with 75%. The smallest fragment, BN on the other hand consists of the lowest native-forest species with 59%, followed by SP with 67% of total species recorded at both sites. The common tailorbird (*Orthotomus sutorius*), a native-forest bird species, was recorded in all six forest fragments. These forests however, share 3 non-forest species which were the Common Iora (*Aegithina tiphia*), Yellow-vented Bulbul (*Pycnonotus goiavier*) and Asian Glossy Starling (*Aplonis panayensis*). Presence of non-forest species is a characteristic of disturbed forest. Besides that, there were other common non-forest species such as Magpie Robin (*Copsychus saularis*), White-throated Kingfisher (*Halcyon smyrnensis*), Blue throated Bee-eater (*Merop sviridis*), Black-naped Oriole (*Oriolus chinensis*) and Common Myna (*Acridotheres tristis*). This study also shows number of native-forest species increase with increasing fragment size, but with exception of AH.

An estimate of similarity index performed with Cluster Analysis (Fig. 3) shows that KD and Bangi were clustered in the same group whereby other sites were clumped in another group. The first group represents fragments with high species richness. The second group which encompassed lower species richness on the other hand, was chained to 2 clusters with AH is a group on its own while SB, SP and BN were clumped together. This analysis also shows SP and BN have the most similar species composition with a Euclidean distance of 5.00. AH on the other hand, is the least similar to BN, SP and SB, due to its size and landscape matrix characteristics.

There were 8 species categorized as 'near-threatened' according to IUCN Red Data List. Two

Table 2. Species list found in each forest fragments with Species type and Conservation status

Family	Common name	Species	Type	Status	BN	SP	SB	Bangi	KD	AH
Accipitridae	Crested serpent eagle	*Spilomis cheela*	forest			/	/	/	/	/
Aegithinidae	Common iora	*Aegithina tiphia*	non-forest		/	/	/	/	/	/
Aegithinidae	Great Iora	*Aegithina lafresnayei*	forest					/		
Alcedinidae	Banded kingfisher	*Lacedo pulchella*	forest							/
Alcedinidae	Oriental dwarf kingfisher	*Ceyx erithacus*	forest							/
Alcedinidae	Ruddy kingfisher	*Halcyon coromanda*	forest							/
Alcedinidae	White-throated kingfisher	*Halcyon smyrnensis*	non-forest			/		/	/	/
Bucerotidae	Black hornbill	*Anthracoceros malayanus*	forest	NT					/	
Bucerotidae	Oriental Pied hornbill	*Anthracoceros albirostris*	forest			/				
Caprimulgidae	Large-tailed nightjar	*Caprimulgus macrurus*	forest				/			
Chloropseidae	Greater green leafbird	*Chloropsis sonnerati*	forest			/	/	/		/
Columbidae	Green-winged pigeon	*Chalcophaps indica*	forest				/	/	/	
Columbidae	Pink-necked pigeon	*Treron vernans*	non-forest							
Columbidae	Zebra dove	*Geopelia striata*	forest		/		/	/	/	/
Coraciidae	Dollarbird	*Eurystomus orientalis*	non-forest					/	/	
Corvidae	Black magpie	*Platysmurus leucopterus*	forest						/	
Corvidae	House crow	*Corvus splendens*	non-forest		/	/			/	
Cuculidae	Asian koel	*Eudynamys scolopacea*	forest		/				/	
Cuculidae	Greater coucal	*Centropus sinensis*	forest				/			
Cuculidae	Indian cuckoo	*Cuculus micropterus*	forest			/			/	
Cuculidae	Plaintive cuckoo	*Cacomantis merulinus*	forest						/	
Cuculidae	Raffles malkoha	*Phaenicophaeus chlorophaeus*	forest					/		
Cuculidae	Rusty-breasted cuckoo	*Cacomantis sepulcralis*	forest						/	
Dicaeidae	Crimson-breasted flowerpecker	*Prionochilus persussus*	forest		/		/	/	/	
Dicaeidae	Orange-bellied flowerpecker	*Dicaeum trigonostigma*	forest						/	
Dicruridae	Crow-billed drongo	*Dicrurus annectans*	forest			/				
Dicruridae	Greater racket-tailed drongo	*Dicrurus paradiseus*	forest				/	/	/	/
Dicruridae	Lesser racket-tailed drongo	*Dicrurus remifer*	forest			/	/	/		
Eurylaimidae	Black-and-yellow broadbill	*Eurylaimus ochromalus*	forest	NT					/	
Eurylaimidae	Black-red broadbill	*Cymbirhynchus macrorhynchus*	forest						/	
Falconidae	Black-tighed Falconet	*Microhierax fringillarius*	forest						/	
Ireniidae	Asian fairy bluebird	*Irena puella*	forest					/		
Laniidae	Brown shrike	*Lanius cristatus*	non-forest							/
Laniidae	Tiger shrike	*Lanius tigrinus*	forest		/		/	/	/	/
Megalaimidae	Gold whiskered barbet	*Megalaima chrysopogon*	forest					/	/	/
Megalaimidae	Yellow-crowned barbet	*Megalaima henricii*	forest	NT				/	/	
Meropidae	Blue throated bee-eater	*Merops viridis*	non-forest			/	/	/	/	/
Monarchidae	Asian paradise flycatcher	*Terpsiphone paradisi*	forest					/		
Motacillidae	Richard's pipit	*Anthus richardi*	non-forest				/		/	
Muscicapidae	Asian Brown flycatcher	*Muscicapa dauurica*	forest						/	/

Table 1 continued...

Muscicapidae	Brown-chested jungle flycatcher	*Rhinomyias brunneatus*	forest	VU	/					
Muscicapidae	Green-backed flycatcher	*Ficedula elisae*	forest					/		
Muscicapidae	Little pied flycatcher	*Ficedula westermanni*	forest				/			
Muscicapidae	Yellow-rumped flycatcher	*Ficedula zanthopygia*	forest					/		/
Nectariniidae	Little spiderhunter	*Arachnothera longirostra*	forest			/	/	/	/	/
Nectariniidae	Purple-naped sunbird	*Hypogramma hypogrammicum*	forest					/	/	
Nectariniidae	Purple-throated sunbird	*Nectarinia sperata*	forest				/			
Nectariniidae	Ruby-cheeked sunbird	*Anthreptes singalensis*	forest			/				
Oriolidae	Black-naped oriole	*Oriolus chinensis*	non-forest		/	/		/	/	
Phasianidae	Red jungle fowl	*Gallus gallus*	forest					/	/	
Picidae	Buff-necked woodpecker	*Meiglyptes tukki*	forest	NT			/	/	/	/
Picidae	Crimson-winged woodpecker	*Picus puniceus*	forest				/		/	
Pittidae	Blue-winged pitta	*Pitta moluccensis*	forest							/
Pittidae	Hooded Pitta	*Pitta sordida*	forest		/					
Ploceidae	Baya weaver	*Ploceus philippinus*					/			
Pycnonotidae	Black-headed bulbul	*Pycnonotus atriceps*	forest					/	/	
Pycnonotidae	Cream-vented bulbul	*Pycnonotus simplex*	forest					/		/
Pycnonotidae	Olive-winged bulbul	*Pycnonotus plumosus*	forest			/	/			
Pycnonotidae	Red-eyed bulbul	*Pycnonotus brunneus*	forest			/	/	/	/	
Pycnonotidae	Spectacled bulbul	*Pycnonotus erytropthalmos*	forest				/		/	
Pycnonotidae	Stripe-throated bulbul	*Pycnonotus finlaysoni*	forest			/			/	
Pycnonotidae	Yellow-vented bulbul	*Pycnonotus goiavier*	non-forest		/	/	/	/		/
Rallidae	White-breasted waterhen	*Amaurornis phoenicurus*							/	
Rhipiduridae	Pied fantail	*Rhipidura javanica*	forest						/	
Strigidae	Collared scops owl	*Otus bakkamonea*	forest		/		/	/	/	
Strigidae	Oriental scops owl	*Otus sunia*	forest			/			/	/
Strigidae	Reddish scops owl	*Otus rufescens*	forest	NT				/	/	
Sturnidae	Common myna	*Acridotheres tristis*	non-forest		/		/	/	/	
Sturnidae	Hill myna	*Gracula religiosa*	forest					/	/	/
Sturnidae	Jungle myna	*Acridotheres fuscus*	non-forest						/	
Sturniidae	Asian glossy starling	*Aplonis panayensis*	non-forest		/	/	/	/	/	/
Sylviidae	Ashy tailorbird	*Orthotomus ruficeps*	forest				/			
Sylviidae	Common tailorbird	*Orthotomus sutorius*	forest		/	/	/	/	/	/
Sylviidae	Dark-necked tailorbird	*Orthotomus astrogularis*	forest							/
Sylviidae	Rufous-tailed tailorbird	*Orthotomus sericeus*	forest					/		
Timaliidae	Black-capped babbler	*Pellorneum capistratum*	forest					/		
Timaliidae	Chestnut-winged babbler	*Stachyris erythroptera*	forest							/
Timaliidae	Fluffy-backed Tit babbler	*Macronous ptilosus*	forest	NT				/	/	
Timaliidae	Short-tailed babbler	*Malacocincla malaccensis*	forest	NT		/		/	/	/
Timaliidae	Stripe-tit babbler	*Macronous gularis*	forest			/	/	/	/	/
Turdidae	Magpie robin	*Copsychus saularis*	forest/ non-forest		/	/		/	/	/
Turdidae	Siberian blue robin	*Luscinia cyane*	forest		/			/	/	/
Turdidae	White-rumped shama	*Copsychus malabaricus*	forest		/	/	/	/	/	

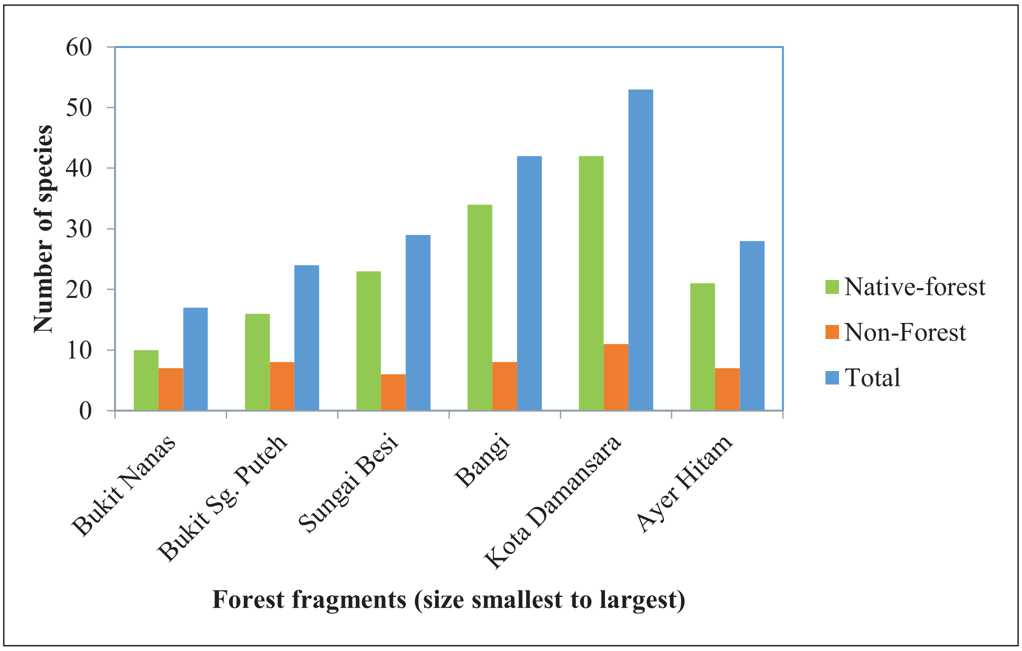

Fig. 4. Number of species found according to species types in every forest fragments.

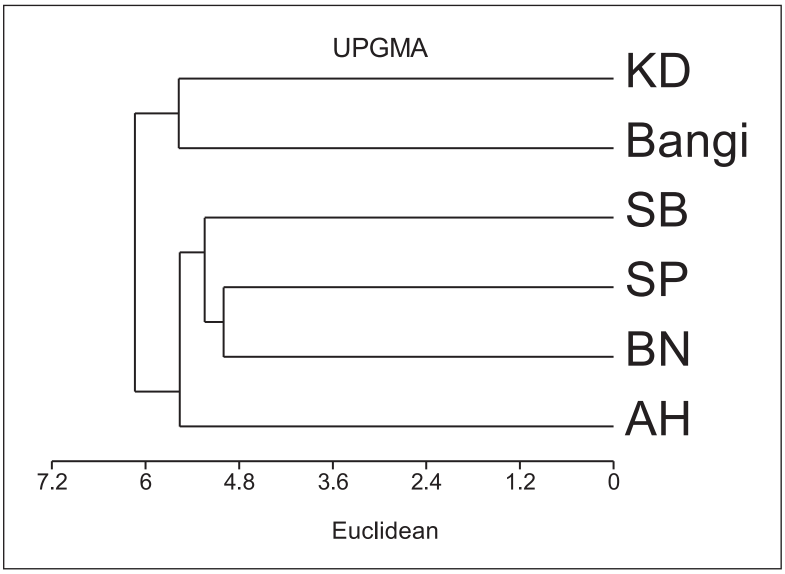

Fig. 5. Similarity index with Euclidean distance among study areas using Cluster Analysis.

species were exclusive to KD; Black hornbill (*Anthracoceros malayanus*) and Black-and-yellow broadbill (*Eurylaimus ochromalus*). The others were Yellow-crowned barbet (*Megalaima henricii*), Buff-necked woodpecker (*Meiglyptes tukki*), Reddish scops owl (*Otus rufescens*), Fluffy-backed Tit babbler (*Macronous ptilosus*) and Short-tailed babbler (*Malacocincla malaccensis*). BN, despite being among the smallest size fragments and also having the lowest species richness, recorded Brown-chested jungle flycatcher (*Rhinomyias brunneatus*), a species listed as 'vulnerable' according to IUCN Red Data List.

DISCUSSION

Fragment size

Many studies show that fragment size is a good predictor of species richness of native-forest birds in fragmented forest. For instance, species richness of forest-dependent birds increased with fragment size in the Cerrado region of Central Brazil (Marini, 2001). Castelletta (2005) found that patch area had the strongest influence on the current species richness of Singapore island. Our study also shows similar trend in general with exception to AH. This can be further explained by edge-effect and landscape matrix of the forest. Isolation might not be the factor in this study as these forests, and in fact all the forest fragments in our study areas were highly isolated in the midst of urban development. A distance as short as 100m may be a barrier that many tropical forest birds are highly reluctant, if not unable to cross (Stouffer and Bierregaard, 1995). Therefore, connectivity is unlikely to be the factor. Native-forest species were also more abundance in the bigger forest indicating these forests provide a habitable place and ample food resources for the birds and other fauna.

Landscape matrix

AH, despite its large size, are isolated in the midst of residential and urban areas. Apart from being oppressed by development pressure surrounding this forest, the low species richness might be due to the breeding season of most bird and also the rainy weather during when the fieldwork was carried out. It also contradicts to the previous study done by Zakaria and Rahim (1999) who recorded 160 species of birds in this forest. However, this may differ in study effort and time of study.

Edge-effect may be so important that they can even swamp the area-related effects of fragmentation (Ewers and Didham, 2006). KD as being the second largest fragment, accounted for the highest number of species, with 79% of them are native-forest species. The two large water reservoirs in the forest may be providing the fauna with additional food resources, especially to insectivorous birds. Apart from that, in some part of the forest edge, there were subtle change of landscape matrix where the forest are surrounded by grassy open-land which serve as stepping stone for the birds. Banks-Leite (2010) in his study on the importance of edge-related effects on tropical birds suggested that many of the area-related effects on birds in fragmented landscapes may in fact be explained by edge-effects and demonstrate the importance of maintaining larger and more regularly shaped fragments wherever possible.

Bangi on the other hand accounted for the highest percentage of native-forest species (81%). This forest partly located within the UKM campus, by chance had a lot of fruiting trees planted around the campus. This provides additional food resources especially to the frugivorous. Herrera (2009) in his study of role of remnant trees within the non-forest matrix demonstrates that in the period of low fruit availability, forest frugivorous are forced to exploit scattered fruit resources, therefore the role of remnant trees may even be equivalent to that played by forest trees. BN fragment contrastingly, recorded the lowest number of species and also the lowest percentage of native-forest species (59%). This forest is subjected to the highest pressure due to urbanization. Located in the midst of KL city, it is having the most severe isolation and edge-effect. The forest inhabitants especially the sedentary birds are confined to this forest which limits their availability to withstand the effect of fragmentation. The most extinction-prone forest bird would be those that suffered from relative immobility (Houtan *et al.*, 2007). Therefore, an important conservation implication of these findings is the importance of the matrix surrounding forest remnants. In addition to providing habitat to many forest species, the non-forest matrix plays an important role in the dispersal of even forest-obligate birds (Sekercioglu, 2007).

In conclusion, patch area and landscape matrix are the two most important factors that influenced the capacity of the forest to harbor fauna species. In order to preserve these forests, we need to maintain their current size and avoid more forest depletion in the future. Apart from that, we would advocate an integrated land-management approach which tries not only to maintain but also to increase the presence of scattered trees over the deforested matrix. This would ultimately act as a passive restoration strategy of the fragmented landscapes.

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REFERENCES

Bank-Leite, C., Ewers, R.M. & Metzger, J.P. 2010. Edge effects as the principal cause of area effects on birds in fragmented secondary forest. *Oikos* **119**: 918-926.

Castelletta, M., Thiollay, J.-M. & Sodhi, N.S. 2005. The effects of extreme forest fragmentation on the bird community of Singapore island. *Biological Conservation* **121**: 135-155.

Ewers, R.M. & Didham, R.K. 2006. Confounding factors in the detection of species responses to habitat fragmentation. *Biological Reviews* **81**: 117-142.

Fischer, J. & Lindenmayer, D.B. 2002. Small patches can be valueble for biodiversity conservation: Two case studies on birds in Southeastern Australia. *Biological Conservation* **106**(1): 129-136.

Herrera, J.M. & Garcia, D. 2009. The role of remnant trees in seed dispersal through the matrix: Being alone is not alway sad. *Biological Conservation* **142**: 149-158.

Houtan, K.S.V., Pimm, S.L., Halley, J.M., Jr., R.O.B. & Lovejoy, T.O. 2007. Dispersal of Amazonian birds in continuous and fragmented forest. *Ecol. Lett* **9**: 1-11.

Jeyarajasingam, A. & Pearson, A. 2012. *A field guide to the birds of Peninsular Malaysia and Singapore*. Oxford University Press, Oxford.

Laurance, W.F. 1991. Edge-effect in tropical forest fragments: Application of a model for the design of nature reserves. *Biological Conservation* **57**: 205-219.

Marini, M.A. 2001. Effects of forest fragmentation on birds of cerrado region, Brazil. *Bird Conservation International* **11**: 13-25.

Ramli, R. 2004. Temporal changes in diversity and similarity of bird communities of three forest fragments in an urban environment in Peninsular Malaysia. *Malaysia Journal of Science* **23**(2):81-88.

Renjifo, L.M. 2001. Effect of natural and anthropogenic landscape matrices on the abundance of sunandean bird species. *Ecological Applications* **11**: 14-31.

Saunders, D.A., Hobbs, R.J. & Margules, C.R. 1991. Biological consequences of ecosystem fragmentation: A review. *Conservation Biology* **5**: 18-32.

Sekercioglu, C.H. 2007. Conservation ecology: Area trumps mobility in fragment bird extinctions. *Current Biology* **17**: 283-286.

Simberloff, D.S. & Abelle, L.G. 1976. Island biogeography and conservation - strategy and limitations. *Science* **193**: 1032-1032.

Sodhi, N., Sekercioglu, C.H., Barlow, J. & Robinson, S.K. 2011. Effects of habitat fragmentation on tropical birds *Conservation of tropical birds*. Wiley-Blackwell, West Sussex.

Stouffer, P.C. & Jr., R.O.B. 1995. Use of Amazonian forest fragments by understory insectovorous birds. *Ecology* **76**: 2429-2445.

Van Balen, S. 1999. Differential extinction patterns in Javan forest birds. *Tropical Resource Management Papers* **30**: 39-57.

Watson, J.E.M., Whittaker, R.J. & Freudenberger, D. 2005. Bird community responses to habitat fragmentation: How consistent are they across landscapes? *Journal of Biogeography* **32**(8): 1353-1370.

Watson, J.E.M., Whittaker, R.J. & Dawson, T.P. 2004. Habitat structure and proximity to forest edge effect the abundance and distribution of forest-dependent birds in tropical coastal forest of southeastern Madagascar. *Biological Conservation* **120**: 311-327.

Zakaria, M. & Rahim, A. 1999. Bird species composition in Ayer Hitam forest, Puchong, Selangor. *Pertanika J. Trop. Agri. Sci* **22**: 95-104.