Decadal Change in the Kerangas Avifaunal Complex in Universiti Brunei Darussalam, Brunei Darussalam

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Abstract

An urbanized forest habitat is often subjected to spatial and temporal changes in the avian assemblage that inhabits it. The Universiti Brunei Darussalam (UBD) campus built on a coastal kerangas forest (tropical heath) in 1985, is a case in point. This forest type is vulnerable to fires and extensive areas have been burnt over the years and parts of the chosen site for the campus too have been affected. Four avian surveys to study the extent of change in the species richness, were carried out in this site in 1989-1991, 1998-2000, 2006-2007 and 2019-2020. When comparing species richness between years and before and after the building of the campus, there was a significant decline after the campus was built. Three kinds of forests were surveyed - undisturbed contiguous forests, fragmented kerangas sites and the UBD kerangas. To understand the significance of this change, the species richness in undisturbed contiguous sites was five times greater than in the fragmented sites, while that in UBD was twice greater than in the fragmented sites. Furthermore, contiguous sites showed a high dissimilarity from the fragmented disturbed sites. Though UBD was grouped together with the fragmented sites it showed a high dissimilarity from them. As expected, species richness increases with site area, the large contiguous kerangas sites harbouring more species than the small fragmented disturbed sites. A scrutiny of the avian species assemblage shows a large shift from the presence of kerangas forest species before building of the campus to habitat generalists especially granivores at present, characteristic of an urbanized forest habitat.

Index Terms: avian species richness**;** kerangas; urban ecology; university campus; urbanised forest

1. Introduction

Heath forests are a distinctive type of tropical Universiti Brunei Darussalam which was established in 1985 and commenced operations in the Gadong campus, moved to the Tungku Link area in Brunei-Muara District in 1995. This area was a kerangas forest (tropical heath), a unique type of forest found along the coastline of Brunei Darussalam. Kerangas forests have a low uniform canopy, trees being generally shorter and smaller than in dipterocarp forests, and form on infertile, highly acidic, base-poor predominantly sandy soils. Several kerangas forest subtypes are recognized,[1-3] *e.g. Gymnostoma*-dominated, *Shorea*-dominated, *Agathis*-dominated, *Dryobalanops*-dominated, *Dacrydium*-dominated, *Dipterocarpus*-dominated and estimated that there are 849 tree species in these forests of which 220 species occur in the lowland dipterocarp forest.

In Brunei Darussalam, most of the 3,455 ha of kerangas forests (about 0.6% of land area[2]) found along the coastal zone have been extensively cleared for urban, residential and infrastructural development. Past woodcutting activities and repeated fires,[4] drought-induced fires forest fires from September 1997 to May 1998 during the El Niño phenomenon and forest fires in May-June 2009 all led to the extensive devastation of

kerangas and swamp forests in forest reserves, forest plantations and forest recreational parks.[5] The Tungku Link area too was cleared to give way to the building of the campus and this took a toll on the diversity of the resident wildlife.

This is a longitudinal study as this paper describes species richness of the avifauna complex prior to the building of the campus and several years after it was built. There were 4 surveys: 1989-1991survey before the University was built, 1998-2000 survey after the occupation of the campus followed by 2006-2007 survey and 2019-2020 survey and this is compared with the situation in other undisturbed and fragmented kerangas forests in Tutong. It has been 30 years between the first survey in 1989 and the last one in 2019. Even before the campus was built, the area has been repeatedly disturbed by sporadic fires with the disappearance of much vegetation. All these effects are reflected in the diversity of the avifauna.

2. Methodology

2.1 Study Site

Universiti Brunei Darussalam (henceforth referred as UBD) located in the Brunei-Muara district of Brunei Darussalam (4º58'22.15"N, 114º53'38.27"E) is approximately 2.46 km^2 (246 hectares). The area that was once a kerangas forest was gazetted to the university and extensive areas of vegetation were cleared to give way to several educational, recreational, residential and administration buildings as well as asphalt-surfaced roads, cemented walkways, parking lots and open surfaces devoid of vegetation. This created pockets of kerangas fragments in an urban matrix. A few fires that occurred in these fragments during the later years further reduced the size of these pockets of vegetation.

2.2 Other sites used for comparison

The sites used for comparison with the UBD site were contiguous and undisturbed kerangas, and fragmented and disturbed kerangas that were used in separate studies.[6-8]

Undisturbed contiguous kerangas sites were in forest reserves at three locations – Bang Nalud (04°39'31.68"N, 114°37'26.40"E, 13,392 ha), Bukit Sawat (04°34'32.58"N, 114°30'16.26"E, 486 ha) and Badas (04°33'54.43"N, 114°25'3.63"E, 1,492 ha). The sites at Bang Nalud and Bukit Sawat were a kerangas-mixed dipterocarp forest complex located in Tutong district, and the Badas site is a kerangas-peat swamp forest complex within the Belait district.

Fragmented and disturbed sites were in four locations Rimba-C (04°57'6.73"N, 114°54'75.53"E, 4.15 ha), Rimba-D (04°57'14.76"N, 114°54'52.16"E, 3.22 ha), Rimba-E (04°57'57.44"N, 114°54'30.74"E, 22.8 ha) and Rimba-F (04°56'49.17"N, 114°54'56.81"E, 3.03 ha). Another disturbed kerangas fragment in Berakas Forest Reserve (04°59'27.93"N, 114°55'15.84"E, 8.9 ha) was exposed to repeated fires during 1992-1997 [4],[9] owing to presence of *Acacia* spp. around it. All these five fragmented kerangas sites were located within the Burnei-Muara district.

2.3 Bird Survey

Four surveys were carried out in different years: 1989-1991, 1998-2000, 2006-2007 and 2019-2020. All surveys employed the line transect method [10]. Each observer followed a predetermined route ranging from 1 km to 2 km (except for the 2019-2020 survey), that traversed as many habitats as possible in the site for 3 hours from sunrise. The 1989-1991 transect was about 2 km long through the kerangas forest covering open areas and forest patches while the 1998-2000 survey roughly followed the earlier transect route along some newly made metaled roads and open areas. The 2006-2007 survey used randomly set transects of 1 to 2km long while the 2019-2020 survey used short transects.

During 1989-1991 Charles carried out 2 visits for each year – November 1989, December 1990 and January 1991. The cumulative number of species for these 3 years and 6 visits was recorded. The 1998-2000 survey was carried out by Charles and Ang – two visits for each year December 1998, November 1999 and December 2000. The total

number of species seen for the 3 years during the 6 visits was recorded. The 2006-2007 survey was conducted by Razali,[6] with a total of 11 visits made. The observer walked along a predetermined route that consists of paths and roads intersecting throughout the university campus, and a different route was randomly selected for each visit. The 2019-2020 survey was carried out by Ang[7] – three transects (Sites A, Site B and Site C) were set up. Each transect was between 500 m to 800 m and was visited 10 times. Site A was located in a forest behind the Herbal Garden, Site B extended from Faculty of Integrated Technology (FIT) to the Bambusetum, and Site C is a transect leading to the water tank area.

There was a space of 7 years between the first 2 surveys, 6 years between the next 2 surveys and 12 years between the last two surveys. A pair of 10 x 42 Leica Binoculars was used in all instances. Birds flying above the canopy were excluded from the surveys. Field surveys were abandoned during rainy days.

2.4 Data Analysis

All statistical analyses and graphs were performed and plotted in R 4.2.3,[17] unless stated otherwise. For figures showing species as present or absent, the following definition was applied: species recorded as 'present' were those observed during a given survey visit, whereas species recorded as 'absent' were not detected during that visit but were observed in at least one other survey period. A chi-square test was used to compare for differences in species richness (all species and excluding migrants) among the four surveying periods, as well as between before and after building UBD. Agglomerative clustering was performed based presence-absence data using Jaccard dissimilarity index to illustrate the groupings of sites based on avian species composition.

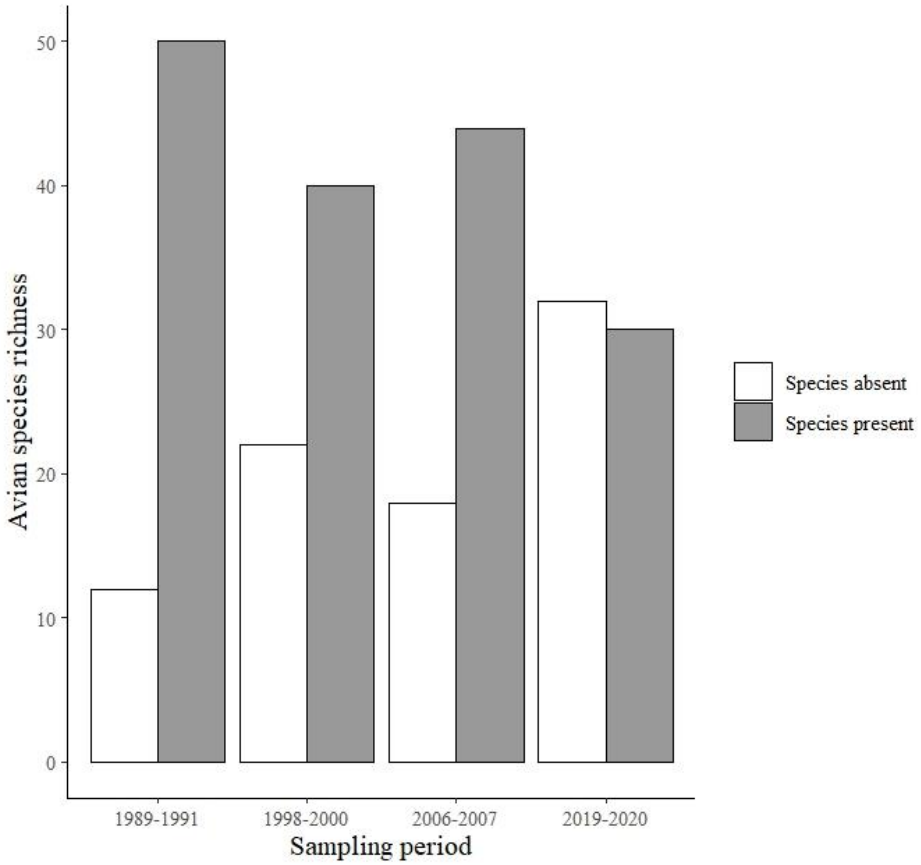

Figure 1. The total number of species present (bird species seen) and absent (bird species not seen) in the different time periods; 1981-1991, 1998-2000, 2006-200 and 2019-2020.

3. Results

3.1 Species richness in UBD kerangas forest between the four periods (1989–1991; 1998-2000; 2006-2007; 2019-2020).

The total number of avian species recorded is 62 (see ***Appendix Table 1***). During the 1st period (1989-1991), 50 species including 4 migrants were recorded while 7 years later in the 2nd period (1998-2000), there were 40 species with 3 migrants (see ***Figure 1***). Six years later in the 3rd period (2006-2007), 44 species including 9 migrants were sighted (see ***Figure 1***) while in the final 4th period (2019-2020), 12 years later, 30 species including 1 migrant, the lowest recorded among the periods (see ***Figure 1***). There was a significant association between the time period and avian species richness ($X^2 = 15.2, df = 3, p = 0.002$). The significance is due to the pairwise comparison between the period of 1989-1990 and 2019-2020 ($p = 0.002$).

The total number of avian species excluding migrants is 53 (see ***Appendix Table 1***). A significant association between the time period and avian species richness (without migrants) is also seen between the periods ($X^2 = 13.2, df = 3, p = 0.004$). The significance is also due to the pairwise comparison between period 1989-1990 and 2019-2020 ($p = 0.004$). Overall, excluding migrants during these periods, the greatest number of species (46 species) was recorded during the 1st period (1989-1991) before the building of the campus (see ***Figure 2***). The lowest number of species (excluding migrants) is 29 recorded in the 4th period (2019-2020) (see ***Figure 2***).

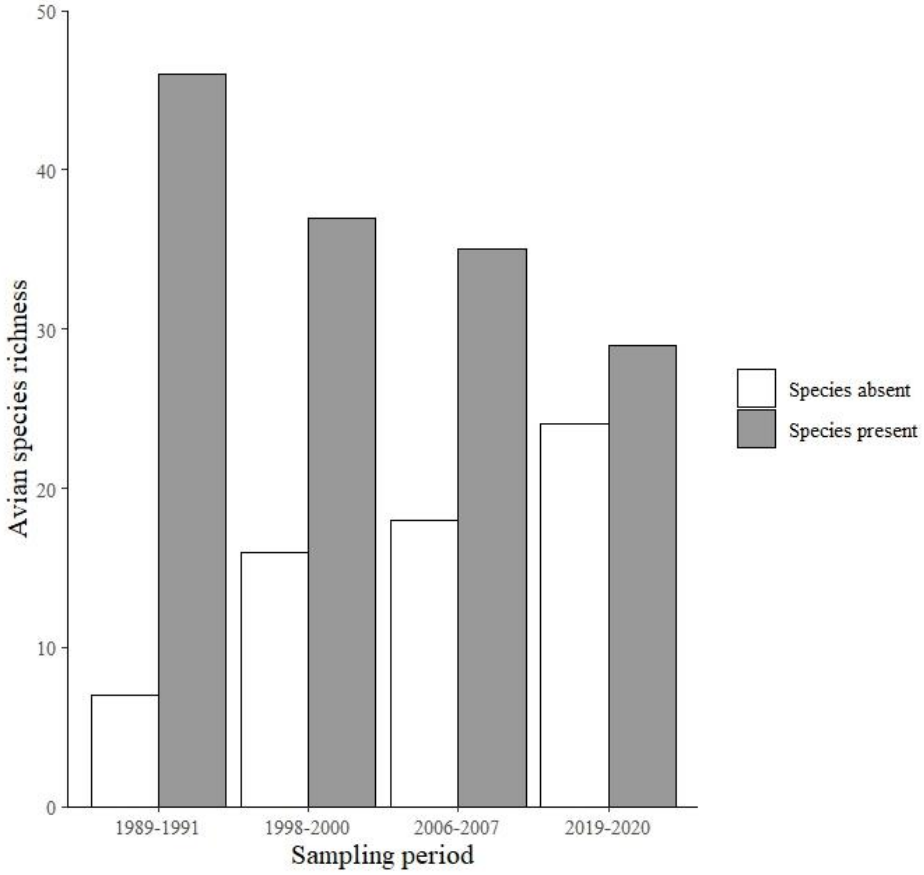

Figure 2. The total number of species present (bird species seen) and absent (bird species not seen) in the different time periods;1981-1991, 1998-2000, 2006-200 and 2019-2020 (without migrants).

3.2 Species richness in UBD kerangas forest between before and after building the university.

The total species documented before building of UBD is 50 while a higher number of 53 species were observed after building of UBD (see ***Figure 3A*** *and* ***Appendix Table 1***). However, there was no association between construction of UBD and avian species richness ($X^2 = 0.229, df = 1, p = 0.632$). Meanwhile, when migrants are excluded, the number of species in before construction of UBD is higher (46 species) than in after construction of UBD (44 species; see ***Figure 3B***). A similar non-significant association was found between construction of UBD and avian species richness ($X^2 = 0.074, df = 1, p = 0.786$).

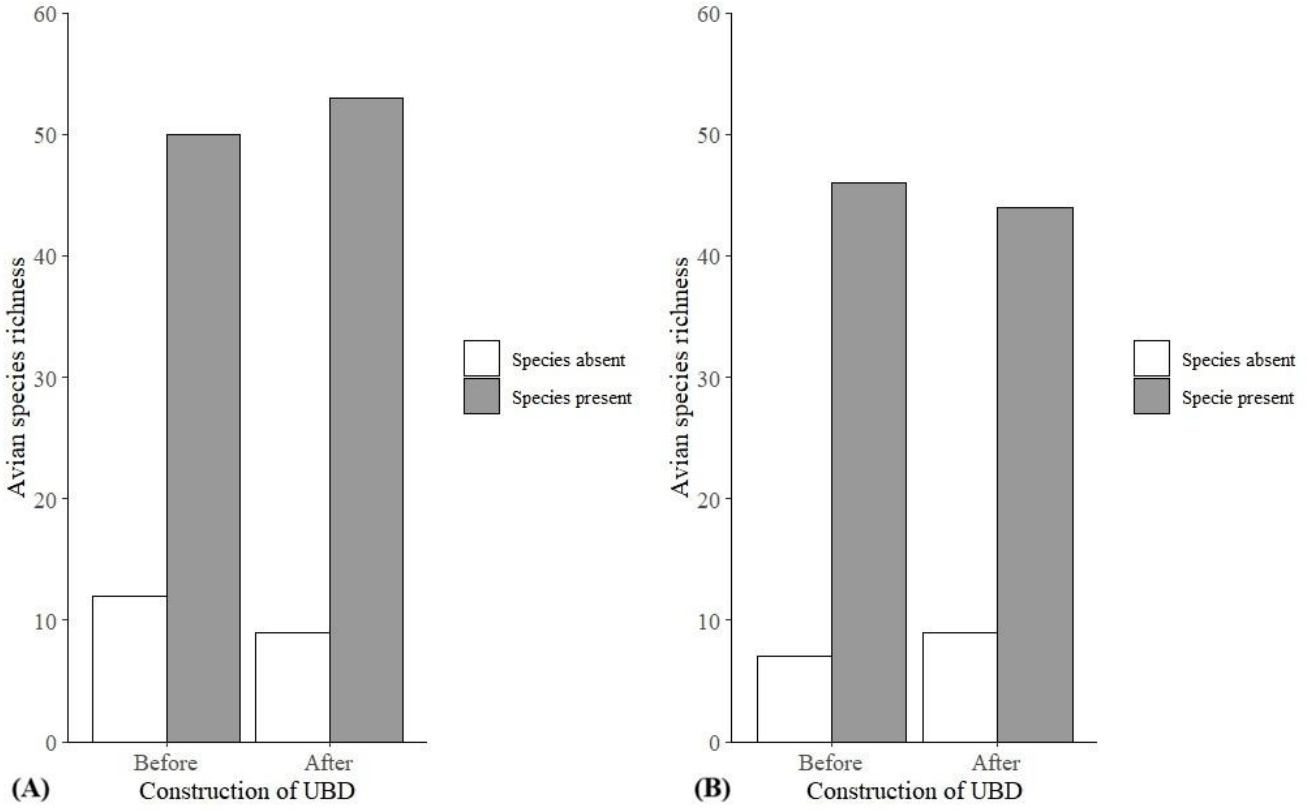

Figure 3. (A) The total number of species present (bird species seen) and absent (bird species not seen) between the period before construction (1981-1991) and after construction (1998-2000; 2006-2007; 2019-2020) of Universiti Brunei Darussalam (UBD). (B) The total number of species (without migrants) present (bird species seen) and absent (bird species not seen) between the period before construction (1981-1991) and after construction (1998-2000; 2006-2007; 2019-2020) of Universiti Brunei Darussalam (UBD).

3.4 Comparing species richness in the contiguous and fragmented kerangas forests.

Of the three contiguous sites, Badas had 67 species while Bang Nalud and Bukit Sawat had 53 and 46 species respectively (see ***Figure 4*** and ***Appendix Table 2***). Overall, 101 species were recorded in the contiguous sites (see ***Appendix Table 3***). The species richness in the five fragmented forests ranged between 18 to 22 species (see ***Figure 4*** and ***Appendix Table 3***). Before and after construction of UBD, the total number of species is 46 and 44, which are much higher than in fragmented forests (see ***Figure 4***).

The three contiguous kerangas sites are grouped together and are separated from the fragmented disturbed kerangas and UBD. These sites showed high dissimilarity from the fragmented disturbed and UBD (87.5% dissimilarity, see ***Figure 5***). Even within the contiguous undisturbed sites, there are high dissimilarity between sites (41.6% and 54% dissimilarity, see ***Figure 5***). UBD (after

and before building UBD) is grouped together with fragmented disturbed sites showing high dissimilarity from within other fragmented disturbed sites (approximately 52.4%, see ***Figure 5***).

3.5. Size of kerangas fragments and avian species richness (species-area relationship)

In accordance with the theory of island biogeography,[18] one would expect fewer avian species in small fragmented kerangas forests when compared with larger fragments. The kerangas fragments in our study shows that avian species richness increases with site area, with larger sites supporting higher number of avian species (see ***Figure 6***).

The paper does not explore the functional aspects of the avian assemblages like diet, habitats and the size of birds.

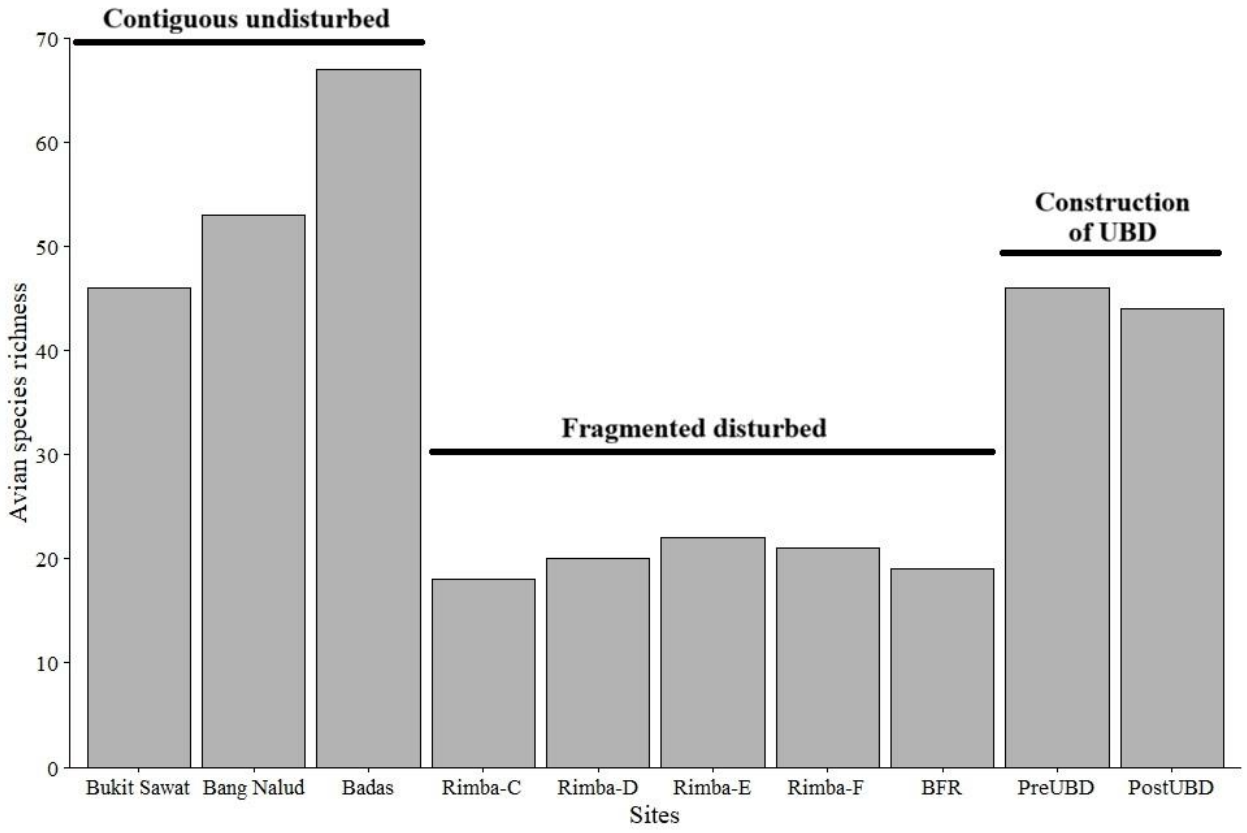

Figure 4. The total number of species (excluding migrants) in contiguous undisturbed kerangas (Bukit Sawat, Bang Nalud and Badas), fragmented disturbed kerangas (Rimba-C, Rimba-D, Rimba-E, Rimba-F and Berakas Forest Reserve (BFR)), before constructing UBD and after constructing UBD. (Data of avian species in contiguous undisturbed kerangas sites and fragmented disturbed kerangas sites were taken from [6]).

4. Discussion

4.1 Variations in the Species richness of the UBD kerangas forest at different periods as well as between before and after building of the university.

From 1989 to 2020, the face of the UBD kerangas forest changed dramatically as more and more kerangas vegetation was removed to accommodate new buildings and other types of vegetation and garden plants were planted in several areas in the campus as part of the beautification process. Perhaps these changes can be quantified by satellite imagery but it is not done here.

Between the four time periods, there was a significant association between the time period

and avian richness - 50 species (inclusive of migrants) in the 1st period, 40 in the 2nd, 44 in the 3rd and 30 in the 4th period. Excluding migrants, the picture shows a clear decline in the avian species richness - 46 during the 1st period to 37 in the 2nd to 35 in the 3rd to 29 in the 4th, as expected, with the lowest in the last period (2019-2020). This trend is masked when avian species richness is compared before and after building of the UBD campus as there was no association. Hence the important trend to note is the significant drop in the species richness between the 1st period (1989-1991) and the last period (2019-2020). As mentioned earlier, it is highly probable that the increasing pace of infrastructural development in the campus, has led to this significant decrease in the species richness after the building of the campus which has inadvertently opened up the forest habitat into more open spaces.

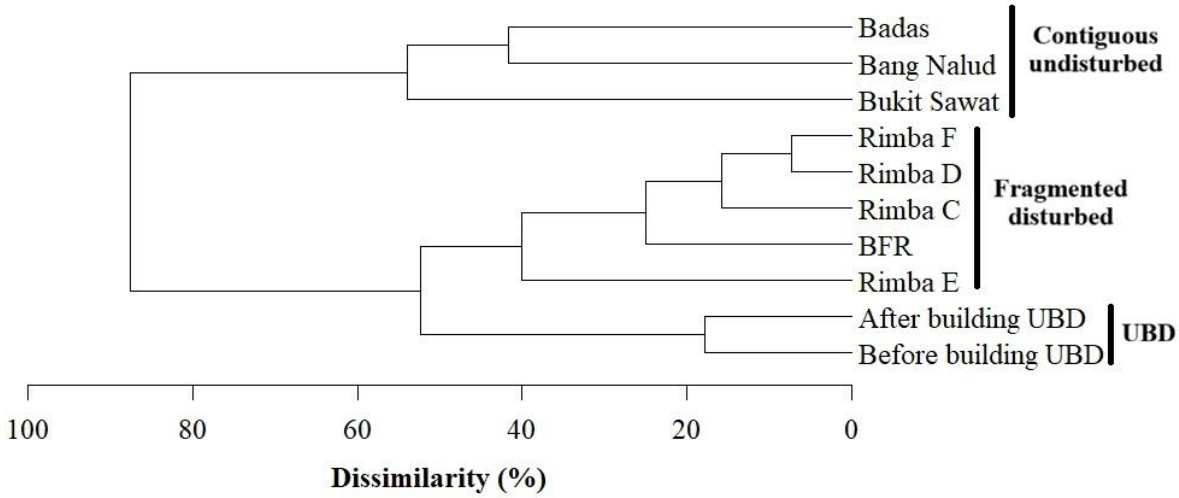

Figure 5. Dendrogram of agglomerative clustering based on the Jaccard dissimilarity index, showing percentage dissimilarity in avian community composition across the kerangas sites derived from a presence-absence matrix.

4.2 Limitation of the study.

In this study, species richness was used to investigate differences between time periods and to compare across study sites, but it does not account for sampling bias arising from varying time periods, observers, and transect layouts that may affect species detectability. To account for sampling bias, richness estimators and curves such as rarefaction and species accumulation would be applied in future studies.[21]

4.3 Temporal sampling effects

Across years, species counts are subjected to bias as sample sizes or detection probabilities can vary. Hence it is important to ensure the same number of samples are collected at the same time of the day. Detection probability when dealing with birds depends on the ability of the observer and his/her prior experience.

In studying observed avian species richness in the UBD mosaic habitat, the length and positioning of the transects would affect the number of species observed. Whenever different persons survey the same habitat but at different periods separated by several years, variations in the methodology are bound to occur. The survey method employed was a line transect that varied from 1 to 2 km in length, traversing as many habitats as possible. The first two survey periods used the same line transect and 2 visits each year for 3 years while the third survey period used 11 visits in the same year. The fourth survey period varied quite widely from the others: 3 transects varying from 500-800 metres were visited 30 times in the same year. Thus, one would expect wide variations in the results obtained and the differences in the species richness may reflect the roles played by several factors that operated during these periods e.g. the drastic physical

changes in UBD as more and more buildings were built during these periods, sporadic fires, bird poaching.

4.4 Species richness in the contiguous and fragmented kerangas forests & percentage dissimilarity within the kerangas avian community

A study of three contiguous and five fragmented kerangas forest sites showed the former had 46 to 67 avian species while the latter had only 18-22 species.[6] The UBD kerangas site which is also a fragmented site with 44-46 species, had about double the species richness of the other five kerangas fragments. It is interesting to note that the total species richness of contiguous sites of 101 species is more than twice that of the fragmented kerangas forests. Another factor that determines the species richness of a site is its size and this was shown earlier that avian species richness increases with site area, larger fragmented forests having more bird species than smaller ones.

The wide differences in the species richness between these sites is further exemplified when the dissimilarity between sites is considered. The contiguous sites showed a high dissimilarity of 87.5% from the disturbed fragments and UBD site. Though UBD is grouped together with the other disturbed fragments, it shows a high dissimilarity of 52.4% from them.

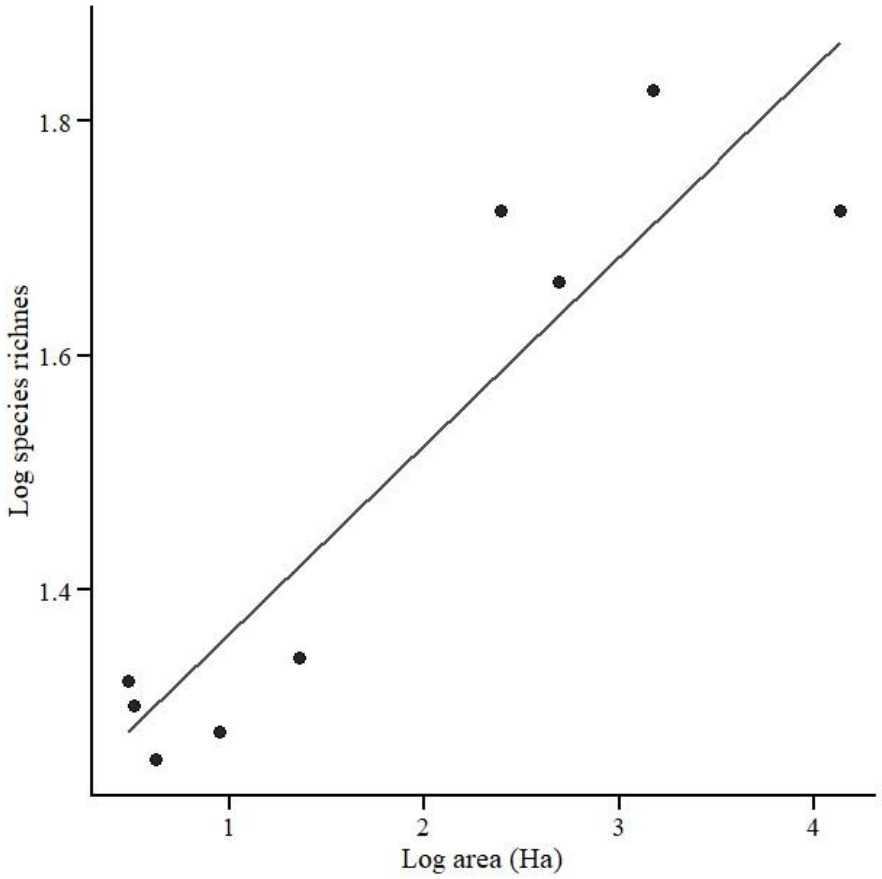

Figure 6. Relationship between logarithmically transformed area (ha) of kerangas fragments and avian species richness.

4.5 Forest disturbance and species richness

Forest disturbance like logging, fires, infrastructural development are common in the Tropics. In a pantropical meta-analysis study using an information-theoretic approach in 48 tropical studies of impacts of selective logging on species richness, it was found that the species richness of invertebrates, amphibians, and mammals decreases with an increase in logging intensity varying with taxonomic group and

continental location.[11] In birds on the other hand, total species richness increases with logging intensity owing to influx of habitat generalists into heavily logged areas while forest specialist species decline.

Another study carried out in Florida, USA, in a frequently burned longleaf pine (*Pinus palustris*) ecosystem, showed that avian species richness increased with pyrodiversity at the community level.[19] It is not known what effects pyrodiversity can have on a highly vulnerable ecosystem like the kerangas forest where sporadic fires are known to remove the native vegetation and change the forest structure.

In the UBD disturbed kerangas forest, habitat generalists or non-forest dependent bird species (*i.e.*, species that prefer open-habitats as opposed to forest dependent ones which prefer forested habitats) have replaced the forest-dependent species and some were present even during the 1st survey in 1989 as the area has already been subjected to human disturbances and occasional fires. The following habitat generalists recorded in the UBD site, can exploit a wide variety of resources and are adapted to the disturbances and hazards of the urban environment – *e.g.* Chestnut Munia *Lonchura atricapilla*, Dusky Munia *Lonchura fuscans,* Scaly-breasted Munia *Lonchura punctulate*, Eurasian Tree Sparrow Passer *montanus*, Pied Triller *Lalage nigra*, Oriental Magpie-Robin *Copsychus saularis*, Yellow-bellied Prinia *Prinia flaviventris*, White-breasted Waterhen *Amaurornis phoenicurus*, Spotted dove *Streptopelia chinensis,* Zebra dove *Geopelia striata,* Yellow-vented Bulbul *Pcynonotus goiavier*.

Some forest-dependent species still persisted in the disturbed UBD campus e.g., Chestnut-bellied Malkoha *Phaenicophaeus sumatranus,* Raffles's Malkoha *Phaenicophaeus chlorophaeus* and Little Green-pigeon *Treron olax*. The following two forest specialist species have disappeared from the present UBD forest mosaic site – Greater Racquet-tailed Drongo *Dicrurus paradiseus* and White-rumped Shama *Copsychus malabaricus*. This trend of habitat generalists or opportunists invading degraded forest fragments and the disappearance of forest specialists has also been shown to occur in small mammals occurring in these kerangas forest fragments.[9]

4.6 Opportunities available to habitat generalists in urbanised forest environments

Though the data presented in this paper has not been analysed into dietary guilds as insectivores, frugivores, omnivores and granivores, one cannot help but notice that of the 11 habitat generalists listed above, five are granivores (seed exploiters) 4 are omnivores **(**diet comprising a mixture of fruits, seeds, insects and nectar) and two are insectivores (insect feeders). The urban environment has ample resources for these generalists like seeds from grasses alongside lawns, paths, parking lots and open spaces, insects and a variety of arthropods and fruits, all acting as supplemental food resources for granivores and omnivores. Common granivores in the UBD campus are Chestnut Munia *Lonchura atricapilla*, Dusky Munia *Lonchura fuscans,* Scaly-breasted Munia *Lonchura punctulate* and Eurasian Tree Sparrow Passer *montanus*. The food opportunities available in the urbanized forest environments can affect avian diversity, density and composition of bird assemblages [12]. It is interesting to note that there are indicators which point to this kerangas habitat in the UBD campus, gradually changing into an urbanized environment by the invasion of habitat generalists like granivores and omnivores and non-native species attracted by the presence of additional ornamental gardens, planting of non-native plants and flower gardens which become resources for survival of habitat generalists and disturbance-tolerant avian species.

It is possible that in future, that the Common Myna *Acridotheres tristis*, an efficient generalist, that invaded Brunei in the 1980s and is very common in the urban areas, could expand its range to the UBD campus.

4.7 The presence of migrants in the UBD campus

Brunei attracts a variety of migrants between the months of September and March especially water

birds. Nine migrants have been recorded in the surveys of which 3 were waterbirds and 6 insectivores. One notable insectivore is the Barn Swallow, *Hirundo rustica* that winters in Brunei in thousands. The 2 water birds (defined as birds living on or near water, and ecologically dependent on wetlands) that winter in Brunei are Medium Egret *Egretta intermedia* and Chinese Pond Heron *Ardeola bacchus* which can be easily noticed near a water body. The Bar-tailed Godwit, *Limosa lapponica*, a water bird, classified as Near Threatened and a common passage and winter visitor to Borneo, is a long-distance traveler. Their presence in the survey coincided with wintering months for water birds in Brunei.

Avian migrants have specific habitat requirements for their breeding and wintering grounds which differ from the habitats in their stop-over sites where they rest and refuel. Selection of stop-over sites are determined by food abundance, absence of predators and lack of competition for food. But there is still a lack of information on how migratory birds select stop-over sites.[13-15]

4.8 The case of the missing frogmouth

Frogmouths are strictly nocturnal inhabitants of the forests and forest edge. The Sunda Frogmouth, *Batrachostomus cornutus* was recorded accidentally sleeping on a branch in the edge of the disturbed UBD kerangas forest in the 1st survey (1989) but not recorded during the other surveys. The Sunda Frogmouth is usually found in disturbed secondary forests and extremely difficult to detect during the day owing to its perfect camouflage with a dead branch. So, it is questionable whether it is actually absent in the UBD campus today.

4.9 The case of the missing White-rumped Shama

The White-rumped Shama is a forest specialist and it was present in the first survey but absent in all the others. Being the best songster in the country, it is avidly sought after by poachers involved in illegal bird trade and used in bird song competitions. Poachers have been seen by the senior author, systematically going through the kerangas forest fragments Rimba C, D, E and F with a live decoy in a cage during the small mammal study in 2000.[20]

4.10 The future of the Oriental Magpie-Robin in the UBD campus

This is another songbird that is being poached for the pet trade and bird song competitions. Attempts have been made by individuals setting decoy traps in the campus but dissuaded by the security guards. The disappearance of this bird from the campus is imminent unless steps are taken to protect it by the campus authorities in future.

4.11 The case of the nocturnal birds in the UBD campus

Nocturnal birds like the frogmouths, owls and nightjars have not been included in this study. It is important to include them in any future study as they are vital links in the forest food web.

4.12 Prospects for future studies

Latest techniques to study birds have moved towards highly technological automated and non-invasive methods which help researchers to monitor behaviour, physiology and movement in real time. Passive acoustic monitoring, using for example, a programmable acoustic recorder, could help long-term detection of rare species and reduce observer bias in gathering permanent, re-analyzable audio data. Uses of AI and computer vision (*e.g.* Merlin Bird ID App) to identify bird images and songs could facilitate rapid data collection.

Using passive acoustic monitoring in the UBD campus for future studies would require researchers to be first trained to recognise target bird species and their songs prior to the application of this technique to help in the proper identification of the birds during the analysis stage. Detection of nocturnal birds, which was not done in the present study, would need the usage of a thermal imaging camera, white light and red-filtered head lights.

4.13 The future of the UBD kerangas forest for avian species

This study of avian species richness survey in the disturbed kerangas forest that commenced before the building of the UBD campus, has shown in the three subsequent surveys at different periods, that forest-dependent species have disappeared to be replaced by habitat generalists and omnivores. The original kerangas forest vegetation conducive to the survival of forest-dependent species have mostly been removed to accommodate new buildings and structures leaving only small pockets of original vegetation and complemented with ornamental gardens and invasive vegetation characteristic of an urbanized environment that are very attractive to habitat generalists. Perhaps attempts could be made to re-vegetate bare open areas in the campus with kerangas tree and plant species plants that could once again attract the invasion of forest-dependent avian species from surviving kerangas forests that still persist outside the boundary of the campus. There are still three forest-dependent species surviving in the UBD campus which could benefit from the suggested kerangas tree planting venture.

From the national perspective, the kerangas forest in Brunei Darussalam is a very valuable national resource which should be conserved and its gradual loss owing to anthropogenic causes is making this coastal habitat into an endangered forest. Future urban planning should take into consideration a balance in infrastructural development and the need for forest, bird and mammal conservation.

Acknowledgements

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Appendix

Appendix Table 1. Checklist of the birds in Universiti Brunei Darussalam kerangas forest recorded during four different periods (1989 –1991, 1998 – 2000, 2006 – 2007, 2019 – 2020). Records from 2006 – 2007 and 2019 – 2020 were taken from Razali.[6] Nomenclature based on Lepage.[16] (Note: Superscript symbols: * migrant; + Bornean endemic)

Index no.	Family	Species name	Vernacular name	1989 – 1991	1998 – 2000	2006 – 2007	2019 – 2020
1	Laridae	*Onychoprion anaethetus*	Bridled tern	-	+	-	-
2	Picidae	*Yungipicus moluccensis*	Sunda Pygmy Woodpecker	+	+	+	+
3	Picidae	*Hemicircus concretus*	Grey-and-buff Woodpecker	+	-	-	-
4	Megalaimidae	*Caloramphus fuliginosus*	Bornean Brown Barbet	+	-	-	-
5	Megalaimidae	*Psilopogon duvaucelii*	Black-eared Barbet	+	-	-	-
6	Halcyonidae	*Todiramphus chloris*	Collared Kingfisher	+	+	+	+
7	Meropidae	*Merops viridis*	Blue-throated Bee-eater	+	+	+	+
8	Cuculidae	*Cacomantis sonneratii*	Banded Bay Cuckoo	+	+	-	-
9	Cuculidae	*Phaenicophaeus sumatranus*	Chestnut-bellied Malkoha	+	+	-	-
10	Cuculidae	*Phaenicophaeus chlorophaeus*	Raffles's Malkoha	+	-	+	+
11	Cuculidae	*Cacomantis merulinus*	Plaintive Cuckoo	+	+	+	+
12	Apodidae	*Hirundapus caudacutus*	White-throated Needletail *	+	+	+	-
13	Apodidae	*Cypsiurus balasiensis*	Asian Palm Swift	+	+	+	-
14	Podargaridae	*Batrachostomus cornutus*	Sunda frogmouth	+	-	-	-
15	Centropodidae	*Centropus bengalensis*	Lesser Coucal	+	+	-	-

16	Columbidae	*Treron olax*	Little Green-pigeon	+	+	+	+
17	Columbidae	*Spilopelia chinensis*	Spotted dove	+	+	+	-
18	Columbidae	*Geopelia striata*	Zebra dove	+	+	+	+
19	Columbidae	*Treron vernans*	Pink-necked Green Pigeon	+	+	+	+
20	Columbidae	*Treron curvirostra*	Thick-billed Green-pigeon	+	-	-	-
21	Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	-	+	+	+
22	Artamidae.	*Artamus leucorhyncus*	White-breasted Woodswallow	+	+	+	+
23	Scolopacidae	*Limosa lapponica*	Bar-tailed Godwit *	-	-	+	-
24	Accipitridae	*Pernis ptilorhynchus*	Oriental Honey Buzzard	-	-	-	+
25	Ardeidae	*Ardea intermedia*	Medium Egret *	-	+	+	+
26	Ardeidae	*Ardea purpurea*	Purple Heron	-	+	+	-
27	Ardeidae	*Ardeola bacchus*	Chinese Pond Heron *	-	-	+	-
28	Campephagidae	*Lalage nigra*	Pied Triller	+	+	+	+
29	Rhipiduridae	*Rhipidura javanica*	Pied Fantail	+	+	+	+
30	Dicruridae	*Dicrurus paradiseus*	Greater Racquet-tailed Drongo	+	-	-	-
31	Aegithinidae	*Aegithina tiphia*	Common Iora	+	+	+	+
32	Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher *	-	-	+	-
33	Muscicapidae	*Copsychus malabaricus*	White-rumped Shama	+	-	-	-
34	Muscicapidae	*Copsychus saularis musicus*	Oriental Magpie-Robin	-	+	+	-
35	Muscicapidae	*Copsychus saularis pluto*	Oriental Magpie-Robin	-	-	-	+

36	Sturnidae	*Aplonis panayensis*	Asian Glossy Starling	+	+	+	+
37	Hirundinidae	*Hirundo rustica*	Barn Swallow *	+	+	+	-
38	Hirundinidae	*Hirundo tahatica*	Pacific Swallow	+	+	+	+
39	Pycnonotidae	*Pycnonotus goiavier*	Yellow-vented Bulbul	+	+	+	+
40	Pycnonotidae	*Pycnonotus brunneus*	Red-eyed Bulbul	+	+	+	+
41	Zosteropidae	*Zosterops palpebrosus*	Oriental White-eye	+	+	+	-
42	Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia	+	+	+	+
43	Cisticolidae	*Orthotomus sericeus*	Rufous-tailed Tailorbird	+	-	+	-
44	Cisticolidae	*Orthotomus ruficeps*	Red-headed Tailorbird	+	+	+	+
45	Pellorneidae	*Pellorneum rostratum*	White-chested Babbler	+	-	-	-
46	Timaliidae	*Mixornis bornensis*	Bold-striped Babbler	+	-	+	-
47	Timaliidae	*Macronous ptilosus*	Fluffy-backed Tit Babbler	+	+	-	-
48	Dicaeidae	*Prionochilus percussus*	Crimson-breasted Flowerpecker	+	-	-	-
49	Dicaeidae	*Dicaeum trigonostigma*	Orange-bellied Flowerpecker	+	+	+	+
50	Dicaeidae	*Prionochilus maculatus*	Yellow-breasted Flowerpecker	+	+	+	-
51	Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird	+	+	+	+
52	Nectariniidae	*Leptocoma sperata*	Purple-throated Sunbird	+	+	-	+
53	Nectariniidae	*jugularis*	Olive-backed Sunbird	+	+	+	+
54	Nectariniidae	*Aethopyga siparaja*	Eastern Crimson Sunbird	+	-	+	-
55	Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	+	+	+	+

56	Passerridae	*Passer montanus*	Eurasian Tree Sparrow	+	+	+	+
57	Motacillidae	*Dendronanthus indicus*	Forest Wagtail *	-	-	+	-
58	Motacillidae	*Motacilla flava*	Yellow Wagtail *	+	-	+	-
59	Motacillidae	*Anthus richardi*	Richard's Pipit *	+	-	+	-
60	Estrildidae	*Lonchura atricapilla*	Chestnut Munia	+	+	+	+
61	Estrildidae	*Lonchura fuscans*	Dusky Munia +	+	+	+	-
62	Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	-	-	-	+
Total species (including migrants)				**50**	**40**	**44**	**30**
Total (only migrants)				**4**	**3**	**9**	**1**
Total species (excluding migrants)				**46**	**37**	**35**	**29**

Appendix Table 2. List of birds observed in the undisturbed contiguous and disturbed fragmented kerangas forests taken from Razali.[6] Nomenclature based on Lepage.[16]

Index No.	**Family**	**Species Name**	**Vernacular Name**	**Contiguous**			**Fragmented**				
				Bukit Sawat	**Bang Nalud**	**Badas**	**Rimba C**	**Rimba D**	**Rimba E**	**Rimba F**	**BFR**
1	Picidae	*Picumnus innominatus*	Speckled Piculet			X					
2	Picidae	*Sasia abnormis*	Rufous Piculet	X							
3	Picidae	*Yungipicus moluccensis*	Brown-capped Woodpecker			X			X		
4	Picidae	*Dendrocopus canicapillus*	Grey-capped Pygmy Woodpecker	X							
5	Picidae	*Dryocopus javensis*	White-bellied Woodpecker	X	X	X					
6	Picidae	*Chrysophlegma mentale*	Checker-throated Woodpecker	X							
7	Picidae	*Mulleripicus pulverulentus*	Great Slaty Woodpecker		X						

8	Picidae	*Dinopium javanense*	Common Flameback	X							
9	Picidae	*Hemicircus concretus*	Grey-and-buff Woodpecker		X	X					
10	Megalaimidae	*Megalaima chrysopogon*	Gold-whiskered Barbet			X					
11	Megalaimidae	*Megalaima rafflesii*	Red-crowned Barbet			X					
12	Megalaimidae	*Psilopogon duvaucelii*	Black-eared Barbet	X		X					
13	Megalaimidae	*Caloramphus fuliginosus*	Bornean Brown Barbet	X	X	X			X		
14	Bucerotidae	*Anthracoceros albirostris*	Oriental Pied-Hornbill			X					
15	Bucerotidae	*Anthracoceros malayanus*	Black Hornbill	X	X	X					
16	Bucerotidae	*Buceros rhinoceros*	Rhinoceros Hornbill		X						
17	Bucerotidae	*Anorrhinus galeritus*	Bushy-crested Hornbill			X					
18	Bucerotidae	*Aceros corrugatus*	Wrinkled Hornbill	X	X	X					
19	Trogonidae	*Harpactes kasumba*	Red-naped Trogon		X	X					
20	Coraciidae	*Eurystomus orientalis*	Dollarbird		X	X					
21	Halcyonidae	*Pelargopsis capensis*	Stork-billed Kingfisher		X	X					
22	Halcyonidae	*Todiramphus chloris*	Collared Kingfisher				X	X		X	X
23	Meropidae	*Nyctyornis amictus*	Red-bearded Bee-eater			X					
24	Meropidae	*Merops viridis*	Blue-throated Bee-eater		X	X	X	X	X	X	X
25	Cuculidae	*Cacomantis sonneratii*	Banded Bay Cuckoo	X	X	X			X		
26	Cuculidae	*Cacomantis merulinus*	Plaintive Cuckoo			X					
27	Cuculidae	*Phaenicophaeus diardi*	Black-bellied Malkoha		X						
28	Cuculidae	*Phaenicophaeus sumatranus*	Chestnut-bellied Malkoha	X	X	X			X		X
29	Cuculidae	*Phaenicophaeus chlorophaeus*	Raffles's Malkoha	X		X		X			

30	Cuculidae	*Phaenicophaeus javanicus*	Red-billed Malkoha	X							
31	Cuculidae	*Phaenicophaeus curvirostris*	Chestnut-breasted Malkoha			X					
32	Centropodidae	*Centropus bengalensis*	Lesser Coucal			X		X		X	
33	Psittacidae	*Loriculus galgulus*	Blue-crowned Hanging-parrot		X	X					
34	Psittacidae	*Psittinus cyanurus*	Blue-rumped parrot		X						
35	Hemiprocnidae	*Hemiprocne comata*	Whiskered Treeswift		X						
36	Columbidae	*Treron fulvicollis*	Cinnamon-headed Green Pigeon			X					
37	Columbidae	*Treron olax*	Little Green-pigeon			X					
38	Columbidae	*Treron curvirostra*	Thick-billed Green-pigeon	X		X					
39	Columbidae	*Ducula aenea*	Green Imperial-pigeon			X					
40	Calyptomenidae	*Calyptomena viridis*	Green Broadbill	X	X	X					
41	Eurylaimidae	*Eurylaimus ochromalus*	Black-and-yellow Broadbill		X						
42	Irenidae	*Irena puella*	Asian Fairy Bluebird			X					
43	Chloropseidae	*Chloropsis sonnerati*	Greater Green Leafbird	X	X	X					
44	Chloropseidae	*Chloropsis cyanopogon*	Lesser Green Leafbird		X	X					
45	Chloropseidae	*Chloropsis cochinchinensis*	Blue-winged Leafbird	X							
46	Corvidae	*Platysmurus atterimus*	Bornean Black Magpie	X	X	X					
47	Corvidae	*Corvus enca*	Slender-billed Crow		X	X					
48	Artamidae	*Artamus leucorhyncus*	White-breasted Woodswallow				X			X	
49	Campephagidae	*Lalage nigra*	Pied Triller				X	X	X	X	X
50	Campephagidae	*Pericrocotus igneus*	Fiery Minivet	X	X	X					
51	Vangidae	*Hemipus hirundinaceus*	Black-winged Flycatcher-shrike	X	X	X					

52	Vangidae	*Philentoma pyrhoptera*	Rufous-winged Philentoma	X							
53	Rhipiduridae	*Rhipidura javanica*	Pied Fantail	X	X	X	X	X	X	X	X
54	Dicruridae	*Dicrurus paradiseus*	Greater Racquet-tailed Drongo		X	X			X		
55	Monarchidae	*Hypothymis azurea*	Black-naped Monarch	X	X						
56	Monarchidae	*Terpsiphone affinis*	Blyth's Paradise-flycatcher	X							
57	Aegithinidae	*Aegithina tiphia*	Common Iora			X	X	X		X	
58	Aegithinidae	*Aegithina viridissima*	Green Iora	X	X	X					
59	Muscicapidae	*Rhinomyias olivaceus*	Fulvous-chested Jungle-flycatcher	X							
60	Muscicapidae	*Rhinomyias umbratilis*	Grey-chested Jungle-flycatcher			X					
61	Muscicapidae	*Copsychus saularis*	Oriental Magpie-Robin			X			X		X
62	Muscicapidae	*Copsychus malabaricus*	White-rumped Shama	X	X	X	X	X	X	X	X
63	Muscicapidae	*Copsychus pyrropygus*	Rufous-tailed Shama	X	X						
64	Sturnidae	*Aplonis panayensis*	Asian Glossy Starling		X		X				
65	Sturnidae	*Gracula religiosa*	Hill Myna		X	X					
66	Sittidae	*Sitta frontalis*	Velvet-fronted Nuthatch	X	X						
67	Pycnonotidae	*Pycnonotus melanoleucos*	Black-and-white Bulbul			X					
68	Pycnonotidae	*Pycnonotus atriceps*	Black-headed Bulbul	X	X	X					
69	Pycnonotidae	*Pycnonotus eutilotus*	Puff-backed Bulbul			X					
70	Pycnonotidae	*Pycnonotus goiavier*	Yellow-vented Bulbul			X	X	X	X	X	X
71	Pycnonotidae	*Pycnonotus simplex*	Cream-vented Bulbul		X	X					
72	Pycnonotidae	*Pycnonotus brunneus*	Red-eyed Bulbul		X	X	X	X	X	X	X
73	Pycnonotidae	*Alophoixus tephrogenys*	Grey-cheeked Bulbul		X						

74	Pycnonotidae	*Alophoixus phaeocephalus*	Yellow-bellied Bulbul		X	X					
75	Pycnonotidae	*Iole olivacea*	Buff-vented Bulbul		X						
76	Pycnonotidae	*Setornis criniger*	Hook-billed Bulbul	X							
77	Cisticolidae	*Prinia flaviventris*	Yellow-bellied Prinia			X	X	X	X	X	X
78	Cisticolidae	*Orthotomus atrogularis*	Dark-necked Tailorbird		X						
79	Cisticolidae	*Orthotomus sericeus*	Rufous-tailed Tailorbird	X				X	X	X	X
80	Cisticolidae	*Orthotomus ruficeps*	Red-headed Tailorbird	X	X	X	X	X	X	X	X
81	Pellorneidae	*Trichastoma rostratum*	White-chested Babbler		X		X	X	X	X	
82	Pellorneidae	*Malacopteron affine*	Sooty-capped Babbler	X		X					
83	Pellorneidae	*Malacopteron magnum*	Rufous-crowned Babbler	X	X	X					
84	Timaliidae	*Pomatorhinus mantanus*	Chestnut-backed Scimitar Babbler	X							
85	Timaliidae	*Cyanoderma rufifrons*	Rufous-fronted Babbler	X							
86	Timaliidae	*Stachyris nigricollis*	Black-throated Babbler	X		X					
87	Timaliidae	*Stachyris poliocephala*	Grey-headed Babbler	X	X		X	X		X	X
88	Timaliidae	*Mixornis bornensis*	Bold-striped Tit-babbler			X					
89	Timaliidae	*Macronous ptilosus*	Fluffy-backed Tit Babbler		X				X		
90	Dicaeidae	*Prionochilus maculatus*	Yellow-breasted Flowerpecker	X	X	X					
91	Dicaeidae	*Prionochilus percussus*	Crimson-breasted Flowerpecker	X	X	X					X
92	Dicaeidae	*Prionochilus thoracicus*	Scarlet-breasted Flowerpecker			X					
93	Dicaeidae	*Dicaeum everetti*	Brown-backed Flowerpecker		X						
94	Dicaeidae	*Dicaeum chrysorrheum*	Yellow-vented Flowerpecker		X						X

95	Dicaeidae	*Dicaeum trigonostigma*	Orange-bellied Flowerpecker			X	X	X	X	X	X
96	Dicaeidae	*Dicaeum concolor*	Plain Flowerpecker	X							
97	Dicaeidae	*Dicaeum cruentatum*	Scarlet-backed Flowerpecker		X				X		
98	Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird			X	X	X	X	X	X
99	Nectariniidae	*Chalcoparia singalensis*	Ruby-cheeked Sunbird	X	X	X					
100	Nectariniidae	*Kurochkinegramma hypogrammicum*	Purple-naped Sunbird			X				X	
101	Nectariniidae	*Leptocoma calcostetha*	Copper-throated Sunbird			X		X	X	X	
102	Nectariniidae	*Cynniris jugularis*	Garden Sunbird				X	X		X	X
103	Nectariniidae	*Aethopyga siparaja*	Eastern Crimson Sunbird		X	X	X	X	X	X	X
104	Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	X	X	X					
105	Nectariniidae	*Arachnothera crassirostris*	Thick-billed Spiderhunter	X							
106	Nectariniidae	*Arachnothera robusta*	Long-billed Spiderhunter	X							
TOTAL				**46**	**53**	**67**	**18**	**20**	**22**	**21**	**19**

Appendix Table 3. Number of bird species recorded in UBD campus, three undisturbed contiguous sites and five disturbed fragmented sites in relation to their size (without migrants)**.** In parenthesis, sampling period.

	Main study site	**Undisturbed sites**			**Disturbed fragmented sites**				
	UBD site	Bukit Sawat	Bang Nalud	Badas	Rimba C	Rimba D	Rimba E	RimbaF	BFR
No. of species	46 (1989 - 1991) 37 (1998 - 2000) 35 (2006 - 2007) 29 (2019 - 2020)	46 (2006 - 2007)	53 (2006 - 2007)	67 (2006 - 2007)	18 (2006 - 2007)	20 (2006 - 2007)	22 (2006 - 2007)	21 (2006 - 2007)	19 (2006 - 2007)
Total no. of species	53 (43.4%)	101 species in undisturbed sites (82.8%)			33 species in fragmented sites (27.3%)				
Size (hectares)	246	486	13,392	1,492	4.15	3.22	22.8	3.03	8.9