

Bird Species Diversity in the Padawan Limestone Area, Sarawak

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Abstrak: Kajian burung telah dilakukan di kawasan batu kapur Padawan selama tujuh hari di setiap dua lokasi kajian, Giam dan Danu, dari Ogos hingga Disember 2008. Tujuan kajian adalah untuk membandingkan kekayaan dan taburan spesis-spesis burung antara kawasan ini dan kawasan batu kapur yang lain, dan juga jenis-jenis hutan yang lain. Kajian ini juga membandingkan kekayaan spesis dan taburan relatif burung-burung di kawasan tidak terganggu dan kawasan terganggu di kedua-dua lokasi kajian. Dua puluh jaring kabut telah dipasang selama 12 jam sehari. Pemerhatian langsung juga telah dijalankan. Sejumlah 80 spesis daripada 34 famili telah direkod di kedua-dua lokasi kajian. Di Giam, 120 burung telah ditangkap. Burung-burung ini mewakili 31 spesis daripada 16 famili. Pemerhatian langsung di Giam merekod 13 spesis daripada 11 famili. Di kawasan tidak terganggu, 21 spesis daripada 13 famili telah ditangkap, manakala di kawasan terganggu, 21 spesis daripada 10 famili telah ditangkap. Di Danu, sejumlah 48 burung, mewakili 25 spesis daripada 12 famili telah ditangkap. Pemerhatian di Danu telah merekod 34 spesis daripada 19 famili. Dua belas spesis daripada 7 famili telah ditangkap di kawasan tidak terganggu, manakala 18 spesis daripada 11 famili telah ditangkap di kawasan terganggu. Analisis statistik menunjukkan bahawa indeks kepelbagaian spesis berbeza secara signifikan antara kawasan tidak terganggu dan terganggu.

Kata kunci: Avifauna, Borneo, Hutan Berterusan, Hutan Batu Kapur, Jaring Kabut, Hutan Primer

Abstract: Bird surveys were conducted in the Padawan Limestone Area for seven days at each of two study sites, Giam and Danu, from August to December 2008. The purpose of the study was to compare the area's bird species richness and abundance of bird species in other limestone areas and in other forest types. The study also compared the species richness and relative abundance of birds in undisturbed and disturbed areas at both study sites. Twenty mist nets were deployed for 12 hours daily. During this study period, direct observations of birds were also made. In all, 80 species from 34 families were recorded at both sites. At Giam, 120 birds were mist-netted. These birds represented 31 species from 16 families. The direct observations at Giam recorded 13 species from 11 families. In the undisturbed area, 21 species from 13 families were mist-netted, whereas in the disturbed area, 21 species from 10 families were mist-netted. In Danu, a total of 48 birds, representing 25 species from 12 families, were mist-netted. The observations at Danu recorded 34 species from 19 families. Twelve species from 7 families were mist-netted in the undisturbed area, whereas 18 species from 11 families were mist-netted in the disturbed area. Statistical analysis showed that the species diversity index differed significantly between undisturbed and disturbed areas.

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Keywords: Avifauna, Borneo, Continuous Forest, Limestone Forest, Mist Netting, Primary Forest

INTRODUCTION

Limestone outcrops occur infrequently throughout Southeast Asia. Approximately 400000 km² of karst areas occur in the region (Day & Urich 2000). The Padawan Limestone Area, the largest outcrop in Sarawak, is one of six limestone biodistricts in Sarawak (Lim 2008). It is located in the southwest part of the Kuching District, where the limestone hills are primarily of the wet type.

The Padawan Limestone is among the oldest limestone formation in Sarawak. It dates from the Upper Jurassic to the Lower Cretaceous period, approximately 150–170 million years ago (Cranbrook 2004). The type section of the Padawan Formation includes Padawan Road between Tiang Bekap and Padawan and the Semadang Valley above Padawan. The formation underlies 435 km² in the Penrissen area (Wilford 1965). The habitat is a mosaic of cultivated farmland interspersed with old secondary forests, orchards and limestone vegetation on the relatively undisturbed limestone hills.

Sarawak's limestone forests are characterised by relatively low, relatively sparse stands of specialised trees and by a slightly impoverished but distinctive bird fauna (MacKinnon & Phillips 1993). Limestone may naturally form precipitous cliffs, pinnacles, caves and underground channels. These geological features characterise karst topography (Banda *et al.* 2004). The complex terrain of fissured cliffs and extensive caves and the variable climatic conditions of karst areas provide many ecological niches and support high species diversity (Clements *et al.* 2006). The unique karst flora may give rise to bird diversity that differs somewhat from that found in non-karstic areas (Clements *et al.* 2006).

To date, very little research has been conducted on the fauna of the limestone areas in Padawan. Studies of the birds of these areas are particularly scarce. Studies of the bird diversity of the Padawan Limestone Area can make an important contribution by offering new knowledge about the area's biodiversity. Such information is very useful for the conservation and management of biodiversity and may promote the tourism industry in Padawan.

The main objective of this study was to compare the Padawan Limestone Area's bird species richness and abundance with the bird richness and abundance of other limestone areas and of other types of forests. An additional objective of this study was to compare the bird species richness and relative abundance of undisturbed and disturbed areas at both study sites in the Padawan area.

MATERIALS AND METHODS

Study Site

Bird surveys were conducted in the Padawan Limestone Area for seven days at each of two study sites, Giam (1° 18.981' N, 110° 16.436' E) and Danu

(1° 17.404' N, 110° 13.559 'E), from August to December 2008. Figure 1 shows the location of Giam and Danu in the Padawan Limestone Area.

The vegetation of Giam is a mixture of limestone forest, orchard and secondary forest. A river (Sungai Sewa) and several caves are found in the area, and swiftlets are found in front of the caves. The undisturbed area (>100 ha) is composed of limestone habitat near the cliffs and is surrounded by secondary forest. In the undisturbed area, wild ginger (*Etilingera littoralis*) and melastoma (*Melastoma malabathricum*) occur and may be seen flowering. Secondary forest and orchard habitat dominate the disturbed area (<30 ha). The two areas are located approximately 500 m apart.

The vegetation of Danu is also mixed and consists of primary forest, secondary forest, mixed dipterocarp forest and kerangas forest. A river (Sg. Kayu) and a waterfall (Atak Kayu) are located in the area sampled by this study. The habitat of the undisturbed area (>100 ha) includes primary and secondary forests and the contact zone between them. Trees of considerable size, such as *Koompassia excelsa* and *Koompassia malaccensis*, are found in the area. In the disturbed area (<50 ha), kerangas forest adjoins the rice fields and the cultivated areas. The two areas are located approximately 700 m apart.

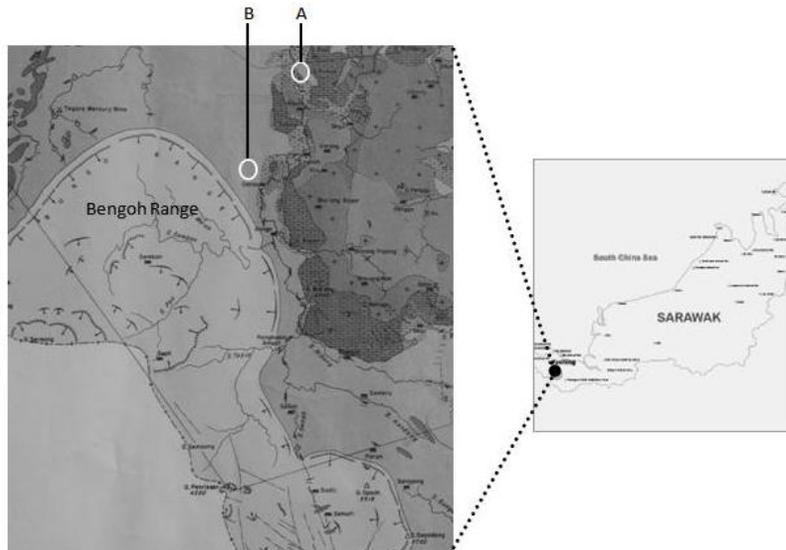


Figure 1: Schematic diagram showing the Giam (A) and Danu (B) study sites in the Padawan Limestone Area, Sarawak, Malaysia.

Mist Netting

Twenty mist nets having three shelves each were deployed in undisturbed areas (10 nets) and in disturbed areas (10 nets) at both study sites. The distances between the nets in Giam and in Danu were approximately 15 m and 50 m, respectively. The nets were erected 0.5 m above the ground and set under a

closed canopy in both areas to avoid sun flecks, which can reduce the effectiveness of mist netting.

The mist nets were left open from morning (0600) until evening (1800) and were checked once every two hours. The captured birds were identified using Smythies (1999) and MacKinnon and Phillips (1993). All of the captured birds were measured (weight, total length, bill, tarsus and wing length). The birds were marked with uniquely numbered aluminium rings bearing the address of Universiti Malaysia Sarawak (UNIMAS) and were then released at the capture sites.

Incidental Observations

Observers walking along the forest trails obtained incidental data by making bird sightings and by identifying bird calls. Observations were made using 8 x 42 binoculars. Birds were identified using MacKinnon and Phillips (1993). Calls were compared with the recorded calls compiled by Scharringa (2005).

Data Analysis

The values of the Shannon-Wiener species diversity index, H' , were calculated for undisturbed and disturbed areas by using the DIVERS programme (Krebs 1989). These diversity index values were statistically compared within each site by using the Zar t -test to detect possible significant differences.

RESULTS

Overall Species Richness and Abundance

In all, 80 species from 34 families were recorded at the Giam and Danu study sites. At Giam, 120 birds were mist-netted. These birds represented 31 species from 16 families (Table 1). Moreover, 13 species from 11 families were recorded through incidental observation (Appendix 1). At Danu, 48 birds were mist-netted. These birds represented 25 species from 12 families (Table 2). A total of 34 species from 19 families were recorded through observation (Appendix 2).

This study recorded one Fairy Pitta [*Pitta nympha* (family Pittidae)]. This species is listed in Part I (Totally Protected Animals) of the Sarawak Wildlife Protection Ordinance 1998. In addition, the study found the White-rumped Shama [*Copsychus malabaricus* (family Turdidae)], the Hill Myna [*Gracula religiosa* (family Sturnidae)], all swiftlet species (family Apodidae), all kingfisher species (family Alcedinidae), all woodpecker species (family Picidae) and all parrot species (family Loriculinae) listed in Part II (Protected Animals) of the Sarawak Wildlife Protection Ordinance 1998.

Species Richness and Abundance in Giam

The family Nectariniidae, with seven species recorded, was the most diverse family found in Giam, followed by the Dicaeidae with five species. The species captured most frequently was the Little Spiderhunter (*Arachnothera longirostra*) (24 birds captured, corresponding to a relative abundance of 20%). Next highest in relative abundance were the Red-tailed Tailorbird (*Orthotomus sericeus*) and

the Plain-throated Sunbird (*Anthreptes malacensis*). Both species had a relative abundance of 9%. The White-bellied Swiftlet (*Collocalia escluenta*) had a relative abundance of 8%, and the Red-eyed Bulbul (*Pycnonotus brunneus*) had a relative abundance of 7%. Birds of several species were recaptured. These species included the Little Spiderhunter, Rufous Piculet (*Sasia abnormis*) and Chestnut-winged Babbler (*Stachyris erythroptera*). None of the mist-netted birds were migrant species.

The 69 birds mist-netted in the undisturbed area represented 21 species from 13 families. The 51 birds mist-netted in the disturbed area represented 21 species from 10 families. Figure 2 shows the number of species captured in the undisturbed area alone, the number captured in the disturbed area alone and the number captured in both areas.

In the undisturbed area, the Little Spiderhunter was captured most often (15 individuals). Next in abundance was the Red-tailed Tailorbird (eight individuals). The Little Spiderhunter was also captured most frequently in the disturbed area (nine individuals). The Plain-throated Sunbird, with seven individuals, was next in abundance.

Species Richness and Abundance at Danu

The family Timaliidae, with seven species captured, was the most diverse family found at Danu. Next in diversity were the Pycnonotidae and the Muscicapidae, with 4 species each. The Little Spiderhunter was the species most often captured (10 birds, a relative abundance of 21%), followed by the Rufous-backed Kingfisher (*Ceyx rufidorsa*) and the Short-tailed Babbler (*Malacocincla malaccense*), (4 birds, relative abundance of 8%). One Fairy Pitta, a migratory bird, was captured in the Danu sampling area.

A total of 17 birds were mist-netted in the undisturbed area. These birds represented 12 species from 7 families. In all, 31 birds, representing 18 species from 11 families, were mist-netted in the disturbed area. Overall, the number of birds captured was higher in the disturbed area than in the undisturbed area. In the undisturbed area, the Short-tailed Babbler and the Little Spiderhunter (three individuals each) were the species most frequently captured. The Little Spiderhunter (seven individuals) was the species captured most frequently in the disturbed area, followed by the Rufous-backed Kingfisher (four individuals). Figure 3 presents the number of species captured in the undisturbed area alone, in the disturbed area alone and in both areas.

Data Analysis

The Shannon-Wiener index of species diversity was calculated from the data. Table 3 shows the values of the Shannon-Wiener diversity index for Giam and Danu. At both study sites, the diversity index differed significantly between the undisturbed area and the disturbed area (Zar *t*-test, $\alpha=0.05$) (Table 4). The null hypothesis that the species diversity index did not differ between the undisturbed and the disturbed area was therefore rejected.

Table 1: Number of bird species and relative abundance of captured birds in Giam, Padawan.

Species	Undisturbed	Disturbed	Total	Relative abundance
Columbidae				
<i>Chalcophaps indica</i>	1	0	1	0.01
Cuculidae				
<i>Cocomantis merulinus</i>	1	0	1	0.01
Apodidae				
<i>Aerodramus salanganus</i>	1	0	1	0.01
<i>Collocalia escluenta</i>	8	1	9	0.08
Alcedinidae				
<i>Alcedo meninting</i>	0	2	2	0.02
Capitonidae				
<i>Megalaima mystacophanos</i>	2	0	2	0.02
Picidae				
<i>Sasia abnormis</i>	4	0	4	0.03
<i>Meiglyptes tristis</i>	0	2	2	0.02
Campephagidae				
<i>Hemipus hirundinaceus</i>	3	0	3	0.03
Pycnonotidae				
<i>Pycnonotus brunneus</i>	5	3	8	0.07
Timaliidae				
<i>Stachyris erythroptera</i>	3	2	5	0.04
<i>Stachyris poliocephala</i>	1	1	2	0.02
<i>Yuhina zantholeuca</i>	0	2	2	0.02
Turdidae				
<i>Copsychus malabaricus</i>	0	1	1	0.01
Sylviidae				
<i>Orthotomus sericeus</i>	8	3	11	0.09
<i>Prinia flaviventris</i>	0	1	1	0.01
Muscicapidae				
<i>Cyornis turcosus</i>	2	0	2	0.02
Sturnidae				
<i>Aplonis panayensis</i>	0	1	1	0.01
Nectariniidae				
<i>Anthreptes simplex</i>	3	2	5	0.04
<i>Anthreptes malacensis</i>	4	7	11	0.09
<i>Anthreptes singalensis</i>	0	1	1	0.01

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Table 1: (continued)

Species	Undisturbed	Disturbed	Total	Relative abundance
<i>Hypogramma hypogrammicum</i>	1	0	1	0.01
<i>Nectarinia jugularis</i>	0	1	1	0.01
<i>Arachnothera longirostra</i>	15	9	24	0.2
<i>Arachnothera crassirostris</i>	0	1	1	0.01
Dicaeidae				
<i>Prionochilus thoracicus</i>	1	0	1	0.01
<i>Prionochilus maculates</i>	2	4	6	0.05
<i>Prionochilus xanthopygius</i>	1	0	1	0.01
<i>Dicaeum trigonostigma</i>	1	3	4	0.03
<i>Dicaeum cruentatum</i>	0	1	1	0.01
Ploceidae				
<i>Lonchura fuscans</i>	2	3	5	0.04
Number of birds	69	51	120	
Number of species	21	21	31	
Number of families	13	10	16	
H'	3.841	4.002		

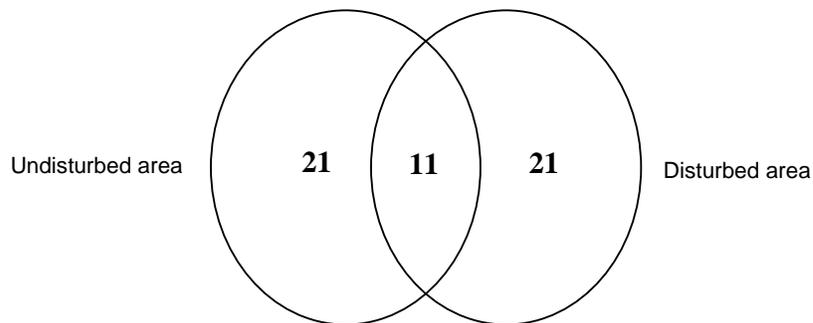
Table 2: Number of bird species and relative abundance of captured birds in Danu, Padawan.

Species	Undisturbed	Disturbed	Total	Relative abundance
Podargidae				
<i>Batrachostomus stellatus</i>	0	1	1	0.02
Trogonidae				
<i>Harpactes duvaucelii</i>	0	1	1	0.02
Alcedinidae				
<i>Ceyx rufidorsa</i>	0	4	4	0.08
Picidae				
<i>Sasia abnormis</i>	1	1	2	0.04
Pittidae				
<i>Pitta nympha</i>	0	1	1	0.02
Pycnonotidae				
<i>Pycnonotus plumosus</i>	0	1	1	0.02
<i>Pycnonotus brunneus</i>	1	0	1	0.02
<i>Alophoixus bres</i>	2	0	2	0.04
<i>Tricholestes criniger</i>	0	2	2	0.04

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Table 2: (continued)

Species	Undisturbed	Disturbed	Total	Relative abundance
Timaliidae				
<i>Pellorneum capistratum</i>	1	0	1	0.02
<i>Trichastoma rostratum</i>	1	1	2	0.04
<i>Trichastoma bicolor</i>	1	0	1	0.02
<i>Malacocincla malaccense</i>	3	1	4	0.08
<i>Malacopteron affine</i>	1	2	3	0.06
<i>Malacopteron cinereum</i>	0	2	2	0.04
<i>Stachyris poliocephala</i>	0	1	1	0.02
Turdidae				
<i>Copsychus malabaricus</i>	1	0	1	0.02
<i>Enicurus ruficapillus</i>	0	2	2	0.04
Sylviidae				
<i>Phylloscopus borealis</i>	1	0	1	0.02
Muscicapidae				
<i>Ficedula dumetoria</i>	0	1	1	0.02
<i>Cyornis caerulatus</i>	0	1	1	0.02
<i>Rhipidura perlata</i>	1	0	1	0.02
<i>Philentoma pyrhopterum</i>	0	1	1	0.02
Nectariniidae				
<i>Arachnothera longirostra</i>	3	7	10	0.21
Dicaeidae				
<i>Prionochilus maculatus</i>	0	1	1	0.02
Number of birds	17	31	48	
Number of species	12	18	25	
Number of families	7	11	12	
H'	3.410	3.804		

**Figure 2:** Number of species captured in undisturbed and disturbed areas in Giam, Padawan; the area of overlap shows the species common to both areas.

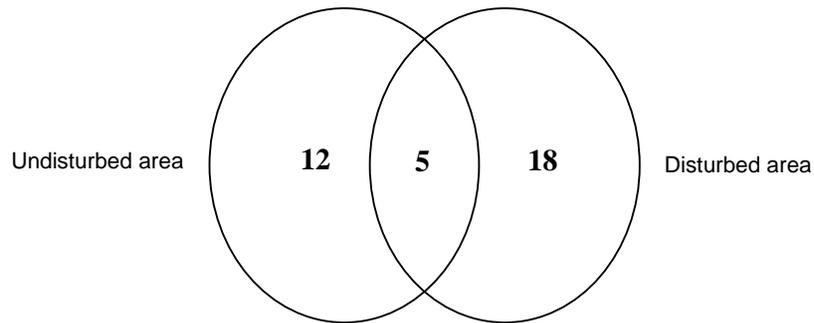


Figure 3: Number of species captured in undisturbed and disturbed areas in Danu, Padawan; the area of overlap shows the species common to both areas.

Capture Rate

The overall capture rate in Giam was 83 birds per 1000 net hours. This total rate represents the sum of the capture rates in the undisturbed area (48 birds per 1000 net hours) and in the disturbed area (35 birds per 1000 net hours). The capture rate in Danu was 40 birds per 1000 net hours. This value represents the sum of 28 birds and 52 birds per 1000 net hours in the undisturbed and disturbed areas, respectively. The overall capture rate for this study, including both Giam and Danu, was 64 birds per 1000 net hours.

Table 3: Shannon-Wiener index of species diversity in Giam and Danu.

	Giam		Danu	
	Undisturbed area	Disturbed area	Undisturbed area	Disturbed area
Shannon-Weiner Index	3.841	4.002	3.410	3.804

Table 4: Comparison of diversity index between undisturbed and disturbed areas at two study sites using the Zar t-test.

Site	Area	t-calculated	t-critical	Significant/not significant
Giam	Undisturbed vs disturbed	-3.865	$t_{0.05(2),117} = 1.980$	Significant
Danu	Undisturbed vs disturbed	-4.516	$t_{0.05(2),120} = 1.977$	Significant

DISCUSSION

Species Richness and Abundance in the Padawan Limestone Area

In this study, the capture rate was higher in Giam than in Danu. This difference may result from the underlying differences in habitat types, weather conditions and net placement effectiveness between the two sites (to be most effective, mist nets must be placed so as to coincide with the birds' flyways). The Giam habitat, including Gunung Sewa, is composed of relatively untouched forest. This forest habitat is used by the birds for roosting or as a refuge site. The birds may leave the forest and fly to adjacent areas to find food. On the contrary, the sampling site in Danu consists of continuous forest. The site includes much sloping terrain. Because the sloping terrain forces birds to fly in many different directions, they do not follow the forest flyways. Rainy conditions in Danu during the first few days of sampling may have reduced the foraging activity of the birds and thus decreased the capture rates.

In Giam, the mist nets were set under both the closed and the open canopy near a limestone cliff that contained numerous caves. Swiftlets are common in limestone habitats because of the presence of caves (Rahman *et al.* 2004), and high capture rates of swiftlets are therefore likely in these habitats. In Danu, however, mist nets were set only under the closed canopy, far from the limestone cliff.

Although the capture rate was lower in Danu, direct observation at this site revealed a high level of species diversity (Appendix 2). This result probably reflects the presence of mixed dipterocarp forest (MDF) in Danu. For certain families in the area, the MDF contains more species of birds (Sim & Kong 2004). Compared with other forests, the primary forest and MDF offer a greater variety of fruit (Smythies & Davison 1999).

The Little Spiderhunter was the species captured most frequently at both sites. This species was recorded in a variety of different habitats that provide a wide range of food sources, microhabitats and refuges from predation (Anwarali *et al.* 2008). This species is a nectarivore or insectivore, and its diet includes nectar, some insects and pollen (MacKinnon & Phillips 1993).

Species Richness and Abundance in Giam

In Giam, the Red-tailed Tailorbird and Red-eyed Bulbul were relatively abundant. This finding reflects their preference for the secondary forest found in both areas sampled in Giam. The Plain-throated Sunbird, like the Little Spiderhunter, found preferred foods, such as nectar from banana flowers (MacKinnon & Phillips 1993), in the area. The sedentary habits of some birds made them prone to recapture. The presence of paddy fields, cocoa plantations, banana plants, *Melastoma* sp. and ginger flowers was probably the main reason that these birds preferred to forage in the area. The occurrence of these food resources explains the large number of species belonging to the families Nectariniidae and Dicaeidae that were captured in Giam.

The capture rate for the undisturbed area was higher than that in the disturbed area, and the index of bird species diversity differed significantly between the two areas. These results are probably a consequence of the differences in the level of disturbance between those areas. Fewer visitors and reduced local activity may increase bird activity in the undisturbed areas (Anwarali *et al.* 2008). The wild ginger and *Melastoma* sp. probably attracted the birds to forage in the undisturbed area.

Species Richness and Abundance in Danu

Most of the birds captured in Danu were insectivorous birds belonging to the families Podargidae, Trogonidae, Picidae, Timaliidae, Turdidae, Sylviidae and Muscicapidae. In Giam, however, a high number of nectarivorous and frugivorous species belonging to the families Nectariniidae and Dicaeidae were captured. More insectivorous birds tend to be captured in primary forest than in secondary forest. The reason for this difference is that in most primary forests, fewer bird species are both frugivorous and insectivorous. Species of this type are generally replaced by the insectivorous birds (Zakaria *et al.* 2005). In the Pasoh Forest Reserve, 61% of all the bird species captured in primary dipterocarp forest were insectivorous (Wong 1986). Most species of dipterocarp trees tend to flower and fruit synchronously once every two to seven years. Because of this phenological pattern, fewer species of nectarivorous and frugivorous birds are found in MDF (Smythies & Davison 1999). The migratory bird captured in the sampling area was a Fairy Pitta, a species that is only recorded from October to March (MacKinnon & Phillips 1993).

The highest number of species recorded was found for babblers of the family Timaliidae. These species forage both on the forest floor and under the canopy (Madoc 1992). Their diet includes insects, larvae and worms, and they inhabit primary and secondary lowland forest (Anwarali *et al.* 2008).

The capture rate in the disturbed area was higher than that in the undisturbed area, and the bird diversity index differed significantly between the two areas. These findings probably result from the differences in vegetation between the two areas. The forest in the undisturbed area is continuous and has considerably more sloping terrain than does the disturbed area. The higher capture rate in the disturbed area may also have resulted from the fact that the mist nets could be placed to coincide with the birds' flyways.

Comparisons with Other Studies

Table 5 compares the capture rates and species richness found in this study with the results of other studies from the literature. The capture rate for this study resembles the capture rates reported in other studies conducted in limestone forests. This similarity is probably a result of the comparable degree of disturbance, availability of food sources and forest vegetation at each of these study sites.

The species richness found by the current study was higher than that found in other limestone forests. The reason for these higher values appears to be the presence of MDF in this study's sampling areas. The vegetation in Bau

consists of limestone forests, orchards and secondary forests, whereas the sampling area in Banggi Island is generally limestone forest.

The species richness found by this study is comparable with that found for MDF at Pueh. The similarity of the forests at these study sites probably accounts for these comparable values of species richness. However, the values of species richness found by the current study were higher than those found for the MDF at Santubong. According to Tuen *et al.* (2000), part of the sampling at Santubong was conducted during a period marked by hazy conditions. The hazy weather may have influenced bird activity. The species richness found by this study was also higher than that found for the peat swamp forest at Gunung Palung. The smaller numbers of individuals and of bird species found at Gunung Palung are consistent with the hypothesis that the peat swamp forests support a depauperate bird community (Gaither 1994). However, the species richness of the peat swamp forest at Unimas was higher than the values found in this study. The methods used by Tuen and Darub (1999) appear to explain this difference. Tuen and Darub (1999) used two replicate sampling periods and deployed a total of 50 mist nets for each sampling period.

Table 5: Comparison of capture rates and species richness between this study and other studies.

Habitat and study location	Capture rate (per 1000 net hours)	Species richness
Limestone forest, Banggi Island, Sabah (Rahman & Abdullah 2002)	70	28
Limestone forest, Bau (Rahman <i>et al.</i> 2004)	65	31
MDF, Santubong (Tuen <i>et al.</i> 2000)	57	28
MD, Pueh (Mawek 2002)	85	46
Peat swamp forest, Gunung Palung (Gaither 1994)	60	34
Peat swamp forest, Unimas (Tuen & Darub 1999)	70	66
This study	64	44

CONCLUSION

The species richness in this study was higher than that previously found for other limestone areas (Bau limestone and Banggi Island). This study recorded birds listed in Part I (Totally Protected Animals) and Part II (Protected Animals) of the Sarawak Wildlife Protection Ordinance 1998. The statistical analysis revealed

significant differences in the species diversity index between undisturbed and disturbed areas at Giam and at Danu.

Limestone areas have potential uses as quarries and for mining. Often, these areas are also known to exhibit relatively low values of biodiversity. Awareness of the importance of limestone areas has recently increased, and studies of the biodiversity of such areas are now being promoted. Quarrying activity in this area will harm its biodiversity.

This study did not include cave systems. However, for the purposes of this research, it was sufficient to perform studies of limestone outcrops, because cave-dwelling birds forage outside caves during the day. Such information is very useful for the conservation and management of biodiversity and may promote awareness of the limestone area.

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Appendix 1.

Species of birds recorded by direct observation in Giam, Padawan.

Family	Common name	Species
Psittacidae	Blue-crowned Hanging Parrot	<i>Loriculus galgulus</i>
Cuculidae	Raffles's Malkoha	<i>Phaenicophaeus chlorophaeus</i>
	Greater Coucal	<i>Centropus sinensis</i>
Capitonidae	Blue-eared Barbet	<i>Megalaima australis</i>
Eurylaimidae	Black-and-red Broadbill	<i>Cymbirhynchus macrorhynchos</i>
	Banded Broadbill	<i>Eurylaimus javanicus</i>
Hirundinidae	Pacific Swallow	<i>Hirundo tahitica</i>
Chloropseidae	Lesser Green Leafbird	<i>Chloropsis cyanopogon</i>
Corvidae	Black Magpie	<i>Platysmurus leucopterus</i>
Timaliidae	Striped Tit-babbler	<i>Macronous gularis</i>
Turdidae	Magpie Robin	<i>Copsychus saularis</i>
Sylviidae	Ashy Tailorbird	<i>Orthotomus ruficeps</i>
Ploceidae	Tree Sparrow	<i>Passer montanus</i>

Appendix 2.

Species of birds recorded by direct observation in Danu, Padawan.

Family	Common name	Species
Accipitridae	Crested-serpent Eagle	<i>Spilornis cheela</i>
Rallidae	White-breasted Waterhen	<i>Amaurornis phoenicurus</i>
Columbidae	Emerald Dove	<i>Chalcophaps indica</i>
Cuculidae	Indian Cuckoo	<i>Cuculus micropterus</i>
	Plaintive Cuckoo	<i>Cacomantis merulinus</i>
	Raffle's Malkoha	<i>Phaenicophaeus chlorophaeus</i>
	Greater Coucal	<i>Centropus sinensis</i>
Apodidae	Black-nest swiftlet	<i>Collocalia maxima</i>
	Mossy Nest Swiftlet	<i>Collocalia salangana</i>
	White-bellied Swiftlet	<i>Collocalia esculenta</i>
Trogonidae	Red-naped Trogon	<i>Harpactes kasumba</i>
Meropidae	Red-bearded Bee-Eater	<i>Nyctornis amictus</i>
Capitonidae	Red-crowned Barbet	<i>Megalaima rafflesii</i>
	Red-throated Barbet	<i>Megalaima mystacophanos</i>
	Blue-eared Barbet	<i>Megalaima australis</i>
	Brown Barbet	<i>Calorhamphus fuliginosus</i>
Eurylaimidae	Black and Yellow Broadbill	<i>Eurylaimus ochromalus</i>
	Green Broadbill	<i>Calyptomena viridis</i>
Chloropseidae	Green Iora	<i>Aegithina viridissima</i>
	Lesser Green Leafbird	<i>Chloropsis cyanopogon</i>
Pycnonotidae	Puff-backed Bulbul	<i>Pycnonotus eutilotus</i>
Dicruridae	Greater Racker-tailed Drongo	<i>Dicrurus paradiseus</i>
Corvidae	Crested Jay	<i>Platylophus galericulatus</i>
	Black Magpie	<i>Platysmurus leucopterus</i>
Timaliidae	Chestnut-winged Babbler	<i>Stachyris erythroptera</i>
	Striped Tit Babbler	<i>Macronous gularis</i>
Turdidae	Magpie Robin	<i>Copsychus saularis</i>
Sylviidae	Dark-neck Tailorbird	<i>Orthotomus atrogularis</i>
	Red-tailed tailorbird	<i>Orthotomus sericeus</i>
	Yellow-bellied Prinia	<i>Prinia flaviventris</i>
Nectariniidae	Purple-naped Sunbird	<i>Hypogramma hypogrammicum</i>
Dicaeidae	Crimson-breasted Flowerpecker	<i>Prionochilus percussus</i>
Ploceidae	Pin-tailed Parrotfinch	<i>Erythrura prasina</i>
	Dusky Munia	<i>Lonchura fuscans</i>