Microhabitat Preference of Frogs at Similajau National Park, Sarawak, Malaysia.

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DOI: 10.29322/IJSRP.9.04.2019.p8819
http://dx.doi.org/10.29322/IJSRP.9.04.2019.p8819

Abstract - Tropical heath forest occurs widely in many places of Borneo. Similajau National Park is one of the locations with heath forest. Because of insufficient data on the anurans of heath forest in Similajau National Park, a survey was carried out in the beginning of August 2014 until January 2015. The objectives of the study were to compare the anuran species diversity between two different study plots and to determine anuran species microhabitat preferences. The sampling method involved a 300m transects line and 240 quadrats method (5m x 5m) at both study sites. A total of 23 species of frogs (299 individuals) belonging to six frog families were detected. The study site was dominated by anurans of the family Dicroglossidae (48.8%) followed by Rhacophoridae (24.7%), Ranidae (17.7%), Ceratobatrachidae (4.7%), Microhylidae (1.3%) and Bufonidae (2.7%). Four endemic Borneo frogs, namely *Ingerophyrus divergens*, *Limnonectes ingeri*, *Kalophrynus intermedius*, and *Philautus tectus* were among anurans captured in this study. The Shannon Wiener Diversity Index, *H'* at forest site was higher than the non-forest site (2.48 ± 0.06 vs. 1.77 ± 0.05). There was no dominant species at forest sites, which was reflected by the low Simpson Index, *D*, 0.091 (±0.01). Conversely, the same index at the non-forest site was higher with 0.201 (±0.04). This is apparent with the presence of *Fejervarya cancrivora* that made up about 20% of the total frogs sampled in the area. Habitat preferences associated with the recovered species from this are discussed in this paper.

Index Terms - Diversity, frog occurrence, kerangas forest, non-forest, Similajau National Park

INTRODUCTION

Tropical heath forest occurs widely in many places of Borneo where they are called kerangas,but occur in small areas in Peninsular Malaysia [62]. Similajau National Park is one of the locations with heath forest. Heath forests are a type of seasonal lowland tropical rain forests that occur extensively in dry land sites; on flat sites, inter-digitations occur correlated with predominantly podzolized, highly acidic and sandy soils [6,15,63]. Many previous studies In Borneo, especially in Sarawak and Brunei, focuses on their ecology, plant community compositions, soil, litter, and environmental characteristics [36,38,44], but less on anurans diversity.

Tropical heath forests are distinctive in their forest structure compared to lowland mixed dipterocarp forests that are more dominant throughout Borneo. There are several factors that contribute to the distinct characteristic of this forest type. First factor is caused by periodic droughts such as decreasing soil depth and increasing variability of water supply under favourable conditions that would create vegetation types similar to the dipterocarp forests [6]. Second includes the striking structural and physiognomic features, such as lower roughness of canopy surface, smaller mean leaf size, steeply inclined leaves and twigs, and shorter and unbuttressed trees [13,62,64].

Nowadays, anurans population and species are representatives of the general loss of biodiversity worldwide [2,23]. About 5,532 species of anurans drive the average threat level for amphibians as a whole with 31.6% representing 1,749 species either threatened or extinct tabout 28 families of anurans are found around the world [27]. In Malaysia, there are 16 families in Peninsular Malaysia, where 12 families of frogs that have been recorded which are Bufonidae, Centrolenidae, Dendrobatidae, Discoglossidae, Hylidae, Hyperolidae, Leptodactylidae, Microhylidae, Pseudidae, Ranidae, Rhacophoridae, andRhinophrynidae [40]. In Borneo, eight families of frogs have been recorded which areBombinatoridae (Firebellied Toads), Bufonidae (True Toads), Ceratobratrachidae (no vernacular name), Dicroglosidae (True Frogs I), Megophyridae (Litter frogs), Microhylidae (Narrow-Mouthed Frogs), Ranidae (True Frogs II) and Rhacophoridae (Afro-Asian Tree Frogs) [19,26].

Studies on the effect of different types of land used in local landscape levels of Borneo are insufficient. There is a need to study species diversity of anurans. In addition, there are insufficient data on the anurans of Similajau National Park, especially in tropical heath forest habitat. Previous research about frogs in Similajau National Park is confined to the characteristics of *Hylarana* sp. [48]. The reason of selection of this area is based on the lack of scientific data and research that has not been systematically examined. The proposed study will provide information about species diversity and their abundance which is important for future conservation plans and also for the determination of habitat preferences which can be used for conservation of species in captivity programs.

The hypothesis is the pattern of frog assemblage including their diversity and presences of dominant species are significantly different in two different habitat types. There is significant difference in species association with microhabitat structures. The objectives of the study are to compare the anuran species diversity between two different study plots, in relation to the effect of reduced habitat cover of Similajau National Park and to determine anuran species microhabitat preferences in association with the study plots.

MATERIALS AND METHODS

Study site

This study was conducted in Similajau National Park, which is located about 30 km from Bintulu town in north Sarawak, Malaysia (Figure 1). Comprising of 8,996 ha, the Similajau National Park reserve generally consists of three distinct habitat types: mixed dipterocarp forest, mangrove forest, and tropical heath forest [21]. During the study period, the climate in the area was typically humid tropic, characterised by yearly high temperature (ranged between 26ºC and maximum of 32ºC) and seasonal heavy rain (ranged between 2000mm and 4000mm per year) overall in a year [9].

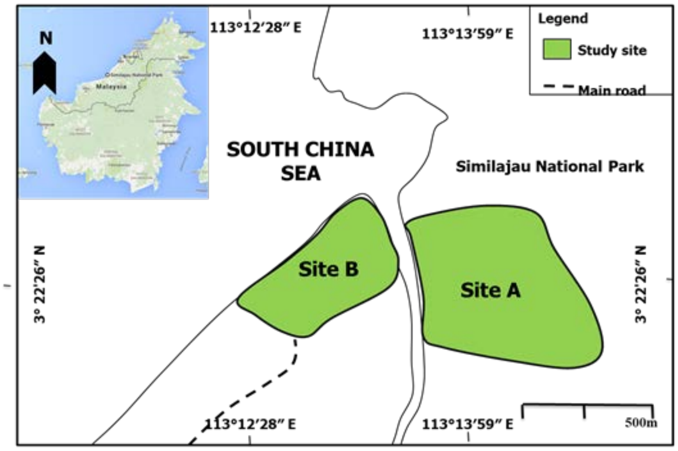

Figure 1. The location of study sites in Similajau National Park which are known as site A indicates the forest site and Site B the non-forest site.

Two sampling plots of different land uses within the Similajau National Park were selected to serve the objectives of this study; (a) forest area (an approximate area of 18-ha tropical heath forest), and (b) developed area (an approximate 14-ha area developed for the park office and lodgings, consisting primarily of casuarina trees as the dominant vegetation). The exact size of study area covers 18.9% of total size tropical heath forest at Similajau National Park. According to the park officer the education trail was almost covered by tropical heath forest. The total length of the trail is 600 meters (0.37 mi) and 95-ha in hectare. The altitude of study sites ranges from 50 m to 220 m for forest plot and 0 m to 50m of developed area. The developed area has a very flat landform because it is near the beach. A limitation faced in our study area was having access to fieldworkers. This is because experienced fieldworkers are limited and expensive if we conducted the study for a long time and recruit more existing ones.

Sampling plots were selected to fit the objectives of testing the effect of habitat cover where (a) each plot represented are a well-defined habitat type, and (b) both plots consisted of at least one constructed or natural water source (river, stream, drain, pool) to ensure the availability of water that frogs require to complete their life cycles within the plot boundaries. The shortest distance between the two plots was about 400 m to ensure the sample independence [22,54,29].

Frog sampling

This study was conducted with the approval from the Sarawak Forestry (Permit no: NCCD.907.4.4 (Jld.10)-251). Initially, the fieldwork was planned to be conducted during the typical dry (April-August) and wet (September-March) climates of Borneo, based on tropical monsoon seasons. However, due to constraints in project funding, the fieldwork period was limited from 13 August 2014 until 22 January 2015 (24 weeks), during which the area was experiencing a wet climate (rainy season).

Active transect-line search and quadrat plot sampling were used during frog sampling in the forest and developed area plots. The following procedures were standardized throughout the study period at both plots; 1) A 300m transect line with an interval distance of 15m sampling points along the line were established during the fieldwork. The total of 20 sampling point at transect line was set approximately parallel to the water source structure. 2) A total of 240 quadrats (5m x 5m each) were established in both study plots where the distance between quadrats was not less than 5m to avoid census duplicate, but every visit to the quadrats established 20 quadrats in the morning, prior to the night fieldwork. At each transect and quadrat, visual encounter search within a range of 10m perpendicular to each sampling point was employed according to past works [11,52].

All fieldworks were conducted at night because frogs are mostly nocturnal and their encounter rate was reportedly higher than during the day [35]. Only visible frogs were registered in the field note during fieldwork. Both survey methods were conducted between approximately 19:30 pm to 22:30 pm, where visual search was assisted by headlamps and carried out by four fieldworkers. Two fieldworkers, including a local fieldworker who is familiar with the frog identification, were assigned to look for frogs; one was assigned to capture the frogs and another was assigned to record the captured information (nominal species, locality, microhabitat structures). Species counts were tallied thereafter as abundance data.

A 10-minutes search was made at each sampling points and quadrat samplings. The encountered individual of a species was kept in a jar for use as a voucher specimen. Other captured frogs were released after field identification. Species identification was conducted in the field whenever possible and in the laboratory by using established taxonomic guidelines [26, Stuebing, personal comm.]. Photographs of every encountered frog were taken in the field and laboratory. Voucher specimens were preserved in 10% formalin for two weeks to fix the tissues and then changed to 70% ethanol for long storage. All voucher specimens were deposited at Universiti Putra Malaysia Bintulu Campus in Sarawak.

Microhabitat variables

During the sampling survey, observations on microhabitat structures were recorded based on microhabitat structures within each quadrat and transect [49,60]. The structures were defined as (1) vegetation – consisting of green leaf, vegetation stems ,and vegetation and grass roots, (2) mineral deposits (bank mud, bank sand/gravel and bank rock), (3) forest litter (leaf litter, rotten twig, dead stump (diameter > 10 mm)) and dead vegetation (diameter < 10 mm), and (4) water sources –(stream bank, in drain and temporary pool). The number of each category present was tallied.

Data Analysis

All data collected using two methods was pooled and separated into forest and non-forest plot for analysis, using the Margalef index, R to determine species richness or, the number of species or species abundance in each study plot [51]. The species diversity for each study plot was calculated by Shannon-Wiener index, H' and the Simpson index, D to quantify species dominance. The Shannon's Evenness index was also used to measure the distribution of species abundance over a number of species present in each study plot. The Jaccard's index was used to identify the level of similarity in diversity between forest and non-forest plots. The index used to indicate the degree at which both areas consisted of the same species and degree of species uniqueness in each area. All biological indices were performed through the Paleontological Statistics (PAST) and Species Prediction and Diversity Estimation (SPADE) software [7,20]. Non-metric multidimensional scale (NMDS) ordination was also performed to assess the similarity and tendency in microhabitat structures selections for each frog species also using PAST. The substrate groups serve as the independent variable, whereas the dependent variable was the species abundance.

RESULTS

Species Composition

A total of 299 individuals belonging to 23 species were observed to inhabit the forest and non-forest plots of Similajau National Park (Table 1). The species recovered from the survey constituted 13.5% of 170 frog species known from Borneo [12,18,26,34,65]. Frog species were fromsix families in which species from the family Dicroglossidae dominated the area (six species, 48.8% of total occurrences), followed by Rhacophoridae (seven species, 24.7%), Ranidae (four species, 17.7%), Ceratobatrachidae (one species, 4.7%), Bufonidae (two species, 2.7%), and Microhylidae (one species, 1.3%). Overall, a higher family diversity was observed in the forest than the non-forest plots (Figure 2)

Table 1. The frog count tally and percentage of their occurrence in Similajau National Park

Taxa	Sampling plot: Forest	Sampling plot: Non-forest	Total	Conservation status
Bufonidae				
*Ingerophyrus divergens** (Id)	6 (5.56)	0	6 (2.01)	Least Concern
Pelophryne saravacensis (Ps)	2 (1.85) †	0	2 (0.67)	Least Concern
Ceratobatrachidae				
Ingerana sp. (Isp)	14 (12.96)	0	14 (4.68)	Unknown
Dicroglossidae				
Fejervarya cancrivora (Fc)	0	59 (30.89)	59 (19.73)	Least Concern
Fejervarya limnocharis (Fl)	0	49 (25.65)	49 (16.39)	Least Concern
Limnonectes paramacrodon (Lp)	8 (7.41)	2 (1.05) †	10 (3.34)	Near Threatened
*Limnonectes ingeri** (Li)	4 (3.70) †	0	4 (1.33)	Near Threatened
Limnonectes kuhlii (Lk)	10 (9.26)	0	10 (3.40)	Least Concern
Limnonectes deinodon (Ll)	14 (12.96)	0	14 (4.68)	Least Concern
Microhylidae				
Microhyla borneensis (Mb)	1 (0.93) †	0	1 (0.33)	Least Concern
*Kalophrynus intermedius** (Ki)	2 (1.85) †	0	2 (0.67)	Vulnerable
Kalophrynus sp.(Ksp)	1 (0.93) †	0	1 (0.33)	Unknown
Ranidae				
Hylarana erythraea (He)	0	24 (12.57)	24 (8.03)	Least Concern
Chalcorana labialis (Hr)	18 (16.67)	0	18 (6.02)	Least Concern
Pulchrana signata (Hs)	7 (6.48)	0	7 (2.34)	Least Concern
Pulchrana baramica (Hb)	4 (3.70) †	0	4 (1.33)	Least Concern
Rhacophoridae				
Nyctixalus pictus (Np)	1 (0.93) †	0	1 (0.33)	Near Threatened
*Philautus tectus** (Pt)	5 (4.62)	0	5 (1.67)	Vulnerable
Polypedates colletti (Pc)	11 (10.18)	3 (1.57) †	14 (4.68)	Least Concern
Polypedates leucomystax (Pl)	0	29 (15.18)	29 (9.69)	Least Concern
Polypedates macrotis (Pm)	0	4 (2.09) †	4 (1.33)	Least Concern
Rhacophorus pardalis (Rp)	0	17 (8.90)	17 (5.69)	Least Concern
Rhacophorus gauni (Rr)	0	4 (2.09) †	4 (1.33)	Near Threatened
Total species	16	9	23	
Total numbers of individual	108	191	299	

*Endemic species, †Rare species; ≤1/10 the highest number of individuals caught for a species in a site
Annotated conservation statuses were inferred from the IUCN website.

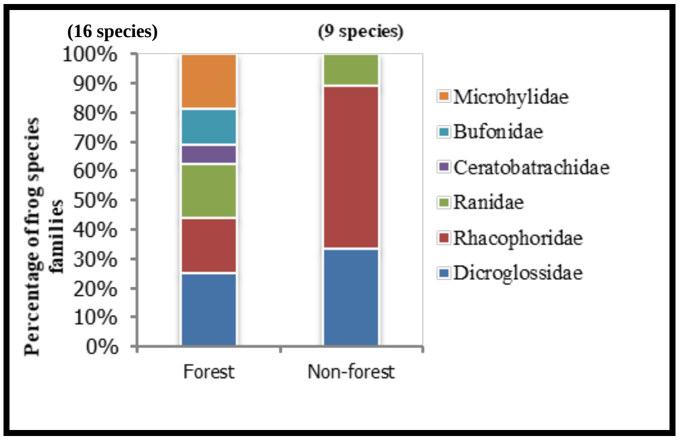

Figure 2. The percentage of frog species families in study sites A and B in Similajau National Park, Sarawak

The number of individuals was higher in the non-forest plot than the forest plotdespite the latter plot harbouring more species (191 vs. 108 individuals). Only *Limnonectes paramacrodon* and *Polypedates colletti* were commonly found in both plots. Four species with endemic distribution to Borneo were found in the forest plot, namely *Ingerophyrus divergens*, *Limnonectes ingeri*, *Kalophrynus intermedius*, and *Philautus tectus* (IUCN, 2015). Four species namely *Limnonectes paramacrodon*, *Limnonecte singeri*, *Nyctixalus pictus* and *Rhacophorus gauni* recovered in the study were classified under IUCN's 'Near Threatened' category and one species was under 'Vulnerable' category (Table 1).

The rank abundance curve was hollow in shape. This means that species community has a small number of abundant species and large number of rare species. For example, the higher abundance species is dominated by *Fejervarya cancrivora* (59 individuals, 19.73% of total occurrence) followed by *Fejervarya limnocharis* (49 individuals, 16.39% of total occurrence). At rank number seven, the three species that have same occurrence of individuals (4.68%) were *Limnonectes deinodon*, *Polypedates colletti* and *Ingerana* sp. with 14 individuals. the rank abundance of fifty was shared by *Pulchrana baramica, Limnonectes ingeri*, *Polypedates macrotis* and *Rhacophorus gauni* with four species (1.33 % of total occurred) respectably. Rare species with only one individual each per species recorded during the study conducted includes *Microhyla borneensis*, *Nyctixalus pictus* and *Kalophrynus* spp.

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Biological Indices

There were marked differences in biological indices between the forest and non-forest plots examined in the study (Table 2). Forest plot consisted of almost double the species richness in non-forest plot ($R_{,forest\ plot}$ = 3.22 vs. $R_{,non\text{-}forest\ plot}$ = 1.52). On the contrary, the number of individuals caught in the forest plot was lower than the non-forest plot (108 vs. 191). Despite the reverse values for R and number of individuals caught between the forest and non-forest plots, the estimation of evenness index, E Shannon was different for both sites (0.75, forest plot vs. 0.65, non-forest plot). The Shannon-Wiener Diversity Index, H' at the forest plot was significantly higher (2.48 ± 0.06) than the non-forest plot (1.77 ± 0.05) at p value of 0.05.Conversely, the Simpson Index for dominance (D) for the non-forest plot was twice higher than the forest plot (0.201±0.04 vs. 0.091±0.01).The study further showed that the Jaccard Similarity, J pooled for both the forest and non-forest plots were 8.7%, indicating a low level of overlap or similarity of frog species between the two study plots.

Table 2. The diversity indices of frogs in forest plots and non-forest plots at Similajau National Park

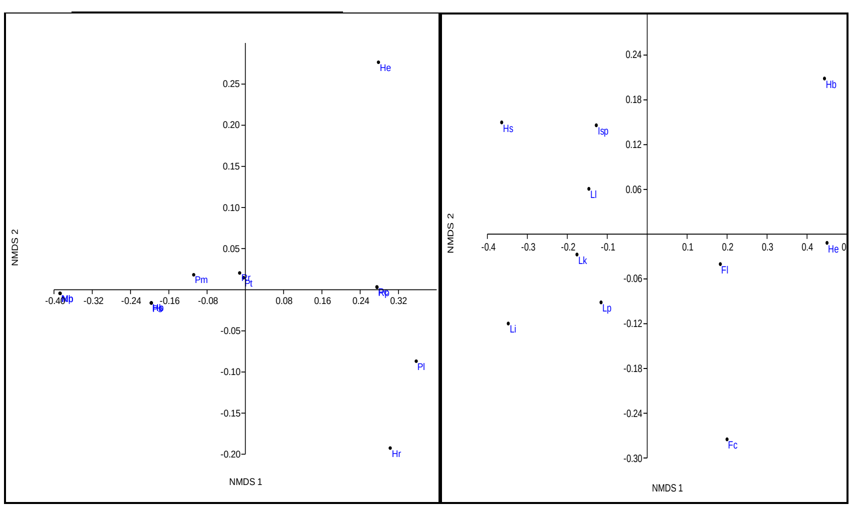
Diversity indices	Forest Plot	Non-Forest Plot
Margalef Richness, R	3.22	1.52
Shannon-Weiner Diversity Index, H'	2.48 (±0.06)	1.77 (±0.05)
Evenness Index, $E_{Shannon}$	0.75	0.65
Shannon Variance	0.0047	0.0029
Dominance, D	0.099 (±0.01)	0.205 (±0.04)
Jaccard Similarity index, *J*	0.087	

Microhabitat variables

The NMDS axes cumulatively accounted for number of species abundance (Axis 1) followed by substrates of microhabitat structures (Axis 2). A total of 13 species associated in vegetation microhabitat structures. The ordination (figure 2a) showed that *Hylarana erythraea* (He) seemed to occur in higher abundance around grasses, benefitting from its background colour. This is followed by *Rhacophorus pardalis* (Rp), *Polypedates leucomystax* (Pl) and *Chalcorana labialis* (Hr) which occurred at green leaves during the study conducted. *Rhachoporus rufipes* (R) and *Philaitus tectus* were in centre of axes which means these species only associated with vegetation especially on stem of vegetation. The rest of species showed negative associations with both axes.

In mineral deposit, *Pulchrana baramica* (Hb) showed strong positive association with both axes as this species was only found to select bank sand or gravel in mineral deposit. *Fejervarya cancrivora* (Fc), *Fejervarya limnocharis* (Fl) and *Hylarana erythraea* (He) were associated with negative axes 2, indicating a strong positive association with mudbank and band sand or gravel. Other species such as *Pulchrana signata* (Hs), *Ingerana* spp. (Is), and *Limnonectes deinodon* (Ll) were associated with negative axes 1 scores, indicating a strong positive association with bank rock.The rest of species showed negative association with mud bank and bank sand or gravel.

a. Vegetation **b. Mineral deposit**



c. Forest litter **d. Water sources**

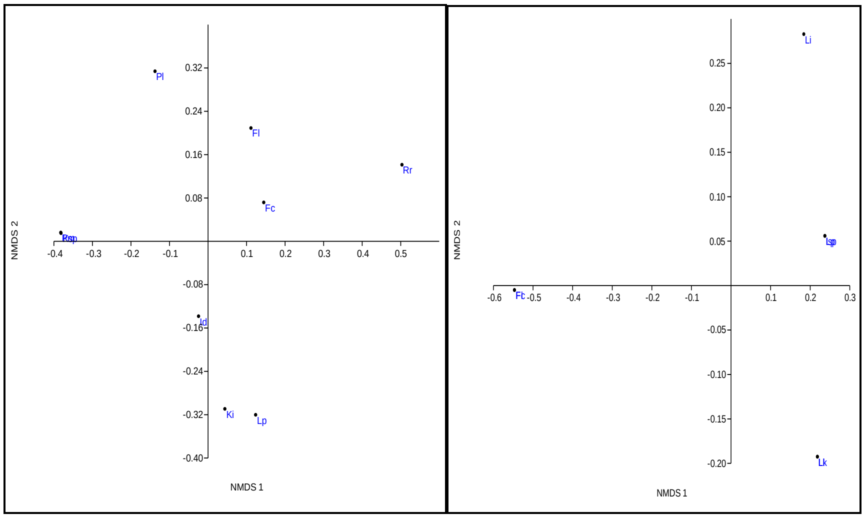


Figure 4. The location of frog species recorded between Aug, 2014 and Jan, 2015 in forest and non-forest plot at Similajau National Park.

In forest litter selection, *Rhachoporus rufipes* (Rr) showed positive ordination because this species only selected rotten twig, compared to *Fejervarya limnocharis* (Fl), and *Fejervarya cancrivora* (Fc) which selected leaf litter and rotten twig for their substrate. *Limnonectes paramacrodon* (Lp), and *Kalophrynu sintermedius* (Ki) selected one substrate which is seen in the position of positive ordination on axes 1. *Polypedates leucomystax* (Pl) was higher in a positive association with the axes 2 which had the tendency to choose forest litter and dead stumps (diameter <10 mm) respectively. The tendency of *Limnonectes paramacrodon* and *Kalophrynus intermedius* to choose their own substrate was reflected by body colour, where these species have light brown to blend well with the forest litter.

For water sources selection, the ordination of *Limonectes ingeri* (Li) was positive of both axes because only one individual was found at the bank stream compared to rest of the species which were also associated with bank stream but have more abundance such as *Ingerana* spp. (Isp), *Limnonectes kuhlii* (Lk), *Limnonectes paramacrodon* (Lp) and *Limnonectes laticeps* (Ll). The tendency of these species to choosetheir substrate reflects their characteristic as ground-dwelling frogs. In contrast, *Fejervarya cancrivora* (Fc) exhibited a relationship with slightly positive values along theaxis 2. Perhaps the attribute to select the drain and temporary pool for their substrate may be explained since there are no stream available at the developed area plot.

DISCUSSIONS

Frog Diversity, Richness and Composition

Variation in habitat structures revealed that frogs have diversity patterns. Predictably, diverse habitats provide more variety in microhabitats and in resources, such as food, space, and cover. However higher population levels are not necessarily correlated with greater species richness [5]. Mature forests predictably possess high plant diversity that provides more complex canopy covers, resulting in more shelter and breeding microhabitats [17]. Although plant diversity was not systematically covered in the method, a rough estimate showed that the forest plot in the study area consisted of 43 tree species (177 individuals) while the non-forest plots contained only 11 tree species (53 individuals). More extensive canopy cover reduces evaporation rates, and thus provides relatively high moisture and humidity for frogs [1,16].

Additionally, controlled evaporation in microclimates allows the proliferation of invertebrates that in turn supplies abundant food resources for frogs [1,5,16,17]. On the contrary, the non-forest study plot homogenously consisted of Casuarina trees where the accumulation of the leaf litter, one of the frogs' important microhabitat features, was conspicuously lower than forest plot. The forest plot consisted of a natural stream that flowed continuously through the plot, containing microhabitat structures that intermittently retain water. Meanwhile, the non-forest plot consisted of an intermittent stream that only sporadically contained water, and lined with water channelling structures, such as cement drains, silt traps forming temporary pools, and permanent puddle from draining effect. The species survival heavily depends on their ability to reproduce, which means that the suitable microhabitats for frogs, especially species of ground-dwelling are very restricted and can inhibit their ability to complete their life cycle [18,66].

Frog abundance in the non-forest plot was relatively higher than the forest plot and possibly due to two factors of abundance pattern which are 1) better detection ability with the absence of diverse vegetation types; 2) the presence of ground-living and non-endemic species that are generalist in behaviour [26,16,59,65]. Lack of habitat covers resulted in an increased probability of individual detection by field observers and also predators [10,37]. The non-forest plot recorded a dominance index twice higher than the forest plot, with the presence of *Fejervarya cancrivora* and *Fejervarya limnocharis*. The presence of dominant species is an ecological phenomenon that needs further investigation.

The evenness index is an important ecological parameter in studies that measure the distribution of species abundance in relation to species presence in a community [14,51,59,61]. The present study revealed that the evenness index was similar in both forest and non-forest plots, as compared to other indices that exhibited marked contrasts, like species richness. Indeed, both research plots in Similajau National Park did not share the same species composition. Species richness composition was affected more by area than isolation [31]. Two possible ecological processes that are not mutually exclusive can be proposed for the park that allowed only certain species to proliferate in either study plots: a) different microhabitat requirements; b) extirpation by means of ecological simplification and the loss of numerous microhabitats. For instance, *Fejervarya cancrivora* and *Fejervarya limnocharis* that were only found in the non-forest plot had a closer access to the coastal sea area than species in the forest plot. An area that is implicated by the seawater salinity may not be suitable for other species but *Fejervarya cancrivora* has the ability to survive under relatively high salinity condition [45], even though it still uses temporary freshwater ponds to breed [33]. *Fejervaryal imnocharis* was co-dominant in the non-forest plot. However, these species prefer shallower pools (approximately 2 – 3 inches deep) as breeding sites and are typically abundant in open field areas [8,26,65]. The non-forest plot provides an advantage for frogs that are adapted to open spaces, explaining why species such as *Fejervarya cancrivora* and *Fejervarya limnocharis* were dominant in the non-forest plot.

Of all species, only two, *Limnonectes paramacrodon* and *Polypedates colletti* were present in both study plots throughout the study period. Individuals of *Limnonectes paramacrodon* were captured in both study plots because the elevation of habitat types was quite similar. The swamp forest in Similajau National Park was in the middle of both areas of forest (heath forest) and non-forest plot. Individuals of *Limnonectes parmacrodon* were collected along gravel and clay stream bank at the forest plot, near to temporary freshwater pond and also on leaf-litter at non-forest plot. Such habitat characteristics were similar to what has been found elsewhere of swampy areas [42,56]. *Polypedates colletti* descends from trees for breeding around the water [26,65]. Various types of shrubs and connected tree branches of *Anisophyllea beccariana*, *Gynostroches axillaris*, *Baccaurea minor*, *Knema* sp., *Maallotu s*sp at forest plot and on *Macaranga gigantea*, *Dillenia suffruticosa* at non-forest plot were recorded. The non-forest plot consisted of small patches of trees that were similar to the heath forest. Such habitat characteristic allows a *Polypedates colletti* that is nocturnal to jump between trees in both plots. Observations from the study recorded that they could be found in trees around 1.5m as high andmore than 6m off the ground.

This study reported that 23 frog species that inhabit the heath forest and non-forest at Similajau National Park consisted of common frogs found in other areas in Malaysia (Table 5.1). Given the small sampling plots for the present study, the species diversity (H' = 2.63) was still relatively higher than an island population, a river-related area, and a plantation site in Malaysia [24,39,56].However, this checklist was slightly lower as compared to a number of species in a study conducted at Gunung Inas Forest Reserve, Kedah and Crocker Range Park, Sabah which documented about 28 and 30 frog species, respectively [25,53]. The differences caused by sampling period, the elevation and also type of habitat were the factors that influenced species diversity [24,56,66]. The probably species founded will be increase if the time of sampling period was employed longer. In addition, if a longer sampling period was conducted at higher elevation of habitat types, the number of species found probably would also increase because the number of species present depends on its proximity to the forest cover [46].

The study plots in Similajau National Park harbour frog species with various IUCN Red List statuses. Two species of concern, *Philautus tectus* and *Kalophrynus intermedius*, are listed as vulnerable (Vu). Found in the forest plot, further forest degradation is likely detrimental to their future survival. Four species were listed by IUCN as Near Threatened (Nt): *Limnonectes paramacrodon*, *Nyctixalus pictus*, *Limnonectes ingeri*, and *Rhacophorus gauni*. The remaining species found are of "Least Concern" (Lc), but their natural habitat preservation must be maintained when delineating future conservation and development plans.

Microhabitat preferences to frog species occurances

Different frog species utilise different microhabitat structures. Three species, namely *Fejervarya cancrivora*, *Fejervarya limnocharis*, and *Limnonectes paramacrodon* were associated with all microhabitat structures, except the vegetated substrates. During the study period, *Fejervarya cancrivora* and *Fejervarya limnocharis* were present in both sampling plots and quadrats, indicating their adaptability to more than one microhabitat structures, from leafy to nearly-bare forest floors and sandy areas (by the beach). Both species dwell in low canopy cover and are commonly associated with disturbed and human environments [3,4,61]. *Limnonectes paramacrodon* was recorded near the coast, stream, and in a peat swamp.

Four species were found in the grass area and bank sand during the study period. They were *Hylarana erythrae*, *Limnonectes ingeri*, *Limnonectes kuhlii*, and *Polypedates leucomystax*. Previous study of *Hylarana erythrae* reported that these species could not be found in forest area as they live in disturbed habitat, natural grasslands, and open area [50] *Polypedates leucomystax* typically occurs in the lowlands of non-forest habitat [57], is acommensal species that indicated the area has been disturbed by humans [43,55]. *Polypedates leucomystax* also occurred in abundant during the study, and dead vegetations and leaf of shrubs like *Melastoma malabathricum* at non-forest plot indicated that the species is associated with vegetation and forest litter substrate. In contrast, *Limnonectes ingeri* and *Limnonectes kuhlii* shared an association with mineral deposit and water source substrate where their abundance were mostly recorded on mud bank and near flowing stream of water. These results supported that both species are related to ancient river systems and living by river banks as well as riparian species [30] though this species was not found in ground floor and no previous studies mentioned about the species because it was considered as a non-stream breeding arboreal frog [39].

Chalcoranal abialis and *Rhacophorus pardalis* were associated with one microhabitat structure and only vegetation substrate. Results showed that *Chalcorana labialis* was the most abundant species in forest plots and not recorded at non-forest plot because this species can increase their abundance in low alteration impacts sites [32]. *Chalcorana labialis* usually perches on seedlings and herbaceous plants [26]. This supports our result, as the species abundance occurrence wason palma leaf like *Pandanus* sp., *Calamus* sp. and *Licuala grandis*, and stems of seedling plants. In contrast, the occurrence of *Rhacophorus pardalis* on stem and leaf of *Zingiber*s sp., *Dillenia suffruticosa* and *Acacia mangium* indicated that they are only associated with vegetation substrate. However, previous studies stated that *Rhacophoru spardalis* lives in the canopy and only comes down during breeding season [55]. Though in our study, it was recorded that 1m of height from the ground floor was the microhabitat they were associated with and was supposed to be supported by the study period which was considered the breeding season. It was clear that this species highly active in calling activities and the individuals recorded were also close to each other, which was lower than 0.5 m distance (personal observation).

The preference of *Pulchrana baramica*, *Pulchran asignata*, *Ingerana* spp., and *Limnonectes deinodon* in terms of microhabitats is structure with mineral deposits. Only two individuals of *Pulchrana baramica* were recorded at a sand bank in the forest plot. Meanwhile, the other three species shared occurrence at bank rock as their substrates. *Pulchrana signata* is categorised as rocky riparian frogs [47] and it was proven during our study that this species' abundance was recorded on the rock and above flowing water. In contrast, *Ingerana* spp. and *Limnonectes deinodon* were commonly found abundant at stone slit and on the bank rock near the stream in forest plot. Both species were also like *Limnonectes ingeri* and *Limnonectes kuhlii* and well known as riparian species. Besides that, *Ingerophyrus divergens* and *Kalophrynus intermedius* shared forest litter as their similar microhabitat structure. Both species of leaf litter frogs have special camouflage characteristics that were difficult to locate their owning [55]. Both species have strong voice but it was difficult to see where the individual was located. Their body was small and the body colour, in which these species have light brown, blend well with the forest.

CONCLUSION

This study is the very first comprehensive research and systematic field survey on frog diversity in Similajau National Park. Although this study was conducted for only a short duration period, the number of species and individuals found in both study plot areas showed clear differences. It provided useful data to initiate an understanding on the impact of variations in habitat covers on local frog species distribution and habitat preferences, besides providing an updated species list and habitat requirement data. Indeed, frogs rely on habitat cover to sustain their populations, thus in the study, such an effect indicatively reduced species richness when habitat cover is decreased. Interspecific competition seems to inherently occur in reduced habitat cover more as a result of reduced richness, where a few dominant species appeared in the area. A study on habitat preference should be concluded that different species have their own associated microhabitats. It can also be concluded that the occurrences of individual's species and richness depends on rainfall, relative humidity and temperature.

APPENDIX

Table 3. A frog diversity in different forest types at Malaysia.

Locality	No. of species	Sampling duration (months)	Samplin g area (hectare)	Elevation of sampling area (from sea level, m)	Habitat types (major vegetation)	Shannon-Weiner Diversity Index, H'	References
Similajau National Park, Sarawak	23	6	32	< 600	Heath forest and non-forest	2.63	Present study
Sungai Ranting Taiping, Perak	12	10	NA	< 200	Lowland forest	1.95	Shahriza et al. 2015
Pasoh Oil Palm Plantation, Negeri Sembilan	9	3	127	< 100	Plantation	1.82	Norhayati et al. 2014
Bukit Panchor State Park, Penang	24	10	445	< 416	Lowland forest	NA	Quah et al. 2013
Jerejak Island, Penang	10	3	NA	< 230	Coastal forest	NA	Ibrahim et al. 2013
Crocker Range Park, Sabah	30	5	25*	600 < 1000	Lowland forest and Lower montane	2.53	Zaini et al. 2012
Gunung Inas Forest Reserve, Kedah	28	6	NA	< 1000	Lowland forest	1.7	Ibrahim et al. 2012

Notes: NA- not available, *approximately estimation area

ACKNOWLEDGMENTS

The authors wish to acknowledge and thank the Department of Forestry Science, UPM Bintulu Sarawak Campus for research facilities provided. The authors areal so very thankful for the tremendous help provided by the park warden and staff of SNP and fieldwork, and the species identification that was supported by Mr. Rob Stuebing. Financial assistance was provided by a grant from the PAAB Sdn. Bhd.

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