Faculty of Resource Science and Technology

ASSEMBLAGES OF STREAM AMPHIBIAN COMMUNITIES AT GUNUNG JAGOI, BAU DISTRICT, SARAWAK

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DECLARATION

I hereby declare that no portion of this dissertation has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

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List of Abbreviations

m	metre
N	North
E	East
SVL	Snout-vent length
TL	Tail length
V	version
mm	millimetre

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Assemblages of Stream Amphibian Communities at Gunung Jagoi, Bau District, Sarawak

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ABSTRACT

This study attempts to determine the diversity and similarity of amphibians at three different streams at Gunung Jagoi, western Sarawak (Borneo). The broad aims of the study were to compare the species diversity, species richness and similarity of amphibians at different streams, and to produce an inventory of amphibians of the site. Field work was conducted between November 2011 to February 2012, and each site had 4 nights of data. The streams are at different elevations and differ in dimensions and other characteristics such as stream width and stream flow velocity. The position of capture for each frog collected was recorded and coded. Data on species diversity, species richness and similarity of anuran amphibians at three streams of Gunung Jagoi were collected, and computed using *EstimateS* V8.2, to determine diversity, species richness and species similarity. There is no literature on the diversity of amphibians at Gunung Jagoi, hence this study provided the first inventory of frogs at this locality. Additionally, it presents new ecological information on several amphibian species. A total of 17 species from 11 genera and six families were recorded. The species accumulation curves of the three study sites reveal that an asymptote is not achieved,indicating that more sampling efforts are required. Different in microhabitat parameters can affect the assemblages and overlap of the frog species. *Hylarana raniceps* was found to be one of the generalist that can be seen in all the study sites with different characteristics. Some species were seen to share the similar microhabitat, different microhabitat parameters can split out the species based on their ecological requirement.

Keyword: Amphibians, species diversity, similarity, Gunung Jagoi, Borneo.

ABSTRAK

Kajian ini bertujuan untuk menentukan kepelbagaian dan kesamaan amfibia di tiga aliran yang berbeza di Gunung Jagoi, barat Sarawak (Borneo). Matlamat umum kajian ini adalah untuk membandingkan kepelbagaian spesis, kekayaan spesis dan keserupaan amfibia di aliran yang berbeza, serta menghasilkan inventori amfibia di Gunung Jagoi. Kerja lapangan telah dijalankan pada November 2011 hingga Februari 2012, dan setiap aliran dikaji untuk empat malam. Aliran tersebut adalah pada ketinggian dan dimensi yang berlainan serta ciri-ciri lain seperti lebar sungai dan halaju aliran air. Kedudukan setiap katak masa penangkapan dicatatkan dan dikodkan. Data mengenai kepelbagaian spesis, kekayaan spesis dan persamaan amfibia di ketiga-tiga aliran di Gunung Jagoi telah dikumpulkan, dan kira dengan menggunakan EstimateS V8.2, untuk menentukan kepelbagaian, kekayaan spesis dan persamaan spesis. Di Gunung Jagoi, tiada kajian pernah dibuat tentang kepelbagaian amfibia. Dengan ini, kajian ini menyediakan inventori yang pertama bagi katak di lokasi ini serta maklumat baru tentang ekologi bagi beberapa spesis amfibia. Sebanyak 17 spesis daripada 11 genus dan keluarga telah direkodkan. Graf pengumpulan spesis bagi ketiga-tiga kawasan kajian tidak mencapai asymtot, ini menunjukkan bahawa lebih banyak usaha masih diperlukan. Parameter microhabitat yang berlainan boleh menjejaskan pertindihan spesis katak.Hylarana raniceps didapati merupakan salah satu katak yang dapat dijumpai di ketiga-tiga aliran. Beberapa spesis didapati berkongsi microhabitat yang sama, parameter microhabitat yang berbeza boleh memecahkan mereka berdasarkan keperluan ekologi mereka.

Kata Kunci: Amfibia, kepelbagaian spesis, persamaan, Gunung Jagoi, Borneo.

1.0 Introduction

The distribution of the world's amphibians range from the tropics to subarctic regions, with most species found in tropical rainforests. Currently, 186 species of frogs have been reported from Borneo (Frost, 2011). However, the total number is on the increase due to discovery of new species almost every year. The known anuran amphibian fauna can be divided into seven families- Bufonidae, Ceratobatrachidae, Dicroglossidae, Megophryidae, Microhylidae, Ranidae and Rhacophoridae. There are a total of 38 genera, and Rhacophoridae has the highest number of species among all the families, with 35 species (Frost, 2011). Bombinatoridae occurs in eastern Asia and in Centre Europe, and on Borneo, is represented by a single species (Inger & Stuebing, 2005).

Species richness is the number of species at an assemblage. It is a classical problem to estimate the number of species at a study site (Chao *et al.*, 2000). Moreover, this happens more to tropical herpetofaunas due to dependence on the sampling method used (Voris, 2006). Three ways can be used to estimate the species richness of a certain species which are species accumulation curves, species abundance distribution or parametric methods, and also non-parametric estimator (Maguran, 2004; Williams *et al.*, 2007). In addition, beta diversity can be used to describe the differences of species between sites based on the similarity or dissimilarity coefficient (Magurran, 2004). This can be done by similarity indices, such as Jaccard, Sorensen, Morisita-Horn and Bray-Curtis similarity indices.

Environmental variables affect the variation of the frog community. Inger and Voris (1993) revealed that the principal factors were stream width and gradient that can affect intra- and inter-locality overlaps. Stream width and gradient affect strongly on the inter-locality overlaps of species abundances. However, only stream gradient affects the inter-locality overlaps of species occurrences. Variation in overlaps due to geographic restrictions of a few species is responsible by regional process which may be timing of barriers or speciation events.

Inger and Colwell (1977) suggested that unpredictable environments prevent the formation of distinct guilds while predictable environment support greater species richness due to guild formation. Ecological organization of community can be compared by taking detailed information of microhabitat occupied by each species in each community. Besides, interaction among species leads to pattern of community due to every species depend on the physical-chemical environment for finding food, reproduction and stay away from potential enemies (including predators and competitors).

Moreover, as the similarity between the samples is high, the data of total collection can reveal more on the general picture of community organization. Inger (1969) showed that physical characteristics of stream determined the existence of riparian species. The success of certain ecological type that included number of species can be determined. This indirectly proved that physical factors are more important than the biotic factors. Relative abundance of ecological types of several streams discloses the differences of the streams after detailed inspection.

In addition, interspecific competition is explained as the replacement species by ecological counterparts. Interspecific competition can caused extinction of one species when the environment is stable. However, natural environment that is fluctuating in physical and biotic factors may long delay competitive exclusion. The replacement of groups can further be explained due to changes in physical environment, appearance of new predators or pathogens, and appearance of competitors (Inger & Greenberg, 1966). Besides, niche differentiation is important for coexistence of ecological differentiation of related and sympatric species.

1.1 Objectives

1. To provide an inventory of the amphibians on Gunung Jagoi, Sarawak (Borneo).
2. To enumerate the species assemblages of amphibians at three streams on Gunung Jagoi.
3. To quantify species diversity, richness and similarity at different streams on Gunung Jagoi.
4. To relate the association between microhabitat and frog species on Gunung Jagoi.

1.2 Hypotheses

Species diversity:

H_O: There are no significant differences in amphibian species diversity between the three streams on Gunung Jagoi.

H_A: There are significant differences in amphibian species diversity between the three streams on Gunung Jagoi.

2.0 Literature Review

Habitat has been defined by Krausman (1999) as presence of resources and conditions in an area that resulted in occupancy, which included survival and reproduction by a given organism. Habitat preference depends on a number of factors, including as distribution of water, availability of resources and predation risk (Enstam & Isbell, 2004). Predation risk is affected by many aspects of habitat structure. For instance, availability of and distance to refuges such as cliffs, burrows, trees and protective cover, and height and density of obstructive cover such as tall grass. Besides, differences in predator species, predator density and habitat structure resulted in variation of predation risk at a habitat.

Habitat selection is essential, especially for animals that inhabit diverse environments being important for enhancing survival rates and reproductive success. Amphibians have a biphasic lifestyle, inhabiting both terrestrial and aquatic systems. Therefore, selection of habitat by both adults and tadpoles of frogs are important data to acquire. Tadpoles are sensitive to fluctuations of the environment, being affected by factors such as temperature, precipitation, humidity, pH, vegetation type, presence of predators and so on (Dey, 2010). On the other hand, adults choose their habitat in order to achieve high survival and reproductive success.

Morphological, physiological and behavioural adaptation of species affects the choice of specific microhabitat (Afonso & Eterovick, 2007). Microhabitat components are site-specific, physical entities can provide condition of environment that is required for a wide range of ecological functions such as reproduction, foraging, predator avoidance or escape, thermoregulation, and resting. Frogs abundance and diversity fluctuate directly with the changes in composition and amount of microhabitats. For instance, stream size determines the characteristics of the adjacent riparian zone and associated wildlife.

The distribution, abundance and diversity of herpetofauna are affected by the changes in microhabitats within a riparian ecosystem (Jones, 1981). Amphibians in streamside zones that associated with close canopy and leaf-litter ground cover will be increased in abundance. Habitat that is heterogeneous also contributes to increase of species richness, as there is higher combination of microhabitat types and ecological niches. Besides, species with broad niches are expected to be more widespread as they may tolerate better at variety of habitat condition.

Keller *et al.* (2009) studied amphibian ecology at Ulu Temburong National Park, Brunei Darussalam. Ten streams between 0.8 m and 3.5 m mean width at similar elevation (50–150 asl.) were selected and frogs were searched visually and acoustically. A total of 27 amphibian species representing five families included Bufonidae, Megophryidae, Microhylidae, Ranidae and Rhacophoridae were encountered. Community structure was mainly determined by stream turbidity, river size and density of understorey vegetation from the study. Species accumulation curves became flattened after three to six visits to the streams. In conclusion, different amphibian assemblages have different assemblage rules and are not comparable.

Telon (2010) studied amphibians at Kampung Giam and Kampung Temurung in Padawan karst, Sarawak, to determine the species richness and species similarity of anuran amphibians. In this study, line transect was used as the sampling method. A total of 43 species of anuran from seven families were collected from this study. *Odorrana hosii* (54) was the highest number of frog being caught in both sites. The data was computed using *EstimateS* programme and ICE was the ideal species richness estimator based on the species richness curve. Species similarity for both sites given by four similarity indices showed a low similarity although the types of habitats were similar.

Ernst and Rödel (2008) examined patterns of community composition in two tropical tree frog assemblages of disturbed and undisturbed lowland rainforest sites at south-western Côte d'Ivoire, West Africa. The study resulted in 3,431 individuals of 14 species under two families were recorded during 385.5 hours of visual and acoustic transect sampling in Tai National Park, while in Mabura Hill Forest Reserve, 4227 individuals of 14 species belonged to three families were collected during 393.5 hours. It was found that disturbance in communities was affecting the community composition.

Hanlin *et al*. (2000) studied three differently managed forests surrounding Carolina Bay in South Carolina to determine the relative abundance, days of surface activity and indices of species diversity, evenness and richness of amphibians. Drift fences with pitfall traps were used in three forest types which included loblolly pine, slash pine and mixed hardwoods. Results showed that amphibians were significantly numerous in mixed hardwood forest. Large number of southern toads (*Anaxyrus terrestris*) reduced evenness, and species diversity of the species was abundant for three habitats especially the mixed hardwood forests.

A study had been done to study the anuran assemblages that relate to species composition, microhabitat partitioning, temporal distribution, and spatial distribution in three natural ponds (Kopp & Eterovick, 2006). A total of 22 species belonged to four families (Bufonidae, Hylidae, Leptodactylidae, and Microhylidae) were recorded, and 11 of these were in larval stage. The most important variables that discriminating adult anuran microhabitat are month of occurrence, height above ground, and type of substrate whereas for tadpole, the variables are position in water column, water depth, and presence of aquatic vegetation. Besides, mean monthly rainfall and temperature have positive correlation with the total number of species and the number of species with calling males was being recorded. The study indicated that environmental and stochastic factors are factors that more likely produce observed patterns of species distribution in anuran assemblages compared to biotic interactions.

Afonso and Eterovick (2007) studied the use of space by anuran during their breeding season in south-eastern Brazil. Substrate and height above ground/ water are used to classify identified microhabitats into 18 types. There were 440 individuals of anuran consisted of 19 species was recorded in these microhabitat types. The study found that generalist did not occur in more streams compared to specialists, and streams with higher species richness did not have more specialists. The studied anuran assemblages showed specific reproductive preferences and colonization abilities affect their distribution patterns rather that the cause of competitive pressure.

A study had been done in south-east Queenland, Australia, to determine habitat variables that affect species richness and frog assemblages in forest streams (Parris and McCarthy, 1999). A total of 19 one hectare survey sites were selected in Mapleton, Kenilworth and Jimna State Forests. Besides, 17 habitat variables that describe the structure and composition of the vegetation, stream characteristics and evidence of disturbance at each site were recorded. From this study, 14 native species of amphibians were collected. Analysis showed that larger streams support greater number of frog species, and species richness had no relationship with elevation and presence of palms or broad forest type.

Lane and Burgin (2008) did a study to determine whether urbanization has affected frog diversity and abundance. The study was done at urban sites (Katoomba and Blackheath) and non-urban sites (Blue Mountains National Park). As a result, six species were found at urban sites (*Litoria peronii*, *Litoria dentata, Litoria verreauxii*, *Limnodynastes dumerilii, Limnodynastes peronii,* and *Crinia signifera*), with up to four species present at a site. However, there was only one species, *Crinia signifera* can be recorded at non-urban sites.

The study showed that there is a dramatic decrease in non-urban sites. Hypothesis was done that salts, detergents and other chemicals in urban wastewaters had provided frogs from disease such as chytridiomycosis.

3.0 Materials and Methods

3.1 Study Sites

The study site was conducted at Gunung Jagoi, Bau, Sarawak, Malaysia. It is located at 1°22.233’N and 110°1.263’E at an elevation of 254.177 meters. The sampling sites chosen are three different sites (Appendix VI) and they are near to human habitation.

Figure 3.1: Location of sampling sites at the Gunung Jagoi**.**

Site A is a small stream with secondary forest that next to a paddy field at Kampung Serasot. It is located at N 01°22.173' E 110°02.481' at the elevation of 70 m. Site B (Bung Jagoi) and Site C (Kampung Duyoh) are from the same stream which is Sungai Duyoh (Figure 3.1). Site B is a secondary forest with fruit trees. The dominant marginal vegetation included Durian tree, Cempedak tree, Engkabang tree, and ferns. Site B is located at N 01°21.368' E 110° 02.213' with elevation of 243 m. For Site C, it is a disturbed riparian forest edge of rocky stream. It is located at N 01°20.782' E 110°02.593' with elevation of 40 m. Selection of streams was made based on its accessibility and time period available.

3.2 Sampling Methods

A total length of 100 metre line transect was established at each sampling site and data recorded while walking along the stream. Line transect has been used to estimate abundance as it can tracks the species numbers effectively, relative abundances, and also densities across habitats. The sampling was conducted between November 2011 to February 2012. The first field trip was conducted during 8 to 12 November 2011 at Kampung Serasot, the second sampling was conducted from 2 to 11 February 2012 at Kampung Duyoh and Kampung Serasot and a third sampling was on 24 February 2012 at Kampung Duyoh. This gave a total of four nights of data for each site. Variation occurred in spacing and number of sampling was caused by impossibility of frogging more than one stream in a night and uncontrollable circumstances, such as heavy rain.

Amphibians were collected by three to seven people along streams between 1830 to 2130 h, when frogs were active. We waded up the beds of the streams and usually spotted the frogs by their eye-shine using flashlights or headlamps. Besides, the calling of the male frogs helped in detecting the frogs especially during their breeding season. The amphibians collected was labelled with a field number, fixed, preserved and accessed with the zoological museum of UNIMAS to serve as voucher specimens. The line transects were measured and marked out at least a day before fieldwork to ensure accuracy.

During sampling, the geographical coordinates and elevation (in m) of the sites were determined by using a Garmin GPS Map 62S with software version 2.90. For each frog captured, date and hour were recorded. At the same time, the measurements of the microhabitat were taken at the time of capture, including stream depth (m), stream width (m), distance from nearest tree (m), diameter at breast height (DBH) (m, to be extrapolated from circumference measurements taken), bank vegetation density, percentage canopy cover and stream flow velocity (number of rotation per minute). Percentage canopy cover was estimated visually, stream flow velocity was taken by using rheometer or water flow meter, while others measurement were taken by using a 100 m and 5 m measuring tape. DBH was calculated by using the circumference of tree measured using the formula (circumference = $2\pi r$, r = the radius of tree trunk and pi = 3.141592). DBH equals radius x 2. Next, vegetation type, substrate, horizontal position and vertical position of each frog were recorded based on microhabitat checklist (Inger, 1994). All measurements of microhabitat were recorded in notebooks during the period of field sampling, and entered into datasheets in the lab.

3.3 Identification and Preservation

The amphibians collected were identified and recorded in a data sheet. Identification was based on Inger and Stuebing (2005), and nomenclature based on Frost (2011) and Haas *et al.* (2010). Specimens were weighed, and measurements were taken. Snout-vent length (SVL) was taken, which is measured from the tip of its snout to its vent. A calliper and ruler were used to take all measurements. Specimens were weighed using Pesola of 10 grammes, 50 grammes and 100 grammes, based on suitability.

Voucher specimens were taken and euthanized using a chlorotone solution. They were set in 10% buffered formalin for 24 hours. After that, specimens were put under running tap water for 24 hours in the laboratory before storage in 70% alcohol. The label contained the field number and name of species and tied to the right limb of frogs.

3.4 Statistical Analysis

Species diversity indices were calculated for all the study sites on Gunung Jagoi. Shannon Index, Simpson’s Index and Brillouin’s Index were calculated using the DIVERS program

(Kreb, 1989) which has been adapted and modified for ease of data input and output. *EstimateS* program was used to estimate the species richness of a study site (Colwell, 2009). The estimators and indices are non-parametric species richness estimators; for abundance-based data (Chao1 and ACE), for sample-based data (Chao2, ICE, Jacknife1, Jacknife2 and Bootstrap) and based in fitting asymptotic function to the sample-based rarefaction curve (Michaelis-Menten equation).

Similarity was computed by using similarity indices such as Chao's estimator of total shared species for sample pairs, classic Sorensen and Jaccard similarity indices for sample pairs based on incidence or abundance data sets, Chao's abundance-based Sorensen and Jaccard similarity indices, and Morisita-Horn and Bray-Curtis similarity indices for sample pairs based on abundance data sets. These similarity indices can be computed in *EstimateS* program.

EstimateS V8.2 software (Colwell, 2009) has been used to compute the species richness and similarity values of amphibians at three different study sites, and M.S. Excel 2010 was used to produce the species accumulation curve. *EstimateS* V8.2 software (Colwell, 2009) has been downloaded for free from http://viceroy.eeb.uconn.edu/EstimateS.

3.4.1 Species Diversity Estimators

Species diversity relates to the number of species and individuals in a community or habitat. It composed of species richness and species evenness. Species richness is the number of species in a community whereas species evenness is the relative abundance of each species. In order to measure the diversity effectively, both species richness and evenness with which individuals are distributed among species are required to account. The most widely used diversity indices in the ecological literature are Shannon Index, Simpson's Index and Brillouin's Index.

3.4.1.1 Shannon Index

Shannon Index assumes that all species are represented in a sample and that the sample was obtained randomly. It is affected by both the number of species and their evenness.

$$H' = -\sum pi\ ln\ pi$$

Where pi represents the proportional abundance of the individuals found in the i_{th} species and *ln* is the natural logarithm. For real communities, the values of Shannon Index are typically fall between 1.5 and 3.5.

3.4.1.2 Simpson's Index

This index is considered to be dominance index as it weights towards abundance of the most common species. In addition, Simpson's Index gives probability of any two individuals that is drawn randomly from an infinitely large community belonging to different species.

$$D_S = \sum_{i=1}^{S} \frac{(n_i(n_i - 1))}{N(N-1)}$$

where n_i is the number of individuals in the i_{th} species, N is the total number of individuals in the sample, and s is the number of species in the sample. Since D_s and diversity are negatively related, the index is often expressed as reciprocal or complementary forms (1/D or 1-D). Simpson's Index ranges from 0 (low diversity) to almost 1 (1-1/s)

3.4.1.3 Brillouin's Index

The Brillouin's Index H_B is preferable to the H' when the randomness of a sample cannot be guaranteed. This index is most sensitive to the abundance of the rare species in the community.

$$H_B = \frac{\ln(N!) - \sum \ln(n_i!)}{N}$$

where N is the total number of individuals and n_i is the number of individuals in the i_{th} species.

3.4.2 Species Richness Estimators

Non-parametric estimators have been used in this study as it requires a presence-absence data only that is suitable for small-scale type of study. A graph of the species richness estimators was produced by M.S. Excel Workbook 2010 based on the values enumerated by *EstimateS*. The estimators chosen are based on the suitability with the data obtained and the objectives that need to be achieved. All formulas used are extracted from *EstimateS* V8.2 User's Guide in Colwell (2009).

Table 3.1: Variables used in computing species diversity in *EstimateS* (Colwell, 2009).

S_{est} :	Estimated species richness, where *est* is replaced in the formula by the name of the estimator
S_{obs} :	Total number of species observed in all samples pooled
S_{rare} :	Number of rare species (≤ 10 individuals) when all samples are pooled
S_{abund} :	Number of abundant species (> 10 individuals) when all samples are pooled
S_{infr} :	Number of infrequent species (each found in 10 or fewer samples)
S_{freq} :	Number of frequent species (each found in more than 10 samples)
m :	Total number of samples
M_{infr} :	Number of samples that have at least one infrequent species
F_i :	Number of species that have exactly *i* individuals when all samples are pooled (F_1 is the frequency of singletons, *F*₂ the frequency of doubletons)
Q_j :	Number of species that occur in exactly *j* samples (Q_1 is the frequency of unique, Q_2 the frequency of duplicates)
P_k :	Proportion of samples that contain species k
N_{rare} :	Total number of individuals in rare species
N_{infr} :	Total number of incidences (occurrences) of infrequent species
C_{ace} :	Sample abundance coverage estimator
C_{ice} :	Sample incidence coverage estimator
γ^2_{ace} :	Estimated coefficient of variation of the F_i for rare species
γ^2_{ice} :	Estimated coefficient of variation of the Q_i for infrequent species