DIVERSITY OF FROGS AND THEIR MICROHABITATS IN TAWAU HILLS PARK, SABAH

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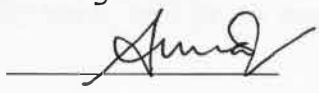

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ABSTRACT

A study on the diversity of frogs using Visual Encounter Survey (VES) was carried out in Tawau Hills National Park (THP), from June 2009 until September 2010. Twenty-eight line transects were established and surveyed resulted in the encounter of 925 individuals from 51 species representing six families. Eighteen species were new locality records for the park, bringing the total number of identified frog species in THP to 68 species. These frogs occupied elevations from lowland area (200m asl) at headquarters of THP, Balong substation and Merotai substation to submontane area (>900m asl) at Mount Maria, Mount Lucia and Mount Magdalena. All 68 species recorded in this study represented approximately 42% of the total frog species found in Borneo Island, with 15% of them are endemic to Borneo. They also represented 62% of the total frog species found in Sabah. Frog species in THP were dominated by Ranidae (39.35%) and Dicroglossidae (24.43%). *Limnonectes leporinus* was the most abundant species (10.16%), followed by *Meristogenys orphnocnemis* (10.05%). The high species diversity and species richness found in THP could be due to the rich topography of this park which provides ample feeding, breeding and shelter for frogs. According to Canonical Correspondent Analysis (CCA), *Philautus petersi* and *Rhacophorus pardalis* have shown preference to natural forest floor whereas *Limnonectes leporinus* and *Staurois natator* showed preference to river bank. The mean distance of frog occurrence to river was 53.52 ± 85.95cm. *Leptobrachium hendricksoni*, *L. abbotti* and *Leptolalax dringi* showed strong association with leaf litters as their vertical position whereas *Limnonectes leporinus*, *L. kuhlii* and *Occidozyga baluensis* showed preference to bare mineral on floor. The mean distance of frog- occurrence from ground level was 51.13 ± 84.37 cm. CCA also shown that *Leptolalax dringi*, *Leptobrachium hendricksoni* and *L. abbotti* showed preference to leaf substrates whereas *Limnonectes kuhlii*, *L. leporinus* and *Ansonia longidigita* showed preferences to rocks substrates.

Keywords: Microhabitats, Tawau Hills Park, Visual Encountered Survey, Canonical Correspondent Analysis.

ABSTRAK

DIVERSITI KATAK DAN MIKRO-HABITATNYA DI TAMAN BUKIT-BUKIT TAWAU, SABAH

Kajian ini telah dijalankan di Tawau Hills National Park (THP) dengan mengaplikasikan Visual Encountered Survey (VES) sebagai kaedah pensampelan katak dari Jun 2009 hingga September 2010. Sebanyak 28 transek telah ditinjau dan sejumlah 925 individu katak daripada 51 spesies dan enam famili telah diperolehi. 18 spesies merupakan rekod baru di THP, maka jumlah spesies katak yang telah dikenal pasti di THP ialah 68. Katak-katak ini menghuni di kawasan tanah rendah (200m dari aras laut: di Head Kuater THP, Sub-stesyen Balong dan Sub-stesyen Merotai) hingga kawasan sub-montane (>900m dari aras laut: di Gunung Maria, Gunung Lucia dan Gunung Magdelena). 68 spesies katak ini merupakan kira-kira 42% daripada jumlah spesies katak yang telah dikenalpasti di kepulauan Borneo, bilangan ini turut mewakili 62% daripada jumlah spesies katak yang terdapat di Sabah dimana 24% daripada mereka merupakan spesies yang endemik di Borneo. Spesies katak di THP didominasi oleh Ranidae (39.35%) dan Dicroglossidae (24.43%). Limnonectes leporinus (10.16%) merupakan spesies yang paling banyak dijumpai dalam THP, diikuti oleh Meristogenys orphnocnemis (10.05%). Kepelbagaian topografi di taman ini telah menyediakan sumber makanan yang mencukupi, tempat pembiakan dan perlindungan kepada katak merupakan faktor utama bahawa kepelbagaian spesies katak di THP tinggi. Menurut Canonical Correspondent Analysis (CCA), Philautus petersi dan Rhacophorus pardalis telah menunjukkan kegemaran kepada lantai hutan manakala Limnonectes leporinus dan Staurois natator menunjukkan kegemaran kepada tebing sungai. Jarak min katak dari sungai ialah 53.52 ± 85.95cm. Sarap daun di atas lantai hutan merupakan mikrohabitat kegemaran Leptobrachium hendricksoni, L. abbotti, dan Leptolalax dringi manakala Limnonectes leporinus, L. kuhlii dan Occidozyga baluensis menunjukkan kegemaran kepada mineral pada permukaan lantai. Jarak min katak dari paras tanah adalah 51,13 ± 84,37 cm. Di samping itu, CCA telah menunjukkan bahawa Leptolalax dringi, Leptobrachium hendricksoni dan L. abbotti menunjukkan kegemaran kepada substrat daun manakala Limnonectes kuhlii, L. leporinus dan Ansonia longidigita menunjukkan kegemaran kepada substrat batuan.

Kata kunci: Mikrohabitat, Tawau Hills Park, Visual Encounter Survey, Canonical Correspondent Analysis.

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LIST OF ABBREVIATION

asl	Above sea level
B	Brillouin Index
CCA	Canonical Correspondent Analysis
df	Degree of freedom
GLM	General Linear Model
i.e.	For example
km^2	Kilometre square
m	Metre
MD	Margalef Index
Mt.	Mount
MVSP	Multivariate Statistical Package
SD	Simpsons Index
Sg.	*Sungai* (river)
SVL	Snout Vent Length
SW	Shannon-Wienner Index
THP	Tawau Hills Park
VES	Visual Encounter Survey

LIST OF SYMBOLS

°C	Degree Celsius
<	Less than
>	More than
/	Per
%	Percentage
-	To

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CHAPTER 1

INTRODUCTION

1.1 Background of studies

Borneo is one of the most important biodiversity hotspots for amphibians where inventory studies had been systematically carried out in Sabah and Sarawak since the late 1850s until as recent as 2000s (Inger and Stuebing, 2005; Matsui 2006, Das and Haas, 2010). More than ten new frog species were discovered in Borneo in the past 14 years. In 1996 there were only 138 frog species recorded in Borneo but the figure increases to 150 species in the year 2005 (Malkmus *et al.*, 2002; Inger and Stuebing, 2005), and 167 species in year 2012 (Inger and Tan, 2010; Frost, 2012).

In Sabah, Tan (1988) initiated a preliminary study in the Crocker Range National Park on frog inventory, which led to the discovery of a new species (Inger, 1989), followed by a series of general ecological studies on amphibians (Inger and Stuebing, 1992). Another new species, *Leptolalax maurus* (Family: Megophryidae), was discovered in Kinabalu Park during a monitoring program initiated by Sabah Parks (Inger *et al.*, 1997). Meanwhile, Stuebing and Nor (1995) carried out the pioneer study of frogs in Tawau Hills Park (Sabah) during a scientific expedition, and they recorded 31 frog species there. In year 2008, Kueh and Ahmad Sudin had discovered the *Gastrophrynoides borneensis* from Microhylidae, a new frog record for Sabah, at Tawau Hills Park (Kueh and Sudin, 2008).

Other published studies on the Bornean anurans include works on population ecology, density and abundance (Inger, 1980a & 1980b; Abdul, 1998; Ramlah, 2011), competition and community organization (Inger and Greenberg, 1966; Inger, 1969), breeding and reproduction (Berry, 1964; Inger and Bacon, 1968; Emerson, 1992), tadpoles and larval survival (Berry, 1972; Inger, 2005), food and diet (Berry and Bullock, 1962; Berry, 1966; Bullock, 1966; Elliot and Karanukaran, 1974), systematics and zoogeography (Boulenger, 1912; Smith, 1930; Kiew, 1972; Berry, 1975; Emerson, 1992; Inger and Stuebing, 1992; Inger, 2005; Hertwig *et* al., 2012;

Hertwig *et al.*, 2013), inventory and guides (Berry, 1975; Dring, 1979; Inger and Stuebing, 1992; Stuebing and Nor, 1995; Inger *et* al., 1997; Inger *et al.*, 2000, Lee *et al.,* 2013) and biodiversity and conservation (Kiew, 1984; Inger, 1999).

1.2 Distribution and habitats of frog

Frogs are dispersed widely in the world ranging from the tropics to subarctic regions. Yet, most of the frog species are found in tropical rainforests (Duellman and Trueb, 1994). They are aquatic, terrestrial, fossorial, arboreal, or several combination of microhabitat and for that reason, frogs are occurring in fundamentally at all terrestrial and fresh water habitat (Heyer *et al.*, 1994). Anurans are often erratic in distribution, where there are usually restricted to certain localities but absent or scarce in similar habitat elsewhere (Hickman *et al.*, 2006). The limited subsets of habitats at each site where any individual of frog occur are termed as its microhabitat, that is, the precise place where individual of frog occur within the general environment (Inger, 1994; Abdul, 1998).

The distribution patterns of anurans existing in various altitudes are led by individual feeding and breeding habits (Fauth *et al.*, 1989). High altitudinal places tend to have significantly lower number of certain frog species due to stream current, presence of organic matter and differences of microhabitats (Pianka, 1966; Beard *et al.*, 2003; Block and Morrison, 1998; Dure and Kehr, 2004; Fauth *et al.*, 1989, Inger and Stuebing, 2005). In addition, it has been widely documented as a general pattern that species richness declines with increasing elevation gradient (Pianka, 1966; Hofer *et al.*, 1999; Maklarin *et al.*, 1999; Rahbek, 1995) due to the steep topography of the streams and the strong current which lead to failure of breeding and feeding grounds (Pianka, 1966; Inger and Stuebing, 2005; Inger and Tan, 2010).

Frogs are functionally vital to the ecosystem as they play a significant role of the earth's biota (Formanowicz and Bobka, 1989; Heyer *et al.*, 1994; Sredland Collins, 1992; Werner and McPeek, 1994). They can act as biological control and a good environment bio-indicator. They are the predator in an ecosystem, eating a great variety of prey such as invertebrates or anything that they manage to capture. They are also the prey for snakes, birds and other reptiles, while the tadpoles are being

eaten by large fishes and animals. In addition, frogs also act as a keystone species in many communities (Sredland and Collins, 1992; Beebee, 1996; Stewart and Woolbright, 1996; Inger and Tan, 2010).

Anurans surveys will not only provide information on the distribution, abundance and density but also help to understand the habitat requirements of species and the environmental variables that control its diversity. Such information is needed for effective conservation planning and management of forest, which include monitoring of anurans populations in a period of apparent global decline and management of effective nature conservation (Parris, 1999).

1.3 Research justification

Tawau Hills Park encompasses 280 km^2 and extends in elevation from virgin lowland dipterocarp forest to montane vegetation around the summit area. With such diversity in vegetation, it attracts the interest of not only local but also foreign researchers.

There were only three published data regarding the frog species found in Tawau Hills Park. First was the scientific paper by Stuebing and Nor (1995), which states that there were 31 species of frogs found in three habitats - on the boundary of, within the lowland areas of Tawau Hills Park and the area adjacent to the cocoa plantations during a scientific expedition organized by Sabah Parks and Universiti Kebangsaan Malaysia Sabah Campus (UKMS) in year 1989. Secondly, a record of a frog study carried out from year 1991 to 1993 by Inger *et al.* (2000) in the lowland of Tawau Hills Park. From the study, there were 42 frogs species found in the Tawau Hills Park (Inger *et al.*, 2000). The last study was done by Kueh and Sudin (2008); which reports the discovery of *Gastrophrynoides borneensis* was discovered in THP. Hence, these studies showed that a total of 50 species recorded in the lowland areas of Tawau Hills Park (Table 2.1).

A comparative study on amphibian population based on habitat disturbance across elevation gradient in Kinabalu Park (Maklarin *et al.*, 1999) has become helpful in this research as it describes about the habitat disturbance across elevation

gradient. However, the microhabitats of the anurans were not described in those studies. In addition, this is the first frog study that had been carried out at highlands in Tawau Hills Park namely Mt. Magdalena, Mt. Lucia and Mt. Maria. Therefore this study aimed to examine and describe the microhabitats of anurans in Tawau Hills Park which is a necessity in order to monitor the anurans populations.

1.4 Objectives of study

This study aimed to provide the understanding the microhabitat variety of anurans in Tawau Hills Park. The objectives of this study are:

- To determine the frogs biodiversity in Tawau Hills Park, including highlands such as Mt. Magdalena, Mt. Lucia and Mt. Maria.
- To determine the types of microhabitat (horizontal position, vertical position and substrate) preference of frogs in Tawau Hills Park.

CHAPTER 2

LITERATURE REVIEW

2.1 Frogs

Frogs are known by their very obvious external characteristics: plump build of body, large eyes, large mouth, and two pairs of limbs in which the hind pair is usually stronger and longer, four fingers and five toes in most of the species. They are tailless amphibians in which several caudal vertebrae are fused into one elongated urostyle (Figure 2.1). They are quadrupedal vertebrates having two occipital condyles on the skull and have only one sacral vertebra.

Frogs are the most diverse and abundant group of living amphibians and occur in essentially all terrestrial and fresh water habitats. Many herpetologists are interested in the anatomical dissimilarities between frogs and toads. However, in general the most representative frogs are the long-legged, slender-bodied members of the family Ranidae, whereas the most representative toads are in the family Bufonidae. Toads are more terrestrial than frogs (Duellman and Trueb, 1994; Heyer *et al.*, 1994; Kent and Miller, 1997).

Frogs are poikilothermic vertebrates which possess nude skin that is often kept moist by secretions from the mucous glands beneath the skin. Frogs breathe via lungs, through the mucous membranes of the mouth cavity, and also through the moist and permeable skin. At the same time, the moist and permeable skin aids in regulates physiological process (Malkmus *et al.*, 2002). As the consequence, frogs are more vulnerable to the fluctuations of the environments than any other tetrapods. In order to survive, unique morphological structures, physiological mechanism and behavioural responses were their solutions to overcome and adapt themselves to the different habitats ranging from terrestrial, arboreal, aquatic and even mangrove swamps (Duellman and Trueb, 1994; Beebee, 1996; Kent and Miller, 1997).

and then amplified by the vocal sac, which is positioned in the throat of frog (Figure 2.3). Each species has its very own unique call to prevent confusion. When the egg bearing female frog attracted to the call and approaching, the male climbs onto the back of female frog and clasps her body with his forelimbs in a position named amplexus. As the female frog expels the eggs into water bodies, male frog releases sperm to fertilize those eggs, then the aquatic life of the tadpoles begin after a day or two (Duellman and Trueb, 1994; Malkmus *et al.*, 2002; Inger and Stuebing, 2005).

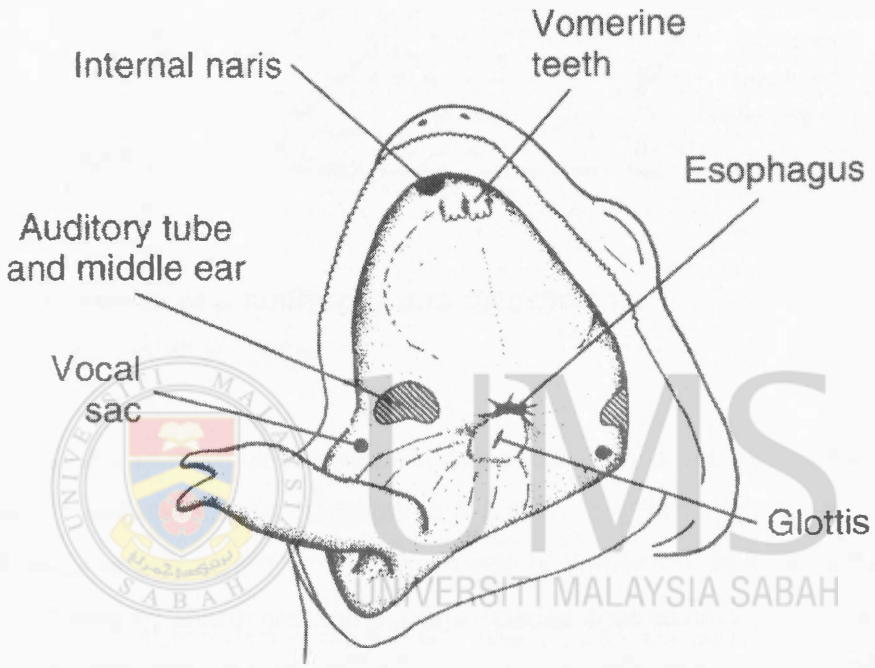

Figure 2.3: The oral cavity of a frog.

Source: Kent and Miller, 1997

The most conspicuous feature of frogs is the specialization of the body skeleton for jumping for their locomotion. The hind limbs and muscles form a lever system that can propel them into the air as well as several other morphological specializations are associated with this type of locomotion whereby the hind limbs are elongated and the tibia and fibula are fused. The hind limbs are responsible in generating adequate power to propel the frog into the air and this high level of power generation results from the structural and biochemical features in the limb muscles (Pough *et al.*, 2005).

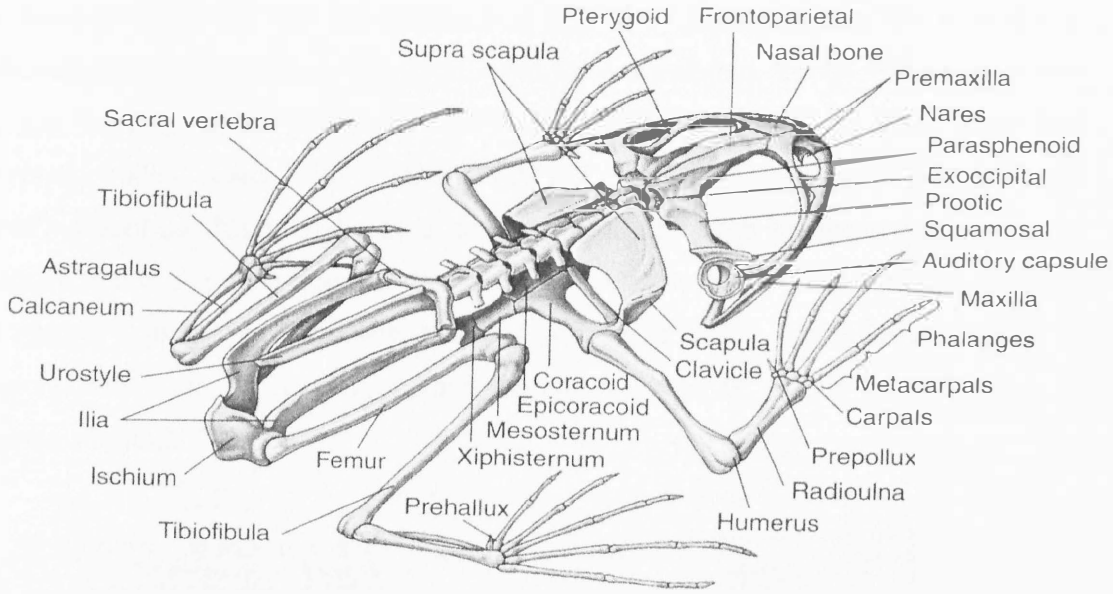

Figure 2.1: Skeleton of a bullfrog, *Rana catesbeiana*.

Source: Hickman *et al.*, 2006

Among all terrestrial vertebrates, frogs conceivably, cover the highest diversity of reproductive behaviours and parental care known in science (Heyer *et al.,* 1994). Their fertilization is external. The primitive mode of life history involves aquatic eggs and larvae. However, there are some frogs species that exhibit specialized modes which include deposition of eggs out of water but aquatic tadpoles, terrestrial eggs undergoing direct development, ovoviviparity and viviparity. On the other hand, some frogs exhibit parental care by guarding or transporting eggs or tadpoles, for instants *Limnonectes palavanensis* and *Limnonectes finchii,* which can be found in Sabah (Duellman and Trueb, 1994; Kent and Miller, 1997; Malkmus *et al.*, 2002; Inger, 2003; Inger and Stuebing, 2005).

One of the distinctive characteristics of frogs is their complex life cycle (Figure 2.2). Frogs start their life as aquatic tadpoles then undergo a continuation of changes named metamorphosis. Tadpoles have an egg shaped body and finned tail which enables them to swim for food and avoid predator. They breathe by using gills instead of lungs as in adult frogs. They feed on aquatic microscopic algae and fungi,

and due to this reason, they have an enormously long, coiled intestine. As they grow, the forelimbs develop first but hidden in a fold of skin, followed by the hind limbs. Metamorphosis begins after the limbs have fully developed. Lungs will develop and the gills will degenerate (Duellman and Trueb, 1994; Malkmus *et al.*, 2002; Inger and Stuebing, 2005). Apart from that, the tail will slowly absorb. Inger and Stuebing (2005) described this process as a peculiar process which involving many internal changes and it is a hazardous for the tadpole-froglet as it will temporary not adept at life neither aquatic nor terrestrial and this process is usually completed in a day or two. Overall, the process of metamorphosis involves 44 stages for a species to become an adult.

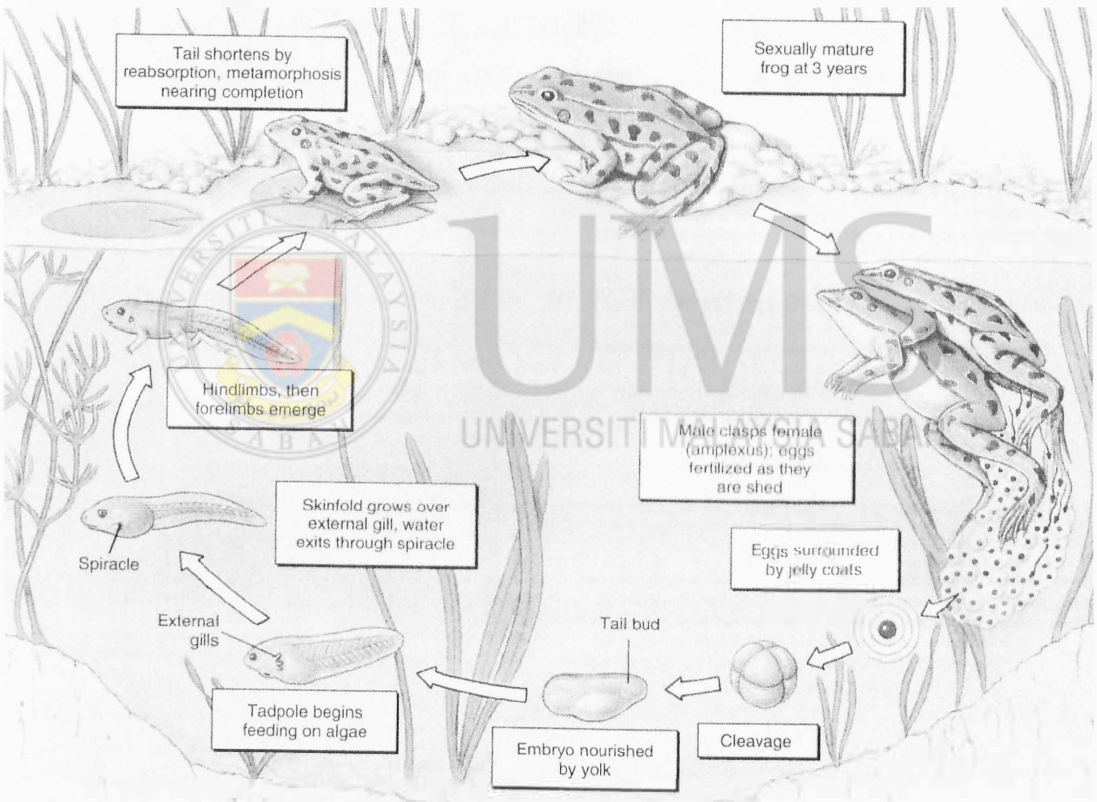

Figure 2.2: The general life cycle of a frog.

Source: Hickman *et al.*, 2006

On reaching maturity, males of most frog species are able to vocalize. The importance of vocalization is to communicate and also attract the opposite sex for mating. The calls are produced by channeling the air back and forth between the lungs and oral cavity, passing past vocal chords which oscillate and produce sounds,