Faculty of Resource Science and Technology

Acoustic Survey on Insectivorous Bats Activity Pattern at Contrasting Elevation in Kubah National Park, Sarawak

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DECLARATION

I hereby declare that in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Bat monitoring mostly done by using mist nets and harp traps but species that fly high still to be missed out. Additional methods such as acoustic sampling would be able to monitor echolocating bats the tend to avoid the nets. Acoustic sampling gives a better perspective for bat activity monitoring including study their habitat use. Bats activity may vary spatially and temporally. In an area with elevational gradient, it is possible to study the activity of bats simultaneously at different elevation by acoustic monitoring. But first, bat echolocation call libraries are needed as a reference to identify the calls of free-flying species. Therefore, the objectives of this study are to build echolocation call library of Kubah National Park for the purpose of species identification of insectivorous bats through echolocation call; compare the activity pattern of insectivorous bats at contrasting elevation by acoustic monitoring; and identify the other factors affecting activity of bats at contrasting elevation in Kubah National Park. Between November 2018 and February 2019, insectivorous bats were trapped at lower elevation (100-250m a.s.l.) and higher elevation (700-800m a.s.l.) in Kubah National Park and echolocation calls were recorded from a total of 68 individuals, representing 13 species from 4 families. The discriminant function analysis indicated that constant frequency (CF) bats comprised of Families Hipposideridae and Rhinolophidae could be easily distinguished from their calls recorded in the detectors. Acoustic survey on their activity was conducted from November 2018 to August 2019 at lower elevation covered with mixed dipterocarp forests, and at higher elevation covered with *Kerangas* forests, scrub forests and lower-montane forest. The activity of insectivorous bats at higher elevation is higher compared to lower elevation with 69% of the total bat passes counted from both elevations. In addition, more species were recorded at higher elevation compared to lower elevation. The result was related with

insect biomass at each elevation but not significantly affected by temperature and moon phase. This study showed that elevational gradient does affect the activity of bats, considering the availability of their food abundance and the habitat use. Overall, acoustic monitoring does provide better way to document species occurrence and ecology information of insectivorous bats. Further investigations on species-specific in response to elevations and climate variables are needed and may increase the power of understanding on factors that influence the bat activity.

Keywords: Acoustic, activity, echolocation, elevation, temperature, call library

Tinjauan Akustik terhadap Corak Aktiviti Kelawar Pemakan Serangga pada Ketinggian Berbeza di Taman Negara Kubah, Sarawak

ABSTRAK

Tinjauan akustik biasanya dilakukan menggunakan kaedah tangkapan dengan jaring kabus dan perangkap kecapi tetapi masih tidak dapat merekodkan spesies kelawar yang terbang lebih tinggi. Penambahan kaedah seperti kaedah akustik mampu memantau kelawar yang menggunakan panggilan ekolosi yang juga memampukan kelawar untuk mengelak dari terkena jaring dan perangkap. Tinjauan akustik memberikan perspektif yang lebih baik kepada tinjauan aktiviti kelawar dan kajian tentang habitat kelawar. Di kawasan yang mempunyai ketinggian, adalah lebih mudah untuk mengkaji aktiviti kelawar secara serentak di ketinggian yang berbeza dengan menggunakan tinjauan akustik. Sebelum itu, katalog panggilan ekolokasi perlu dibina sebagai rujukan untuk mengenalpasti spesies yang berterbangan. Oleh itu, objektif kajian ini adalah untuk membina katalog ekolokasi yang dihasilkan oleh kelawar sebagai rujukan untuk identifikasi spesis kelawar; membandingkan aktiviti kelawar pemakan serangga pada ketinggian berbeza melalui pemantauan akustik; mengenalpasti faktor lain yang mempengaruhi aktiviti kelawar pada ketinggian berbeza di Taman Negara Kubah. Tangkapan kelawar telah dilakukan pada bulan November 2018 dan Februari 2019 (12 malam), kelawar pemakan serangga ditangkap di ketinggian yang lebih rendah (100-250m a.s.l.) dan yang lebih tinggi (700-800m a.s.l.) di Taman Negara Kubah, manakala panggilan ekolokasi juga direkod daripada 68 individu yang mewakili 13 spesis daripada 4 keluarga. Analisis fungsi diskriminasi menunjukkan bahawa kelawar yang menggunakan frekuensi tetap, terdiri daripada keluarga Hipposideridae dan Rhinolophidae lebih senang untuk dibezakan melalui panggilan yang direkod dari pengesan kelawar. Tinjauan akustik terhadap aktiviti kelawat juga telah dijalankan dari November 2018 sehingga Ogos 2019

di kawasan ketinggian rendah yang ditumbuhi hutan pelbagai dipterokapta dan juga pada kawasan paras lebih tinggi yang ditumbuhi hutan kerangaas, hutan belukar dan hutan gunung yang rendah. Aktiviti kelawar di ketinggian yang lebih tinggi adalah lebih banyak dengan 69% daripada jumlah kiraan kelawar yang lalu di kedua-dua ketinggian. Lebih banyak spesis kelawar pemakan serangga telah direkodkan dari ketinggian yang lebih tinggi berbanding di kawasan yang lebih rendah. Hasil kajian ini dikaitkan dengan biojisim serangga di setiap ketinggian tetapi tidak ketara dipengaruhi oleh suhu dan fasa bulan. Kajian ini juga menunjukan bahawa kecerunan ketinggian mampu memperngaruhi aktivity kelawar, dengan mempertimbangkan ketersediaan sumber makanan dan penggunaan habitat. Dengan ini, tinjauan menggunakan kaedah ekolokasi telah menyumbang kepada dokumentasi kehadiran spesies dan memberikan informasi mengenai ekologi kelawar pemakan serangga. Penyiasatan lebih lanjut terhadap spesis yang lebih spesifik dalam memberi respon terhadap ketinggian dan pembolehubah iklim diperlukan untuk meningkatkan pemahaman mengenai faktor yang memepengaruhi corak aktiviti kelawar.

Kata kunci: *akustik, corak aktiviti, ekolokasi, ketinggian, katalog panggilan akustik*

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LIST OF ABBREVIATIONS

a.s.l.	Above sea level
CF	Constant Frequency
FM	Frequency Modulated
g	Gram
kHz	Kiloherzt
KNP	Kubah National Park
UNIMAS	Universiti Malaysia Sarawak
QCF	Quasi Constant Frequency

CHAPTER 1

GENERAL INTRODUCTION

1.1 Project Overview

Southeast Asia is urgently in need of greater biodiversity understanding as well as inventories to underpin conservation strategies as only about 15% remained as primary forest while about 10% are protected habitat (Sodhi *et al.*, 2010; Kingston, 2013). Borneo is part of the Sundaic hotspot of Southeast Asia with its tropical rainforest are globally known for high level of species diversity and endemism (Sodhi *et al.*, 2004). Unfortunately, Borneo is suffering from high deforestation, habitat degradation, land conversion and fragmentation that trigger a serious concern for conservation (Curran *et al.*, 2004; Fitzherbert *et al.*, 2008). Therefore, it is crucial to have scientific documentation on species information especially for less charismatic taxonomic group such as bats (Struebig *et al.*, 2010) and studying their response to anthropogenic disturbances (Mohd-Hanif *et al.*, 2015).

Bats are most vulnerable among other mammals that response inversely on anthropogenic changes of its habitat (Fukuda *et al*., 2009). The knowledge on bats biology has been mostly obtained from capturing bats by using nets and traps. Only currently, bat surveys are mostly relied on acoustic methods and become a popular tool to monitor bat activity (Stahlschmidt *et al.*, 2012; Walters *et al.*, 2013). Bat researchers used ultrasonic detectors to record bat calls and assessing bat behavior, their habitat preferences and presence or absence (Hayes, 1997; Clement *et al.*, 2014). The use of both traditional methods and acoustic methods provides better ways for bat monitoring (Russo *et al.*, 2018).

Over 80% of all bat species use echolocation to forage, communicate and find their prey (Schnitzler *et al.*, 2003; Walters *et al.*, 2013). Bats emit ultrasonic sound frequencies of more than 20kHz that are inaudible to human (Jones *et al.*, 2013). Bat detector is a tool that able to convert the inaudible, ultrasonic signals into audible signals, making it possible for human to hear (Pettersson, 2004).

Several new improved bat detectors with better sensitivity that include omnidirectional microphones can capture overall bat detection from any directions (Britzke *et al.*, 2013). Bat detector not only helps to account for the bat activity and their habitat used but can detect more species compared to capture methods. However, acoustic methods are unable to clearly quantify the population abundance (Hayes, 1997; Murray *et al.*, 1999; O'Farrell & Gannon, 1999; Britzke *et al.*, 2010). Hence, capture sampling methods complements acoustic monitoring methods when assessing bat species diversity and habitat use while collecting the biological and morphological data for identification (O'Farrel & Gannon, 1999; Weller & Lee, 2007; Armitage & Ober, 2010).

Acoustic monitoring has reasonable reason to assume that sites with higher level of bat activity has better use by bats than sites with less activity (Frick, 2013). In addition, bat activity pattern may differ spatially and temporally. The nightly activity of bat may influence by the changes in nightly conditions (Hayes, 1997). On top of that, changes in latitude may also be a general indicator to bat activity along with climatic changes occur at given location that may alter any latitudinal pattern (Erickson & West, 2002). Hence, it is in need to understand the influence of climatic factors on bat activity which can provide insights into bat distributions in an area, especially at higher latitude or mountainous regions where environmental conditions may be extreme. This data would be critical in area such as Kubah National Park which include a combination of elevational gradient as

well as vegetation gradient that can make trapping effort difficult but can be achieved using the acoustic monitoring.

Kubah National Park covers 2,230 hectares and comprises heavily forested slopes and ridges of the Serapi range (Law & Lo, 2016). This park is open to public and is the only park with paved tar road heads to the peak of Gunung Serapi (911m a.s.l.) that is clearly bisecting the forest. This road is used by army and telecommunication transport while visitors' vehicles are strictly not allowed to trek along this road (Mohd Azlan *et al.*, 2018). Kubah National Park comprises patches of *Kerangas* forests, scrub forests, mixed dipterocarp forests, and lower-montane forest (above 700 m a.s.l.) (Pearce, 1994; Hazebroek & Abang-Morshidi, 2000; Das *et al.*, 2007; Dow & Reels, 2013; Mohd-Azlan *et al.*, 2018).

1.2 Problem Statements

Bat monitoring has been mostly done by traditional methods such as harp trapping and mist netting which are only highly effective in monitoring bats in the forest understory (Tanshi & Kingston, 2021). Although using multiple capture techniques with mist nets, canopy nets and harp traps documented more species, aerial insectivorous bats are still under-represented (Simmons & Voss, 1998; Clarke *et al.*, 2005; MacSwiney G *et al.*, 2007; MacSwiney G. *et al.*, 2008). Bats that forage in open spaces, or in forest gaps or edges are most likely to be missed out and their abundance cannot be assessed by trapping methods alone because echolocating insectivorous bats often avoid mist nets (Heaney *et al*., 2006; Yoh *et al.*, 2022). Therefore, additional method such as acoustic sampling would contribute to more species, mostly those aerial insectivorous bats that forage far from where nets are typically positioned (Bernard *et al*., 2011). This can give a different

prospect on bat activity study while using only mist nets and allows a long-term monitoring at multiple locations simultaneously (Miller, 2001).

Most of bat ecology studies in Sarawak have focused on the species diversity (e.g. Kumaran *et al*., 2006, Khan *et al*., 2007; Naharuddin *et al*., 2015). However, little is known about the foraging activity pattern of bats in their habitat. Bat detectors are the available tools to investigate foraging insectivorous bats (Kunz, 2004). Effect of altitude on bat diversity and activity pattern information are crucial for conservation of small geographical scales (Sánchez-Cordero, 2001). In Sarawak, very limited bat diversity surveys were conducted that involved elevational gradient (Tuen *et al*., 2002; Mohd-Azlan *et al*., 2008, Kumaran *et al*., 2011) and highland bat diversity surveys are still lacking (Kumaran *et al*., 2006). Similarly, bat activity also may vary daily or seasonally due to changes on nightly conditions such as temperature, humidity, and insect abundance (Hayes, 1997). So far, no related study in Sarawak that suggest this factor may influence the bat foraging activity level in tropical forest.

Therefore, this study aimed to compare the activity patterns of insectivorous bats between lower and higher elevations in Kubah National Park; and to determine other possible factors such as temperature, humidity and insect abundance that may influence the bat activity levels at each elevation. Every call species was identified from the calls collected from captured individuals from the area itself.

1.3 Research Objectives

The objectives of this study are:

i. To build echolocation call library for the purpose of species identification of insectivorous bats through echolocation call recording in Kubah National Park, Sarawak, Malaysia.

ii. To compare the activity pattern of insectivorous bats at contrasting elevations in Kubah National Park by using acoustic method.

iii. To identify the other factors affecting activity of bats at contrasting elevation in Kubah National Park.

1.4 Project Outlines

This thesis is presented in five chapters. Chapter 1 consists of general introductions and main objectives of this study. Chapter 2 is the literature review that discuss on previous related studies that had been conducted by other researchers. Meanwhile, Chapter 3 presents the description of echolocation calls of insectivorous bats collected from Kubah National Park that are used to identify bat occurrence and for future acoustic monitoring purposes. Further in Chapter 4, the possible factors that influence bat activity pattern such as climatic conditions, and insect abundance are investigated. Lastly, in Chapter 5, overall results and conclusion of factors affecting bat activity pattern are discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Order Chiroptera

The name Chiroptera is derived from the Greek roots *cherir* (hand) and pteron (wing) that implies the bat wing as a highly modified hand (Kunz and Pierson, 1994). Previously, bats were divided into two suborders where echolocation is the difference between them: Non-echolocating Old World bats and echolocating bats. Recently, molecular phylogenetic studies have subdivided bats into two suborders: Yinpteropchiroptera and Yangochiroptera (Teeling *et al*., 2005). Bats are among the most diverse mammals' group with about 1455 species from 18 families worldwide (Simmons & Cirranello, 2022). Bat diversity is not only reflected by number of species but also include other aspects of their biology behavior (Altringham, 1996).

Bats play a crucial role as contributors to forest ecosystem health and in ecosystem services on tropical rainforest such as plant pollinators, seed dispersals, and major consumers of nocturnal-flying insects (Fujita & Tuttle, 1991; Kunz and Pierson, 1994; Brigham *et al.*, 2002). Frugivorous bats and nectar-feeding bats are potential natural pollinators and seed dispersers that help to facilitate forest regeneration especially the forest that suffer from deforestation and landscape transformation (Kelm *et al*., 2008; Sritongchuay *et al.*, 2016). In Southeast Asia, Durian (*Durio zibethinus*) and petai (*Parkia speciosa*) are among the plants that highly rely on bats for pollinations (Kunz *et al.*, 2011; Maas *et al.*, 2016; Frick *et al.*, 2019; Chaiyarat *et al.*, 2020). On the other hand, insectivorous bats have substantial role in controlling insect population that feed on airborne insects and other arthropods including agricultural pest species and insects that

transmit specific pathogens to human and animals (Kunz *et al.*, 2011). They consume more than 30% of their body weight and 50% by nursing mothers (Fenton, 1983).

Bats have important part as valuable biodiversity indicators and ecosystem quality, and respond to environmental changes (Jones *et al.*, 2009). Bat population tend to reduce, and they may function as a measure of habitat integrity when their habitat is disturbed and will start to look for new place to colonize (Noss, 1990; Blair, 1999). Despite the great diversity of bats, the intense threats such as forest loss, logging, hunting, quarrying, and urbanization have led to population declines (Kingston, 2010; Kingston, 2013). Worldwide, a total of 1335 known species which is about 80% of bats classified in IUCN (2022) required conservation or research attention. In Borneo, the bats are facing major threats from habitat loss, cave disturbance and hunting (Struebig *et al.*, 2009, 2010; Mohd-Ridwan *et al*., 2011).

Forest and other subterranean features such as caves and mines are the most important habitats for bats. Forest-roosting species are more influenced to habitat quality and show immediate response to changes in forest quality and availability as it affects their roost availability and foraging success (Kingston, 2010). The importance of forest is not only to provide essential foraging habitats, but also acts as roosting sites to many bat species such as in hollow tress, cavities of standing and fallen trees, under bark or in foliage (Frick *et al.*, 2020). Consequently, further loss and degradation of tropical rainforests is a severe threat to bat diversity globally.

Meanwhile, cave roost is an essential habitat that protects them from harsh environmental conditions, predators, place for mating and rear young (Mohd-Ridwan *et al.*, 2011). About 50 bats species in Borneo are known as cave-dwellers (Phillipps &