

**INSECTIVOROUS BAT ASSEMBLAGES IN RELATION TO
SPATIAL ASPECTS OF VIRGIN JUNGLE RESERVES IN
PENINSULAR MALAYSIA**

JOANN CHRISTINE LURUTHUSAMY

**FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR**

2010

**INSECTIVOROUS BAT ASSEMBLAGES IN RELATION TO
SPATIAL ASPECTS OF VIRGIN JUNGLE RESERVES IN
PENINSULAR MALAYSIA**

JOANN CHRISTINE LURUTHUSAMY

**DISSERTATION SUBMITTED IN FULFILMENT
OF THE REQUIREMENTS
FOR THE DEGREE OF MASTERS OF SCIENCE**

**FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR**

2010

ACKNOWLEDGEMENTS

First and foremost, my gratitude goes out to the Forest Research Institute of Malaysia (FRIM) for their financial support, from which the completion of this study would not have been possible. Also to University of Malaya (UM) for giving me the opportunity to pursue my academic ambitions. Thank you to my supervisor, Prof. Dr. Rosli Hashim for his willingness to take me under his supervision and for all his advice and support during the duration of my study. My heartfelt thanks go out also to my advisor in FRIM, Dr Christine Fletcher. Thank you for presenting me with opportunities here at FRIM, for sharing your expertise and for your support throughout this journey. But most of all, thank you for believing in me.

A huge appreciation goes out to my dedicated field assistant, Rozaimi, who assisted me since day one of my field sampling. Also to the reliable Orang Asli, especially those in PITC, Gerik and Berembun, Negeri Sembilan, without whom the successful completions of the field sampling, would not have been possible.

I am also very grateful to Dr Rhett Harisson and Dr Matthew Potts for patiently teaching me the fundamentals of statistics at the numerous statistical workshops held and for commenting on my chapters. To Dr Rahman Kassim who always had time to answer my questions, no matter how busy he may be. Dr Tigga Kingston, thank you for your guidance at the early stages of the project. Your thoughts, insights and materials contributed greatly towards the foundation of this study. To my friends, Hannah Salim and Sofie Sharuddin, thank you for taking time to proof-read my chapters.

I would also like to extend my appreciation to the Project support Unit of the Conservation of Biological Diversity (CBioD) project for logistical support. And to the amazing Rapid Biodiversity Assessment (RBA) team in which I had the privilege of working with, especially Zati, Liz and Dzamir, thank you for filling each trip with humor and making this journey a memorable and fun-filled one.

Finally and most importantly, to my family especially my parents and Jay, thank you for your prayers and support throughout this journey. And last but not least, I owe the successful completion of my study to the One above.

ABSTRACT

The tropical region supports the highest diversity of bat fauna known. Reasons for their success are mainly due to their large geographical ranges, the diversity of habitats, various foraging strategies and the tendency to exhibit a variety of roosting behaviour. This study addresses the issue of insectivorous bat distribution in relation to spatial aspects such as geography, size, distance and topography. This information was gathered from the 958 individuals and 27 insectivorous bat species that were captured and identified over a span of 18 months. This study which included six virgin jungle reserves of various sizes across Peninsular Malaysia revealed that the Peninsular is dominated mainly by the Hipposiderids and Rhinolophids family and that bat species composition is driven by elevational range and forest surroundings, and not by geography. As for the effect of primary habitat size, this study showed that VJR size did not show any correlation with insectivorous bat assemblages. The impact of VJR size class on its surrounding logged over forest indicated that the population of bats 200 m away from the VJR tend to increase with increasing VJR size but the proportion of bats furthest away from the VJR (> 600 m) decreased. Although topography did not have an effect on bat distribution within each site, bat abundance and species richness were the highest at the valley. Despite the various aspects of a forest (topography, size, distance, etc.), there is no one single reason behind bat species distribution, but an interaction of a few factors. Different species tend to be most abundant around their environmental optimum. Therefore conservation strategies should focus on determining a balance forest structure for the survival of each bat species.

ABSTRAK

Hutan tropika dikatakan mempunyai kepelbagaian kelawar yang paling tinggi. Ini kerana kelawar dapat menguasai kebanyakan kawasan geografi, habitat, mempunyai pelbagai cara untuk mencari makanan dan tempat berlindung. Objektif utama kajian ini adalah untuk mengkaji kesan kepelbagaian kawasan hutan seperti faktor geografi, saiz dan jarak hutan primer (VJR) dan topografi ke atas komuniti kelawar pemakan serangga. Kajian ini telah dijalankan di enam hutan simpan dara yang terdiri daripada pelbagai saiz di Semenanjung Malaysia. Melalui hasil kajian ini, 958 individu yang terdiri daripada 27 spesis kelawar serangga menunjukkan bahawa kebanyakan kelawar di Semenanjung Malaysia di dominasi oleh kelawar dari famili Hipposideridae dan Rhinolophidae. Faktor geografi didapati tidak mempengaruhi komposisi spesis kelawar tetapi sebaliknya dipengaruhi oleh ketinggian kawasan dan mutu persekitaran hutan tersebut. Saiz hutan primer (VJR) juga tidak menunjukkan sebarang korelasi dengan populasi kelawar. Bagi kesan saiz VJR dengan kawasan hutan di sekitarnya pula, didapati semakin besar saiz VJR semakin kurang kelawar yang ditangkap pada jarak 600 m dari sempadan VJR. Topografi (tebing, cerun, lembah) juga tidak menunjukkan kesan terhadap taburan komuniti kelawar. Tetapi kawasan lembah jelas menunjukkan bahawa ia menjadi tumpuan kebanyakan kelawar kerana bilangan individu dan spesis yang ditangkap di kawasan tersebut adalah paling tinggi. Walaupun terdapat banyak aspek hutan yang boleh mempengaruhi taburan komuniti kelawar di dalam hutan, namun tidak ada satu faktor yang boleh menentukannya. Ini kerana setiap spesis mempunyai kawasan tarikannya yang tertentu

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii	
ABSTRACT	iv	
ABSTRAK	v	
TABLE OF CONTENTS	vi	
LIST OF FIGURES	x	
LIST OF TABLES	xiv	
LIST OF SYMBOLS AND ABBREVIATIONS	xvi	
CHAPTER 1	GENERAL INTRODUCTION	1
CHAPTER 2	INSECTIVOROUS BAT ASSEMBLAGES IN PENINSULAR MALAYSIA	
2.1 INTRODUCTION		5
2.1.1 Ecology of bats		5
2.1.2 Study of bats		8
2.1.3 Bats of Peninsular Malaysia		9
2.2 METHODS		11
2.2.1 Study sites		11
2.2.1(a) Semangkok Forest Reserve		14
2.2.1(b) Berembun Forest Reserve		14
2.2.1(c) Gunung Tebu Forest Reserve		14
2.2.1(d) Ulu Gombak Forest Reserve		14
2.2.1(e) Kledang Saiong Forest Reserve		15

2.2.1(f) Gunung Angsi Forest Reserve	15
2.2.2 Sampling design	15
2.2.3 Field sampling	16
2.2.4 Statistical analysis	16
2.3 RESULTS	19
2.3.1 Bat assemblages	19
2.3.2 Bat species composition	22
2.3.3 Bat distribution	26
2.4 DISCUSSION	31
2.4.1 Bat assemblage	31
2.4.2 Bat species composition	32
2.4.3 Bat distribution	35
CHAPTER 3	SIZE EFFECT OF VIRGIN JUNGLE RESERVES ON INSECTIVOROUS BAT ASSEMBLAGES
3.1 INTRODUCTION	38
3.1.1 Forestry in Malaysia	38
3.1.2 Bats and the forest	40
3.2 METHODS	42
3.2.1 Study sites	42
3.2.1(a) Semangkok Forest Reserve	44
3.2.1(b) Gunung Tebu Forest Reserve	44

3.2.1(c) Gunung Angsi Forest Reserve	44
3.2.1(d) Ulu Gombak Forest Reserve	45
3.2.1(e) Kledang Saiong Forest Reserve	45
3.2.1(f) Berembun Forest Reserve	45
3.2.2 Sampling design	46
3.2.3 Field sampling	46
3.2.4 Habitat survey	47
3.2.5 Statistical analysis	47
3.3 RESULTS	50
3.3.1 Differences of bat community between VJR size classes	50
3.3.2 Differences of bat community between distances	56
3.3.3 Differences in habitat variables	64
3.4 DISCUSSION	67
3.4.1 Bat assemblage between size classes	67
3.4.2 Bat distribution between distances	73
CHAPTER 4	EFFECTS OF SPATIAL DIVERSITY ON SPECIES COMPOSITION OF INSECTIVOROUS BATS
4.1 INTRODUCTION	78
4.1.1 Forest topography	78
4.1.2 Bats and the forest	79
4.1.3 Spatial effects	81
4.3 METHODS	83

	4.3.1 Study site	83
	4.3.2 Sampling design	85
	4.3.3 Field sampling	86
	4.3.4 Habitat survey	86
	4.3.5 Statistical analysis	88
4.4 RESULTS		90
	4.4.1 Bat species composition in relation to topography	90
	4.4.2 Habitat structure in relation to topography and local climate	100
	4.4.3 Habitat structure and species composition	104
4.5 DISCUSSION		106
	4.5.1 Habitat structure in relation to topography and local climate	106
	4.5.2 Bat species composition in relation to topography	108
CHAPTER 5	GENERAL CONCLUSION	115
REFERENCES		119
APPENDIX		
A	Bat species captured that is listed as Near Threatened (NT) under the International Union for Conservation of Nature and Natural Resources (IUCN, 2009).	134
B	Rules governing the laying out and maintenance of virgin jungle reserves (Putz, 1978)	135
C	Topographic map of study sites. <i>Source: Forestry Department of Peninsular Malaysia</i>	137

LIST OF FIGURES

Figure		Page
2.1	Location of the six of the study sites in Peninsular Malaysia	12
2.2	Family compositions of insectivorous bats caught at six forest reserves in Peninsular Malaysia; (a) number of species by family and (b) number of individuals by family.	20
2.3	Bat abundance and number of species captured in six forest reserves in Peninsular Malaysia.	21
2.4	Species rank abundance for (a) Gunung Tebu Forest Reserve in Terengganu; (b) Kledang Saiong Forest Reserve in Perak; (c) Semangkok Forest Reserve in Selangor; (d) Ulu Gombak Forest Reserve in Selangor; (e) Berembun Forest Reserve in Negeri Sembilan, and (f) Gunung Angsi Forest Reserve in Negeri Sembilan. See Table 2.3 for species codes.	24
2.5	Species accumulation curve for six forest reserves in Peninsular Malaysia using rarefaction method.	27
2.6	(a) Annual mean rainfall (mm) and (b) annual mean temperature (°C) compared with number of bats caught for the six study sites. Climate data obtained from the nearest meteorological station: Kledang Saiong – Lubuk Merbau Station, Perak; Semangkok and Ulu Gombak - Kuala Kubu Bharu Station, Selangor; Berembun and Gunung Angsi – Seremban Hospital Station, Negeri Sembilan; Gunung Tebu – Kuala Terengganu Airport Station, Terengganu.	28
2.7	Cluster dendogram using Sorenson dissimilarity index of bat species presence/absence.	30
2.8	Cluster dendogram using Steinhaus dissimilarity index of proportion of bat species caught in the six study sites.	30
3.1	Bat abundance and species richness at six VJR size classes in hectare (< 50 - Class I; 51–100 - Class II; 101–300 - Class III; 301–700 - Class IV; 701–1500 - Class V; >1500 - Class VI).	52

3.2	Simpson's Diversity Index (1-D) and Pielou's evenness index at six VJR size class in hectare(< 50 - Class I; 51-100 - Class II; 101-300 - Class III; 301-700 - Class IV; 701-1500 - Class V; >1500 - Class VI).	52
3.3	Species accumulation curve for six forest reserves in Peninsular Malaysia using rarefaction method (< 50 - Class I; 51-100 - Class II; 101-300 - Class III; 301-700 - Class IV; 701-1500 - Class V; >1500 - Class VI).	54
3.4	Species rank abundance curve with labels of the five most abundant species at six VJR size class in hectare (a) Class I - < 50 (b) Class II - 51-100 (c) Class III - 101-300 (d) Class IV - 301-700 (e) Class V - 701-1500 (f) Class VI - >1500. See Table 3.2 for species codes.	55
3.5	Cluster dendrogram using Sorenson dissimilarity index of species presence-absence six size classes (in hectare) at the ridge(< 50 - Class I; 51-100 - Class II; 101-300 - Class III; 301-700 - Class IV; 701-1500 - Class V; >1500 - Class VI).	57
3.6	Proportion of bats (%) caught within the Virgin Jungle Reserve (VJR), 200 m away and 600 m away from the VJR in each size class in hectare (< 50 - Class I; 51-100 - Class II; 101-300 - Class III; 301-700 - Class IV; 701-1500 - Class V; >1500 - Class VI).	58
3.7	Species that contribute $\geq 5\%$ of the total population in each site and the proportion (%) caught within the Virgin Jungle Reserve (VJR), 200 m away and 600 m away from the VJR. See Table 3.2 for species codes.	62
3.8	Cluster dendrogram using Steinhaus dissimilarity index of dominant species proportion in six size classes at the ridge (< 50 - Class1; 51-100 - Class2; 101-300 - Class3; 301-700 - Class4; 701-1500 - Class5; >1500 - Class6)	63
3.9	Non-metric multidimensional scaling (NMDS) of bat species abundance ($\geq 5\%$ of the population) and sites categorized as 'within' for within Virgin Jungle Reserve (VJR), 'Away200m' and 'Away600m' for traps at 200m and 600m away from VJR, respectively. The numbers (1-6) indicate the size class (1 - Class I; 2 - Class II; 3 - Class III; 4 - Class IV; 5 - Class V; 6 - Class VI). Distances between sampling sites on the ordination reflect dissimilarity in bat species composition using Bray-Curtis coefficients. See Table 2.2 for species codes.	65

3.10	(a) Total basal area per hectare, (b) mean tree height (m) within the Virgin Jungle Reserve (VJR), 200 m and 600 m away from the VJR at six sites (< 50 - Class I; 51–100 - Class II; 101–300 - Class III; 301–700 - Class IV; 701–1500 - Class V; >1500 - Class VI).	66
4.1	Sampling plot for habitat survey established at each sampling site.	87
4.2	Total number of bats and species caught at the ridge, slope and valley across six sites.	92
4.3	Species rank abundance at the ridge, slope, and valley across six sites. Codes indicate the ten most abundant species caught at each topographic site. See Table 4.2 for species codes.	93
4.4	Proportion in percentage of all the species caught at the ridge, slope and valley across six sites. Table below displays the number of individuals caught. See Table 4.2 for species codes.	94
4.5	Cluster dendogram using Sorenson dissimilarity index of species presence-absence at the ridge (R), slope (S), valley (V) at six sites.	96
4.6	Cluster dendogram using Steinhaus dissimilarity index for proportion of species contributing > 5% of the total capture (<i>Hipposideros bicolor</i> 131, <i>H. bicolor</i> sp., <i>H. cervinus</i> , <i>H. larvatus</i> , <i>Kerivoula hardwickii</i>) at ridge (R), slope (S), valley (V) for six sites.	97
4.7	Non-metric multidimensional scaling (NMDS) of bat species abundance and sites categorized as ridge, slope and valley. Distances between sampling sites on the ordination reflect dissimilarity in bat species composition using Bray-Curtis coefficients. See Table 4.2 for species codes.	99
4.8	Cluster dendogram using Steinhaus dissimilarity index for proportion of trees at different height classes according to ridge (R), slope (S), valley (V) for six sites.	102
4.9	Cluster dendogram using Steinhaus dissimilarity index for proportion of trees at various basal area classes according to ridge (R), slope (S), valley (V) for six sites.	103

4.10 Mean (a) temperature ($^{\circ}\text{C}$) and (b) relative humidity (%) obtained from the data logger HOBO[®] placed on each transect at each study site. The graph shows a missing value for the mean relative humidity for the slope in Berembun due to a faulty data logger. 105

LIST OF TABLES

Table		Page
2.1	Details of the study sites in Peninsular Malaysia.	13
2.2	Simpson's diversity index (1-D) and Pielou's Evenness index for six forest reserves in Peninsular Malaysia	21
2.3	List of bat family and species caught in six sites across Peninsular Malaysia and the International Union for Conservation of Nature and Natural Resources (IUCN) status (IUCN, 2009). [<i>Hipposideros 'bicolor'</i> comprises of two phonic types with mean echolocation call frequencies of 131 kHz and 142 kHz. They were distinguished in the hand by forearm length <i>H.bicolor 131</i> > 45 mm and <i>H.bicolor 142</i> < 43 mm. Individuals with forearm 43 – 45 mm is identified as <i>H.bicolor</i> sp. Species classification is according to Kingston <i>et al.</i> (2006). (see Appendix A).	23
2.4	Extrapolated species richness with Chao estimates in six sites (SE.- standard error)	27
2.5	Block Multiple Response Permutation Procedure (MRPP) results Chance-corrected within-group agreement (A) describes within-group homogeneity. If all observed items are identical within groups, A=1, which is the highest possible value. If there is less agreement within groups than expected by chance, A < 0. The higher the A value the more identical the sites are in terms of bat communities. p< 0.05 indicates that the pair is significantly not similar.	29
3.1	Details of selected Virgin Jungle Reserves in Peninsular Malaysia	43
3.2	List of bat family and species caught in six sites across Peninsular Malaysia, < 50 – Class I; 50-100 – Class II; 100-300 – Class III; 300-700 – Class IV; 700-1500 – Class V; >1500 – Class VI. [<i>Hipposideros 'bicolor'</i> comprises of two phonic types with mean echolocation call frequencies of 131 kHz and 142 kHz. They were distinguished in the field by forearm length <i>H.bicolor 131</i> > 45 mm and <i>H.bicolor 142</i> < 43 mm. Individuals with forearm 43–45 mm is identified as <i>H. bicolor</i> sp. Species classification is according to Kingston <i>et al.</i> , 2006; Hill, 1983].	50
3.3	Extrapolated species richness with Chao estimates in six study sites (SE. - standard error)	54

3.4	Pearson's correlation (r) of habitat variables with bat abundance and Simpson's Diversity Index (1-D).	58
3.5	Block Multiple Response Permutation Procedure (MRPP) for comparison between species composition within and distances away from the VJR. Chance-corrected within-group agreement (A) describes within-group homogeneity. If all observed items are identical within groups, $A=1$, which is the highest possible value. If there is less agreement within groups than expected by chance, $A < 0$. The higher the A value the more identical the sites are in terms of bat communities. $p > 0.05$ indicates that the pair is dissimilar.	59
3.6	Families and species that contribute $\geq 5\%$ to the population in at least one site size class are listed. Shaded values indicate site in which the species contributed $\geq 5\%$ to the population (< 50 - Class I; 50-100 - Class II; 100-300 - Class III; 300-700 - Class IV; 700-1500 - Class V; >1500 - Class VI).	61
4.1	Details of selected forest sites in Peninsular Malaysia	84
4.2	List of bat family and species present at the ridge, slope and valley across six sites in Peninsular Malaysia.	91
4.3	Extrapolated species richness with Chao estimates for the ridge, slope and valley (SE - standard error)	102
4.4	Block Multiple Response Permutation Procedure (MRPP) results Chance-corrected within-group agreement (A) describes within-group homogeneity. If all observed items are identical within groups, $A=1$, which is the highest possible value. If there is less agreement within groups than expected by chance, $A < 0$. The higher the A value the more identical the sites are in terms of bat communities. If the p value is $p < 0.05$, it indicates that the pair is significantly dissimilar.	94
4.5	Mean tree height and basal area per tree at the ridge, slope and valley for the six sites	95

LIST OF SYMBOLS AND ABBREVIATIONS

VJR	Virgin Jungle Reserve
ca.	Circa (approximately)
°C	Degree Celsius
%	Percentage
asl	above sea level
F.R	Forest Reserve
m	meter
m ³	meter cube
cm	centimeter
DBH	diameter at breast height
>	More than
<	Less than
≥	Equal or more than
/	Divide
IUCN	International Union for the Conservation of Nature
S.E.	Standard Error
FRI	Forest Research Institute (now known as Forest Research Institute of Malaysia - FRIM)
Min.	Minimum
Max.	Maximum
pers. obs.	Personal observation