MINERAL LICK VISITATION BY BATS: A STUDY IN BORNEAN TROPICAL RAINFOREST, DERAMAKOT FORESTRY DISTRICT, SABAH

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2016

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THESIS SUBMITTED IN FULFILLMENT FOR DEGREE OF MASTER OF SCIENCE

INSTITUTE FOR TROPICAL BIOLOGY AND CONSERVATION
UNIVERSITI MALAYSIA SABAH
2016

DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries, each of which has been properly acknowledged.

Lawrence Alan Bansa

24 March 2016

MX1211007T

ACKNOWLEDGEMENT

I would wish to convey my deepest gratitude to the personnel and institutions that had contributed directly or indirectly throughout my study as a master student, particularly to my supervisor, Assoc. Prof. Dr. Abdul Hamid Ahmad for his patience, support, guidance, and constructive criticisms. My co-supervisor, Assoc. Prof. Dr Hisashi Matsubayashi, I am truly grateful for his idea to this research, trust, patience, and comments.

I would like to offer my greatest appreciation to the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, with extra remarks to Prof.Dr. Charles Vairappan, Acting Director of the institute, for the permission and providing this valuable tract and facilitated this work. Without the transportation, field apparatus and technical support, annual research symposium and other related supports, this study had not been developed and possible. Not to forget, Dr. Fazley A.B., Dr. Mahadi M.D., and Dr. Arman H.F., I am really thankful for their support and their commitment throughout my field as a master student. Particular thanks to the examiners for their attention and comments for this thesis.

Sabah Forestry Department, especially to the director himself, Datuk Sam Manan, with official permission from this foundation, the fieldwork of this work was made possible. Particular thanks to the organisation committee of Deramakot Forestry Department, Balat Station and Tangkulap Forestry Department, especially to the supportive Mr. Jhonny Kissing (Director of Deramakot Forestry Department), Mr. Peter Lagan, Mr. Azny Ahmad, and Mr. Edward, for the communication, invaluable field support, flexibility, accommodation, and kindness. My earnest thanks to the Deramakot's field assistant team for being supportive, kind, fun and helpful throughout the fieldwork.

I would wish to show my appreciation to Mr. Simon Kuyun and Joumin Rangkasan, field assistants from ITBC, who had been really supportive to ensure my safety and for their field support during the fieldwork in the Deramakot Forestry District.

Particular thanks to the Faculty of Science and Natural Resources, especially the botany lab, UPRL and chemistry lab, for creating the chemical formulation and analysis possible.

I would like to offer my appreciation to Mr. Majid Khan, for the guidance in statistic, financial supports and kindness. Periodic anxiety passed with support from my fellow grad-students, Philip Yap, Elisa Panjang, Sabilah Tahir, Lusia Moses, Angelina Lee,Haliza Hassan, Musa, Hasrin, Afifi, Vickly, Emmanuel, Usran, and ITBC's students. I am luck to have a supportive, patient and caring family, with especial attention to my parents for their continuous prayer and living.

Lastly, special thanks to the Ministry of Education Malaysia for the scholarship and Universiti Malaysia Sabah for the accommodations and adjustments. Special remarks to the Japanese Society for Promotion of Science (JSPS) core-to core program.

Lawrence Alan Bansa
March 2016

ABSTRACT

Bats, like many terrestrial animals are attracted to visit and use mineral licks to meet their nutritional requirements. Although the importance of natural mineral licks for terrestrial animals is widely acknowledged, few studies have been done on natural mineral licks visitation on the bat fauna, particularly in Borneo and Southeast Asia in general. It is not known what species of bats frequently using mineral licks, and their daily temporal visitation pattern. Furthermore, it is not known how habitat disturbance affects the natural licks and how this in turn affects the bats behaviour and their persistence. A study on visitation of bats to mineral licks was conducted at eight sites within Deramakot Forest Reserve and Tangkulap Forest Reserve located in central part of Sabah, Malaysia, Northern Borneo. The sampling sites include six natural mineral licks and two other sites serving as control treatments. The specific objectives of the study were to determine the bat species richness and community assemblages at mineral licks, to determine the temporal pattern of bat visitation to mineral licks and visitation behaviours of bats at mineral licks. The main findings of the present study revealed that Palaeotropical frugivorous bats using mineral licks, specifically five species of common frugivorous bats. There was low evidence to support that insectivorous bats were the significant user to mineral licks based on the lower species occurrence at mineral lick and lower concentration of earthly materials, Al and Si at their faeces. Most of the frugivorous bats caught at mineral licks were reproductively inactive females compared to reproductively active females, with domination of post-lactating female bats. This study found that more bats actively visited mineral licks after the peak of their foraging activity (1800-2000h), at range 2200-0600h. Visitation of frugivorous bats was affected more by the human disturbances and structures of mineral lick puddles rather than concentrations of mineral contents in the water at mineral licks. Frugivorous bats were directly observed swiftly drinking from mineral licks (n=9). Observation of bats using licks showed two identified behaviours: A. Drink on the wing; B. Cling and drink. This drinking behaviours showed in a short period of time (less than 30 sec. appx.).In conclusion, results of present study demonstrated that frugivorous bats using mineral licks with domination by female bats as their visiting pattern peaked after peak of foraging period and visiting behaviours to mineral licks is affected by human disturbances. Mineral licks are important features in the forest and should be managed as part of the conservation strategies for bats population.

Keywords: Mineral lick, Palaeotropical Bats, Deramakot Forestry District, Sabah, Borneo

ABSTRAK

Kedatangan Kelawar ke Perigi garam: Satu Kajian di Hutan Hujan Tropika Borneo, Daerah Perhutanan Deramakot Sabah

Kelawar seperti haiwan-haiwan yang lain tertarik untuk datang dan menggunakan perigi garam untuk memenuhi keperluan nutrisi mereka. Kajian-kajian membuktikan perigi garam mempunyai banyak kepentingan pada kebanyakan haiwan daratan namun begitu kajian mengenai perkaitan kelawar dan perigi garam adalah terhad khususnya di Borneo dan secara amnya di Asia Tenggara. Spesies kelawar yang menggunakan perigi garam dan corak penggunaan mereka masih belum diketahuai. Selain itu, kesan gangguan habitat terhadap perigi garam dan perkaitan diantara tingkah laku dan kemandirian kelawar yang menggunakan perigi garam masih belum diketahuai. Satu kajian mengenai kedatangan kelawar ke perigi garam telah dijalankan di Hutan Simpan Deramakot dan Hutan Simpan Tangkulap, Sabah Malaysia. Tapak kajian merangkumi enam perigi garam semulajadi dan dua tapak pemalar. Objektif-objektif kajian ini ialah untuk mengenal pasti kekayaan dan kelimpahan spesies di perigi garam, untuk mengenal pasti corak kedatangan sementara kelawar ke perigi garam dan gaya tingkah laku di perigi garam. Dapatan utama kajian ini mendapati kelawar buah Paleotropika menggunakan perigi garam, khususnya lima spesies kelawar buah yang biasa. Manakala kelawar pemakan serangga tidak dapat dibuktikan dengan jelas menggunakan perigi garam kerana kewujudan mereka kurang di perigi garam dan kepekatan unsur-unsur tanah dalam najis mereka. Kebanyakan kelawar buah yang ditangkap merupakan kelawar betina yang tidak aktif, dengan dominasi kelawar betina yang telah melepasi fasa penyusuan anak. Kelawar didapati datang ke perigi garam selepas kemuncak waktu makan mereka (1800-2000h) iaitu pada 2200-0600h. Kedatangan kelawar ke perigi garam dipengaruhi oleh kesan gangguan manusia dan struktur perigi garam berbanding dengan kepekatan mineral dalam air perigi garam. Kelawaryang menggunakan perigi garam menunjukan dua jenis tingkah laku: A. Minum sambil terbang; B. Berpaut sambil minum. Kesimpulannya, dapatan daripada kajian ini menunjukkan kelawar pemakan buah menggunakan perigi garam dengan dominasi oleh kelawar betina dimana kedatangan mereka lebih banyak selepas tengah malam dan kesan gangguan manusia mempengaruhi kedatangan mereka. Perigi garam ialah ciri-ciri penting yang terdapat dihutan dan wajar diuruskan secara mapan sebagai salah satu strategi bagi memastikan kelestrian spesies khususnya populasi kelawar.

Kata kunci: perigi garam, kelawar Palaeotropika, Dearah Perhutanan Deramakot, Sabah, Borneo

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LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Percentage
<	-	Less than
=	-	Equal
>	-	More than
±	-	Plus-minus
AAS	-	Atomic absorption spectrophotometer
Al	-	Aluminium
appx.	-	Approximately
Ca	-	Calcium
CCA	-	Conical Components Analysis
Ce	-	Cerium
cm	-	Centimetre
CI	-	Confidence interval
CW1-2	-	control wallow 1 to 2
DFD	-	Deramakot Forestry District
DFR	-	Deramakot Forest Reserve
et al.	-	*et alia* (and others)
FMU	-	Forest Management Unit
GPS	-	Global positioning system
h	-	Hours
ICP-MS	-	Inductively coupled plasma mass spectrometry
ICP-OES	-	Inductively coupled plasma- optical emission spectrometer
K	-	Potassium
La	-	Lanthanum
Md	-	Mendelevium
Mg	-	Magnesium
ML1-6	-	Mineral lick 1 to 6
Na	-	Sodium
Nd	-	Neodymium
ppm	-	Part per millions
m	-	Metre
km	-	Kilometre
SD	-	Standard deviation
Si	-	Silica
Spss	-	Statistical package for social science
TFR	-	Tangkulap Forest Reserve
ver.	-	Version
XRD	-	X-ray Diffraction method
XRF	-	X-ray florescence spectrometry

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Generally, diet of bats ranged from insects, nectars, fruits and even small mammals (Gnahem, 2012). Interestingly, other than their common foods, bats also reported to consumed soil (Gnahem, 2012). Bats, like many terrestrial animals are reported visiting mineral licks to ingest soils (Gnahem, 2012; Bravo *et al.*, 2012; Bravo *et al.*, 2010a; Bravo *et al.*, 2010b; Bravo *et al.*, 2008; Voigt *et al.*, 2008). This shows that there is a close relationship between the environment, particularly Geo-resources and processes with bats (Gomes and Silva, 2007). The first part of this write-up is about the introduction to some of the important terms which are mineral licks, geophagy and visitation of animals to mineral licks.

Mineral licks are well-defined landscape elements that are present in both temperate and tropical ecosystems (Molina *et al.*, 2013; Link *et al.*, 2011) to arctic (Ramachandran 1995; Calef and Grant, 1975) and montane (Ramachandran, Cowan and Brink, 1949). Mineral licks are included as keystone resources, act as critical or limiting crucial resources in a particular habitat for many wildlife species (Montenegro, 2004) hence becoming an important habitat feature for the ecology of animals (Molina *et al.*, 2013; Rea *et al.*, 2004; Panichev *et al.*, 2002). Generally, licks are mineral-rich places where animals frequently and actively visited (Hon and Shibata, 2013) to consume earth (Ping *et al.*, 2011; Bravo *et al.*, 2010b). Animals do lick from clay-enriched muddy spring water or eating the mineral-rich soils in order to obtain minerals and other compounds (Brightsmith *et al.*, 2008).

The minerals provided by mineral licks are reliable resources in the dietary compounds (Hon and Shibata, 2013; Krishnamani and Mahaney, 2000) that would otherwise be difficult to obtain by animals (Molina *et al*., 2013). Other than physiological benefits (Brightsmith *et al*., 2008; Burger and Gochfeld, 2003; Klaus and Schmid, 1998), mineral licks may contribute to their social role as many animals community using the same lick (Molina *et al*., 2013; Ayotte, 2004; Klaus and Schmid, 1998). In addition mineral lick seems to be "long lasting and seasonally stable" (Link *et al*., 2011). Thus, this lead to conservation implications (Rea *et al*., 2004) since licks may affect the distribution (Panichev *et al*., 2002), density (Ping *et al*., 2011; Molina *et al*., 2003) and temporal structure of animal populations (Ghanem, 2013; Rea *et al*., 2004; Panichev *et al*., 2002).

The use of mineral lick is closely related to the geophagic behaviours. Geophagy can be described as an intentional and regular consumption of earthy materials (soil, clays and related mineral substances) (Pebsworth *et al*., 2013; Stephenson, *et al*., 2011; Young *et al.,* 2010) by animals and humans (Panichev *et al*., 2013; Young *et al.,* 2010; Chandrajith *et al*., 2009; Wilson, 2003). This represents a close association between the environment, particularly geo-resources and processes with human/animal health (Gomes and Silva, 2007). This behaviours is widespread throughout the animal kingdom (Blake *et al.,* 2011; Mahaney and Krishnamani, 2003) and animals are reported to ingest various types of geo-resources such as clay (Gilardi *et al*., 1999), soils (Chandrajith *et al*., 2009), mineral spring (Rea *et al.,* 2004), and mineral-enhanced seepages and pools (Dudley *et al*., 2012). Consumption of soil associated with insect eating (Krishnamani and Mahaney, 2000) and other involuntary ingestion of soil such as grazing (Selinus *et al*., 2013) does not fall into this category (Krishnamani and Mahaney, 2000). In relation to animal's health (individuals or populations) (Molina *et al*., 2003), geophagy possibly evolved because of their innate ability to explore and taste the chemically environment (Mahaney and Krishnamani, 2003) and then frequently visiting that particular place as that place provide benefits to them.

Term visitation is commonly used in documentation (Gnahem and Voigt, 2013; Gnahem, 2012; Bravo *et al*., 2012; Bravo *et al*., 2010a; Bravo *et al*., 2010b;

Bravo *et al.*, 2008; Voigt *et al.*, 2008) to describe the deliberate presence of animals at licks for geophagy behaviours. The frequency of visitation and species composition of visitor to lick may differ from one lick to the next (Burger and Gochfeld, 2003). Moreover, studies documented that mineral licks are used by a wide range of species with different feeding guild such as herbivorous, frugivorous, folivorous (Morales, 2009; Krishnamani and Mahaney, 2000), insectivorous (Matsubayashi *et al.* 2007a) and omnivorous (Hon and Shibata, 2013). Such variation may reflect differences among species preferences, the mineral composition of licks and availability of licks in different habitat (Blake *et al.*, 2011; Link, *et al.*, 2011). Herbivorous are among the most common visitor to the mineral licks (Blake *et al.*, 2010).

1.2 Significance of Study

Studies reported that mineral licks play vital roles to animals (Bravo *et al.*, 2012; Ping *et al.*, 2011; Blake *et al.*, 2010;) with direct conservation implications for protecting a fully functioning forest ecosystem (Bravo *et al.*, 2012; Ghanem, 2013) because animals frequently and actively visited (Hon and Shibata, 2013) mineral-rich places to consume earth (Ping *et al.*, 2011; Bravo *et al.*, 2010b) and this lead to the survival of those animals using that mineral licks. Visitations of animals to mineral licks are covering variety of vertebrates terrestrial (mammals, birds, reptiles) and invertebrate taxa (Blake *et al.*, 2010; Morales, 2009; Voigt *et al.*, 2008; Wilson, 2003).

As there were many studies conducted on mineral licks, there are still some remaining issues and gaps that drive to this study, particularly bats. The presence, visitation and usage of mineral licks for bats are yet remaining unclear in Southeast Asia, particularly in Borneo. Bornean tropical rain forests are known to be a region of high mammalian species diversity (Matsubayashi *et al.,* 2007a) as its tropical soil tends to be nutrient-poor habitat (Klaus *et al.*, 1998), which makes mineral licks as an important habitat feature. Matsubayashi *et al.* (2011; 2007a; 2007b) had done studies on mineral licks and mammals in Deramakot Forest Reserve but the bats were excluded from the study.

In Neotropical regions such as Peruvian and Ecuadorian Amazon tropical rainforest, mineral licks are acknowledged as an important habitat feature for the ecology of bats (Gnahem, 2012; Bravo *et al*., 2012; Bravo *et al*., 2010a; Bravo *et al*., 2010b; Bravo *et al*., 2008; Voigt *et al*., 2008) because mineral licks provide limited mineral resources to the bats. Most studies investigating the relationship of mineral licks and bats were done in Neotropical regions, and these findings are not necessarily indicative of how Palaeotropical bat communities may respond to mineral licks as the bat communities in the old world tropics are structured differently to those in the Neotropics (Turner, 2011; Kingston *et al*., 2003). Studies done in Neotropical regions reported that mineral licks are important habitat feature for the ecology of bats in most of the tropical regions and this lead to the conservation aspect of bats since mineral lick serve functions that lead to their survival and make bats frequently using this place (Gnahem, 2012; Bravo *et al*., 2012; Bravo *et al*., 2010a; Bravo *et al*., 2010b; Bravo *et al*., 2008; Voigt *et al*., 2008).

Other findings from Neotropical regions showed that herbivorous-frugivorous and omnivorous bats visiting mineral lick (Ghanem, 2013). Mineral licks are regularly visited by frugivorous bats and they drink water from puddles that were built up by larger geophagous animal at mineral licks and so become their activity hotspots, especially Sternodermatinae bats (Bravo *et al*., 2010; Bravo *et al*., 2008). The pregnant and lactating frugivorous bats were reported visiting mineral licks in large numbers (Bravo *et al*., 2008). The high demand of these frugivorous bats towards mineral nutrients and clay explains the frequent visitation by them. Female frugivorous bats may require more essential elements than their diet of fruit can supply during reproduction and they need to detoxify the secondary plant compounds in their diet (Bravo *et al*., 2008).

As bats are reported frequently using this keystone resource in the Neotropical regions (Gnahem, 2012; Bravo *et al*., 2012; Bravo *et al*., 2010a; Bravo *et al*., 2010b; Bravo *et al*., 2008; Voigt *et al*., 2008) it is relevant to study bats associated with mineral licks. Since animal respond toward licks are varied seasonally and geographically (Rice *et al*., 2010), studies from other regions are essentials for better understanding on visitation of bats to mineral licks across regions since bats play vital roles in ecosystems (Ghanem, 2013) and further understanding on bats' exploitation of this important habitat feature may lead to their conservation. Bats are interesting and important species as the play vital roles in the ecosystem which showing direct conservation implications for protecting a fully functioning forest ecosystem and tropical forest succession (Muscarella and Fleming, 2007) through ecological services that they provide (Ghanem, 2013; Bravo *et al.*, 2012). In addition they posses combination of traits which make them sensitive to environmental disturbances as they have evolved to suit particular habitats (Struebig *et al.,* 2010; Purvis *et al.*, 2000).

1.3 Background of Study

The aim of this study was to study the visitation of bats to mineral licks in the tropical rain forests of North Borneo, Deramakot Forestry District of Sabah, Malaysia. In this study, mineral licks are referring to the establish wet licks in Deramakot Forest Reserve, which are small, open muddy spring or seepage areas that are often contained running water (Ghanem, 2013; Voigt *et al.*, 2008; Voigt *et al.*, 2007; Rea *et al.*, 2004). This study focuses more on the ecological aspect rather than geochemistry and nutritional aspect.

Studies on mineral licks have been documented worldwide showing that mineral licks are important habitat features for the ecology of animals throughout the world (Rea *et al.*, 2004). As the response and behaviours of animals seemingly different across the globe, Palaeotropical bats may show different species exploitation than Neotropical bats (Kingston *et al.*, 2003). These species exploitations include the patterns of visitation, composition of visiting species, and together with their behaviours while using mineral licks. Herewith, better understanding on visitation of bats to mineral licks through their species exploitation was done through this study.

Identification of bat species that use licks, determine the species assemblages, temporal use and visitation of bats to licks, and observation of bats' behaviours while using licks were covered in this study. In this study, term 'frugivorous bat' was used to represent the Old World megabats, as this term was a common term used in documentation. Frugivorous bats were known to visit mineral licks and studies of bats visiting mineral licks were done mostly using mist-nets for bat sampling. Different species of bats are more susceptible to different trapping techniques (Struebig and Sujarno, 2006). Mist nets typically capture fruit bats and many of the insectivorous species with sophisticated echolocation flying will avoid the net. This may explain captures were mainly consisting of frugivorous and frugivores-omnivores bats. Regarding with this, the combination of both mist-nets and harp trap were used for bat sampling. Together with behaviours explanation, this probability of bats used mineral lick was tested by using field experimental design, species occurrences and insoluble soil tracer test, which further explained in methodological section.

1.4 Objectives and Hypothesis

The objectives of this study are to:

a) To determine the bat species richness and community assemblages at mineral licks
b) To determine the temporal pattern of Bat Visitation to mineral licks
c) To determine the visiting behaviours of bats at mineral licks.

Based on the similar studies on bats visitation in Peruvian and Ecuadorian Amazon tropical rainforest, proposed hypotheses for this study are made:

1) There are more frugivorous bats visiting mineral licks compared to insectivorous bats.
2) Bats that are caught at mineral licks do visit mineral licks (not by chance).
3) Insectivorous bats are expected to use mineral licks since insects are more mineral-depleted than fruits.
4) Female bats with reproductively active conditions are recorded the most compared to the others.
5) In this study, the human disturbances are expected to affect the visitation of bats rather than the mineral contents.

CHAPTER 2

LITERATURE REVIEW

2.1 Geophagy among Animals

Purposeful consumption of earthly materials (Dissanayake and Chandrajith, 2009) such as soils, clays, and related mineral substances is a common and widespread practice that can be observed in wide range of animal taxa (Wilson, 2003) and even in certain human societies from many parts of the globe, most commonly seen in tropics (Wilson, 2013). Some of several terms used in the literature to describe this phenomenon are lithophagy (from the Greek word λίθος—"rock"and φάγειν—"to eat") and geophagy (from the Greek word γη—"earth" and φάγειν—"to eat") (Panichev, *et al.* 2013). Above all, 'geophagy' is the most common term used in English literature to describe this phenomenon and this term was chosen and used throughout this review. Meanwhile, involuntary ingestion of soil material is not falling into this category.

Wild animals do regularly visit particular places for consuming those earthly materials (Panichev, *et al.* 2013). Wild animals are reported to ingest variety of geophagic earthly materials ranging from cave materials, ground depressions, weathered volcanic regolith, weathered rocks, granitic soils, termite mounds, bases of fallen trees (Ayotte, 2004; Jones and Hanson, 1985), clay exposed in or along river banks, cliffs, and an area where young geological materials have been exposed on soil ground surface (Blake *et al.*, 2011). The earthly materials intake by animal usually selective (Krishnamani and Mahaney, 2000) and their respond towards those sites may differ between specific sites and sometimes even particular soil horizon being exploited (Abraham, 2013).

The selective function of this geophagic material indicates certain qualities of land desirable for animal (Abraham, 2013) and these possibly evolved because of their natural ability to explore and sample the chemical environment (Mahaney and Krishnamani, 2003). It seems that in an area where many geophagic sites can be found, not all of those sites are necessarily used by all species (Abraham, 2013). For instance, particular species may concentrate on one location or few sites only and ignore the other areas for geophagy (Krishnamani and Mahaney, 2000; Abraham, 2013). This may be due to some factors such as concentration, abundance, and distribution of geophagic soil (Abraham, 2013).

The ability and senses to search and find this specific soil among wild animals remain unclear, perhaps the role of animal's olfactory nerve might be reasonable to explain the ability of wild animal to locate specific soil for geophagy (Krishnamani and Mahaney, 2000). The hypothesis proposed by Krishnamani and Mahaney (2000), suggested that soil ingestion behaviours is related to its smell since some animals respond to the smell of salt (Mloszewski, 1983; Krishnamani and Mahaney, 2000). This is supported by Johns (1990) where he postulated that animal's olfactory nerve has sensitivity to be able to recognize sweet, salty, sour and bitter smells. The smell comes from the presence of organic matter in organically bound mineral soil such as soils rich in clay and minerals may provide an olfactory simulation (Johns 1990). Another assumption for detection of geophagic soil by animals is through the pleasant touch of the ingested clay which leads to initial stimulus for geophagy in animals and next becomes a learned behaviour (Dissanayake, and Chandrajith, 2009). This means that animals are able to learn to identify such soils through the sense of touch (Dissanayake, and Chandrajith, 2009). Other than that, the sense of sight with the help of particular colours of certain geophagic soils can be a stimulus for detection of geophagic soil (Wilson, 2003). Another assumption is soil ingestion behaviour is also related to traditional behavioural, where this behaviour is learned from the others because they are doing likewise (Abraham, 2013). There have been many hypotheses proposed but limited geophagy literature documented to support them and this should be more explored experimentally (Krishnamani and Mahaney, 2000).

Geophagy has been reported for a wide range of animals such as reptiles (Wilson, 2003), birds (Diamond *et al.*, 1999; Gilardi *et al.*, 1999), mammals, particularly for generalist herbivores (Kreulen, 1985), many nonhuman primates (Krishnamani and Mahaney, 2000) and even invertebrates. In addition, several carnivores were recorded at geophagic sites (Blake *et al.,* 2011; Matsubayashi *et al.*, 2011; Montenegro 2004; Krishmanani and Mahaney, 2000) but the reasons of their visitation or presence still remain unclear (Montenegro, 2004). The general list of animals that potentially engages in geophagy (recorded at geophagy sites) or apparently involved in geophagy is illustrated in Table 2.1.

2.2 Geophagy by Bats

The geophagic earthly materials ranging from cave materials, ground depressions, weathered volcanic regolith, weathered rocks, granitic soils, termite mounds, bases of fallen trees (Ayotte, 2004; Jones and Hanson, 1985), clay exposed in or along river banks, cliffs, and an area where young geological materials have been exposed on soil ground surface (Blake *et al.*, 2011). Bats are reported to use mineral licks (Ghanem, 2013; Bravo *et al.*, 2012; Bravo *et al.*, 2010a; Bravo *et al.*, 2010b; Bravo *et al.*, 2008; Voigt *et al.*, 2008; Voigt *et al.*, 2007), mineral rich water-holes formed by seepage permeating through limestone, and also lick the surface of limestone rocks (Adams. *et al.*, 2003). The documentation on bats consume dry earthly materials such as clay exposed on ground surface was limited. This showed that bats have some selection for their geophagy site.