UNIVERSITI PUTRA MALAYSIA

A STUDY ON BURROWING SYSTEM OF COMMON PORCUPINES (Hystrix brachyura)

NURUL NAZIRA AZAMAN

A STUDY ON BURROWING SYSTEM OF COMMON PORCUPINES (*Hystrix brachyura*)

By

NURUL NAZIRA BINTI AZAMAN

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Special dedication goes to my beloved parents Azaman Hassan & Jamilah Che Hamid, my family, Baharin Daud and all my best friends for their moral support and encouragement. Thanks for being the truly awesome person that you are and for being the best thing that ever happened to me.

ABSTRACT

This study examines external and internal characteristics of porcupines burrow (*Hystrix brachyura*) and recorded the morphological of porcupine burrowing system in the area of Bintulu-Miri. All characteristics of burrow such as type of burrow respectively to the floor and roof of entrance hole in term of earthy, rocky or mixed, entrance exposure (North, South, East or West), hole dimension of height and width, soil texture, soil pH, slope angel and bearing or back bearing of entrance were determined and recorded. There are three different burrow construction observed in this study; earthy, mixed and rocky burrow. The roof' construction of burrows are different from each other (rock, compact soil and fallen tree) while floor' construction is prevalently based on earthy element as they dig their burrow by themselves. The temperature surrounding entrance opening is range from 26°C-28°C while pH of the soil tend to be little acidic which range from 4.99-5.90. Porcupines preferred to excavate their burrow in clay loam area which gives high stability than sandy soil. Burrow' entrance hole preferred moderate steep slope (class B: 20-39°) descending the burrow tunnel with exposed to the East. This burrow architecture is assumed to provide them from predators and environmental changes.

ABSTRAK

Kajian ini adalah bertujuan untuk mengkaji ciri-ciri luaran dan dalaman busut landak serta merekodkan sistem binaan busut landak yang terdapat di sekitar kawasan Bintulu- Miri. Ciri-ciri utama busut seperti jenis busut yang merujuk kepada lantai dan atap lubang busut sama ada terbina dari tanah, batu atau campuran tanah dan batu, arah pendedahan pintu masuk (Utara, Selatan, Timur atau Barat), dimensi lubang masuk iaitu tinggi dan lebar, tekstur tanah, pH tanah, sudut kecerunan pintu masuk, kedudukan "*compass*" dari segi arah bearing dan "*back bearing*" dikenal pasti dan direkodkan. Terdapat tiga perbezaan dalam binaan busut landak telah diperhatikan dalam kajian ini iaitu dibina dari unsur tanah, campuran dan unsur batu. Binaan siling busut landak adalah berbeza di antara satu sama lain (batu, tanah yang padat dan pokok yang tumbang) sementara binaan lantai lazimnya dibina dari unsur tanah disebabkan landak menggali busut mereka sendiri. Suhu pada sekitar kawasan bukaan busut adalah di antara 26°C-28°C sementara pH tanah menunjukkan sedikit berasid iaitu di antara 4.99-5.90. Landak lebih cenderung untuk menggali busut mereka di kawasan tanah liat berlempung (*clay loam*) yang lebih stabil untuk pembinaan busut mereka berbanding tanah berpasir. Landak lebih cenderung memilih sudut kecerunan yang sederhana cerun (kelas B: 20-39°) menuruni pintu terowong busut yang terdedah kearah Timur. Kesimpulannya, sistem binaan busut landak ini dianggapkan dapat memberikan perlindungan dari pemangsa dan perubahan persekitaran yang melampau.

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APPROVAL

I certify that this research project entitle "A study on burrowing system of common porcupines (*Hystrix brachyura*)" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Science Bioindustry in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

Mrs. Marina Binti Mohd Top @ Mohd Tah
Faculty of Agriculture and Food Sciences
Universiti Putra Malaysia Bintulu Sarawak Campus
(Supervisor)

Prof. Dr. Lapar Sidik Bin Bujang
Dean
Faculty of Agriculture and Food Sciences
Universiti Putra Malaysia Bintulu Sarawak Campus

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LIST OF ABBREVIATIONS

Abbreviations	Definition
°	Degree
%	Percentage
°C	Degree Celsius
et al.,	And all
m	Meter
cm	Centimeter
‘	Minutes
N	North
S	South
E	East
W	West
NA	Not applicable
LAKU	LOJI AIR DAN KUMBAHAN

CHAPTER 1

INTRODUCTION

1.1 Background

Porcupines can be classified under order of Rodentia comprising of 2 families with 7 genera and 21 species that spread over the world (Nowak, 1999). The division of porcupines can be categorized in two families which are Hystricidae (Old World Porcupines) and Erethizontidae (New World Porcupines). Erethizontidae consists of four genera which are *Erethzon*, *Coendou*, *Echinoprocta* and *Chaetomys* whereas Hystricidae also has four genera which are *Thecurus*, *Hystrix*, *Atherurus* and *Trichys* (Siddique and Arshad, 2004).

Hystrix brachyura or "Landak Raya" can be classified as one of the Old World porcupine. This Malayan porcupine can be found in Malaysia. It is the largest porcupine species in Malaysia than three another species which are *Thecurus crassispinis* or Thick-spined porcupine, *Atherurus macrourus* or Brushed-tailed and *Trichys fasciculata* or Long-tailed porcupine (Junaidi and Charles, 1998).

The habitats of rodents are highly diversified as expected from the large number of species. They occur in every habitat from the high Arctic Tundra, where they live and breed under snow to the hottest and driest region.

Porcupines are nocturnal animal which active during at night and spending their daytime to rest. They are herbivorous animal that feed mainly on vegetation, plantation crops and fallen fruits. This type of rodents are highly adaptable and will

colonize at variety habitats including burrow, cave and around fallen tree. They will choose their habitat based on their daily activities such as feeding, resting and sleeping or other activities (Nowak, 1999). Usually they will dig their burrow as their habitat from caves, rock crevices or dead trees. They often excavate their own burrow but also modify burrow of other animals such as aardvark (*Orycteropus afer*) (Skinner and Smithers, 1990).

Burrow of porcupines can be defined as a system with numerous number of nest chamber that will associate and interconnect to the tunnels with a number of entrances (Jackson, 2000). Their burrows consist of prominent mounds and may have one to several entrances with distinct paths leading to them (Skinner and Smithers, 1990). They will use their burrow for nesting and food storage that they seek during at night. Besides, burrow also will provide them with shelter to get protection from any predators that will threat them during their surface and social activity (Kucheruk, 1983). Normally, they build their burrow based on direction towards food sources in the way to ease them get their food source.

1.2 Objectives

This study was conducted to identify morphological characteristics surrounding burrow of porcupines besides to investigate any factors that influence the construction of burrow.

CHAPTER 2

LITERATURE REVIEW

2.1 Porcupines

Kingdon (1997) has reported that among the mammals in this world, rodents constitute the most diverse group. Nearly 40% of all mammal species are belonging to the order of Rodentia. According to Nowak (1999) rodents have more members than any other order of mammals. Porcupines in the world also can be classified under order of Rodentia which consists of 2 families with 7 genera and 21 species distributed over the world (Nowak, 1999). Table 1 shows the world distribution and origin of porcupines. The taxonomy classification of Malayan porcupines (*Hystrix brachyura*) can be classified as below;

Kingdom: Animalia

Phylum: Chordata

Subphylum: Vertebrata

Class: Mammalia

Order: Rodentia

Suborder: Hystricognatha

Family: Hystricidae

Species: *Hystrix brachyura*

(http://zipcodezoo.com/Animals/H/Hystrix_brachyura/)

Table 1: World origin of porcupines

Common name	Scientific name	Origin
African brush-tailed porcupine	*Atherurus africanus*	Africa
Asiatic brush-tailed porcupine	*Atherurus macrourus*	S.E. Asia
Thin-spined porcupine	*Chaetomys subspinosus*	South America
Prehensile-tailed porcupine	*Coendou prehensilis*	South America
Upper Amazonian porcupine	*Echinoprocta rufescens*	South America
North American porcupine	*Erethizon dorsathum*	North America
Southern crested porcupine	*Hystrix africaeaustralis*	Southern Africa
Malayan porcupine	*Hystrix brachyura*	S.E.Asia
Thick-spined porcupine	*Hystrix crassispinis*	S.E.Asia
Crested porcupine	*Hystrix cristata*	Northern Africa and Southern Europe
Indian Crested porcupine	*Hystrix indica*	India
Mexican porcupine	*Sphiggurus mexicanus*	Central America
Long-tailed porcupine	*Trichys fasciculata*	S.E.Asia

(Source of http://www.glenoakzoo.org/Porcupine%20standards.pdf)

The families of porcupines can be divided into two families which are Hystricidae or Old World Porcupine distributed over the regions of Asia, Europe and Africa and Erethizontidae or New World Porcupine distributed all over the North America to Northern Mexico (Nowak, 1999).

2.1.1 Hystricidae

Family of Hystricidae or Old World porcupine is a large representative of terrestrial rodent mammals. They include of three genera with eleven species distributing over the regions of Asia, Europe and Africa. This type of rodent is characterized by the imperfectly rooted cheek-teeth, imperfect clavicles or collar bones, cleft upper lip, rudimentary first front-toes, smooth soles, six teats and also many cranial characters. (Lekagul and Mc Neely 1977; Medway, 1978; Nowak, 1999).

2.1 Porcupines in Malaysia

According to Nowak (1999) we have four species of porcupines in this country that spread over Peninsular and Borneo region. They are Malayan porcupine or *Hystrix brachyura*, Brush-tailed porcupine or *Atherurus macrourus*, Long-tailed porcupine or *Thrichys fasciculata* and Thick-spined porcupine or *Thecurus crassispinis*.

2.2.1 Malayan porcupine

Its scientific name is *Hystrix brachyura* and its local name called "Landak Raya" in which this porcupine is the larger species that can be found in our country. The length of its head and body generally achieved in between 60 cm to 93cm with the tail length is 8 to 17cm long. Usually, it will appear in black and having longer spines with white and black band over the tip. While, the dark brown and black

coarse bristles have covered over the head, neck, shoulders, limb and also underside of its body. It feeds on roots, tuber and fallen fruits (Lekagul and Mc Neely, 1977; Nowak, 1999).

2.2.2 Brush-tailed porcupine

This type of porcupine has a scientific name called *Atherurus macrourus* and its local name is "Landak Nibung". It has 26.5 to 57 cm long of body length with length of its tail is between 10.2 to 26 cm long. This type of porcupine is different with Malayan porcupine where it has grayish to blackish brown in colour and the spine is softer around the head, leg and under body side (Nowak, 1999).

2.2.3 Long-tailed porcupine

This *Thrichys fasciculata* also known as "Landak Padi". It can be found along the border of the north in Peninsular of Malay (Medway, 1978). According to Nowak (1999) this porcupine can achieve the body length in between 35 to 48 cm long while its tail is about 17.5 to 23 cm long.

2.2.4 Thick-spined porcupine

Medway (1978) has pointed out that, this Borneo porcupine or *Thecurus crassispinis* is widely distributed in Borneo region. The spines appear in dark brown colour with white tip and base. This porcupine feeds mainly on fallen fruits and other vegetable materials.

2.3 Porcupine's behavior

Nowak (1999) has stated that this type of rodents are nocturnal animal which being active at night while spending the rest time on day time. They generally can be classified as ground dwelling animal because of using the burrow excavated by them to build their home. Usually, they will live by group in the range of four to eight members and sharing food sources, trails, excrement depositories, refuges and also territories.

2.4 Porcupine's feeding

Food availability is a fundamental factor that can influence the abundance and distribution of consumers (Boutin, 1990). For porcupines, they can be categorized as herbivorous animal which only feed on vegetation, crops and natural sources such as roots, bark, fruits and tubers that they find during at night (Medway, 1978; Lekagul and Mc Neely, 1988).

Malayan porcupines are mainly feed on barks, roots, tubers, rhizomes, bulbs, fallen fruits and also cultivated crops. It is different with Indian porcupines that the main diets for them are vegetables material including fruits, grains and roots. In a natural environment, food may be available to organisms in variety of ways. Another example is African porcupine which feeds on variety of subterranean and above-ground plant parts including geophytes, rootstocks and stem tissue of trees (Medway, 1978)

2.5 Porcupine's habitat

Many organisms include animals have broad global distribution. The habitats occupied by any species, their population densities and most aspects of their ecology can be widely differentiated between ranges of species (Hewson, 1991). Animals will choose their habitat based on many aspects related to their daily activities such as food sources, resting time, sleeping and their social activities also influence in choosing the habitat (Boutin, 1990).

Habitats of rodents are highly diversified as expected from the large number of species. Habitat selection is very important when they want to find the right home as they must considered many aspects such as easy to get food sources, safety from predators and far away from bad weather. Kinlaw (1999) has stated that semi-fossorial rodents use multiple dimensions of space, digging burrows for nests and refuges from predators and environmental stress while Daly *et al.,* (2000) has stated that they spent their time above ground to forage, defend ranges and seek potential mates.

Fruit availability is also a factor that influences rodents to make their burrow. Litvaitis *et al.*, (1994) have pointed out that habitat selection is a process where the animals choose from among alternative habitat resources to find the most suitable habitat for them. The main assumption of the theory of the habitat selection is maximizing the reproductive success of an individual and can be highly achieved by selection of those habitats that guarantee the greatest fitness output (Rosenzweig, 1981). According to Henriques and Alho (1991) rodents usually selecting their habitats that positively associated with herbaceous plant, tree and shrub cover of the

area. For porcupines, most of them are highly adaptable in variety of habitats and they can be found in all types of forests, plantations, rocky areas, deserts and mountains as well. Malayan porcupines can be found in all types of forest, plantation and rocky areas. They will excavate their burrow usually from caves, rock crevices, decaying logs and hollow trees (Nowak, 1999). It is quite different with brush-tailed porcupine (*Atherurus africanus*) as they do not dig their own burrows but prefer living along stream beds where cavities eroded out of rocks or tree roots are more common (Kingdon, 1974).

2.6 Burrow

According to Jackson (2000) burrow can be defined as a system with numerous nest chambers and associated that will interconnect the tunnels with a number of entrances. Nevo (1979) stated that burrowing animals usually show morphological and physiological adaptations for underground life with strongly convergent traits often evolving repeatedly in separate lineage. Vertically, underground resources usually show a peak value at some depth below the surface, so increasing of net energy yield can be achieved by situating a burrow as near as possible to the zone of maximum density of resources while minimizing the cross-sectional area of burrow (Andersen, 1982).

Underground mammals represent the most specialized burrowing animals due to their habit which spending most of their live in extensive burrow system. In underground life, most burrows constructed must satisfy the requirements for respiration, food, reproduction and defense against predators (Nevo, 1999; Hansell, 2005). For porcupines, they usually used caves, rock crevices and dead tree burrow

dig by them to build their burrow (Nowak, 1999). Burrows play an important role for rodents to provide a shelter that will help avoid from predators during daytime. It also can be used for nesting and food storage as they will build their burrow near the food sources (Kucheruk, 1983). There are many factors may influence the use of burrow by rodents including food availability, habitat heterogeneity, moisture regimes, population density and also predators (Ostfeld, 1990).

2.6.1 Type of burrow

Porcupines usually dig their burrow from caves, rock crevices and dead tree. Burrows generally can be found in hollow trees, stumps, logs, under large rocks and the root of overturn trees within caves or rocky ledges (Nowak, 1999). A type of burrow varies depending on animal itself. Some rodents like *Tatera indica* dig their burrows in glacifluvial sand or silt which may be a suitable material for their den construction (Yigit *et al*., 2001).

2.6.2 Morphological and construction of burrow

The construction of burrow in term of selecting its location, right direction, depth and respiratory system can be different based on species variability, topography of the area and seasons (Xu, 1994). In addition, burrow structure must contact the outside world to allow foraging, respiration and mating (Vander Wall, 1990). The construction of a burrow usually is a relatively simple with most of the entrance is a single tunnel but there are some with two to four individual burrow entrances. The depth of a burrow is different between others because it is affected by the energetic costs of digging (Vleck, 1981) whereby it is related to the size of animals, soil type, climate and season (Davies and Jarvis, 1986). According to Nevo (1999) burrowing

system of subterranean rodents is a three-dimensional network of tunnels, nests, food storage and sanitary area.

2.7 Burrow system

2.7.1 Nests of a burrow

Nests of burrow are usually used as sleeping area with only one nest containing two small bulbs. Nest of underground rodents are usually situated much deeper than foraging tunnels because the deeper position of a nest will prevent the burrow from collapse easily (Davies and Jarvis, 1986). Preferred nests are tended to be near the centre of the burrow system and located in hollowed-out chambers with a single entrance in the wall of the main tunnel (Herbst and Bennett, 2006).

2.7.2 Food storage of a burrow

Food stores usually located in close proximity of the nesting chambers in a blind ending site branch (Herbst and Bennett, 2006). Food stores represent small of energy refuges which then can be used during lack of food sources.

2.7.3 Seasonal influence on burrowing activity

Usually, animal activity will be influenced by both abiotic and biotic conditions. Climate and topography affect can be considered as abiotic factors while foods and mate availability are biotic factors. Thus, their burrowing activity is affected by both the physical characteristics of the soil and food availability. Rainfall will ease the way to dig their burrow as it will moisten the soil compared to the dry soils (Collis-George, 1959).

2.7.4 Microclimate of burrow

An expectation made by Sumbera *et al.*, (2004) that the design of burrow system including the size and depth of its components represent not only a compromise between food availability and preventing from collapse or predators but also a way of saving energy and maintaining the microclimate within their burrow. Microclimate includes temperature, humidity and atmospheric composition (concentration of respiratory gases) in burrows are influenced by corresponding characteristics prevailing above ground, vegetation cover, soil quality (mainly porosity), depth, length, diameter and shape of burrows as well as encompassing the whole architectural scope of burrow system. Burrows and soil temperatures are affected by fluctuation of ambient temperature in both, open and closed burrow systems (Kennerly, 1964). Activity and metabolic rate of burrow inhabitants may influence the concentration of respiratory gases. Oxygen concentration is expected to be lower whereas carbon dioxide concentration should be higher because porcupines usually digging their burrows by themselves. It is believed that working animals have higher metabolic rates and breathe into the small space between nose and soil (Arieli, 1979). Humidity is probably the most stable factor in burrows with the air of sealed burrows being almost saturated with water even if soil is dry or frozen (Kay and Whitford, 1978).

CHAPTER 3

METHODOLOGY

3.1 Study area

Porcupine burrows were studied during September 2008 to December 2008. The study sites were conducted at Bintulu and Miri areas in Sarawak in which the sites are characterized by a tropical climate with hot and humid. Bintulu site (Latitude 03°12.544' ; Longitude 113°06.034') can be classified as reserved forest of LAKU while study area at Miri (Latitude 04°06.125' ; Longitude 113°49.272') is characterized as secondary forest which functions as reservoirs for native species. After initial field survey, preferable locations of porcupine burrows from the areas of Bintulu-Miri were selected as study areas. Burrows locations were marked and positioned with Hand-held Garmin (GPS).

3.2 Burrow identification and positioning

Burrows were identified based on the information about porcupines burrow from the villagers and their activities as forest and agricultural pest in many countries. For recording the presence of porcupines and the activeness of the burrow, camera trap and animal trap were setting up near the burrow for three to five nights. The activeness of the burrow was indicated by the presence of activities within the burrow and its area besides by presence of characteristics of food biting, spines and specific footprint found near the burrow. Hand-held Garmin (GPS) was used to record the numbers of the entrances for each burrow and to determine specific location of the burrow.

3.3 External burrow classification

The morphological characteristics (types, slope angle, topography, hole dimension, exposure, and entrances) for each site of the identified burrow were recorded and described. Types of burrows were determined based on burrow's construction (soil, mixture of soil and rock or rock). Each site of the burrow were classified whether exposed to North, South, East or West and the degree of exposure will be recorded also.

For each entrance, the hole dimensions (height and width), internal and external slope angle (respectively, just inside and outside of the entrance whether it has positive value; inside the entrance or negative value; outside the entrance), entrances floor and roof (rock, earth, or mixed) were measured. The width and height of burrow entrances was measured directly. Entrance width was measured as the distance between the side walls of the entrance at its lowest point and height the greatest distance between the "floor" and "roof" of entrances. The shape of the burrow entrance was also described.

3.4 Laboratory analysis of microclimate parameters

To determine whether microclimate (temperature, soil pH and soil texture) are influenced by the presence of porcupine burrow, a series of laboratory experiments were conducted. Soil sample for each burrow area was taken by an auger (depth 0-10cm) and while taking the soil samples, temperature was measured in-situ by thermometer. Variation in sand surface temperature (at 1mm depth) along the depth of burrows was measured at specific time whereby burrows with different opening sizes were selected haphazardly along transect. Soil samples were dried by the air

and carried out for further analysis (texture and pH). Soil texture measurement was carried out ex-situ by mechanical laboratory analysis. After obtaining the percentage of clay, silt and sand, this result was referred to USDA Textural Triangle to get more precise result.

CHAPTER 4

RESULTS

4.1 Study area

There were 3 potentially new active burrows were recorded from 2 different sites which situated at Kg Terahad, Bekenu (Figure 1) and LAKU, Bintulu (Figure 2) areas. Of these, 2 were located in Bekenu; entrance 1 and 2 (Latitude 03°12.544' ; Longitude 113°06.034') and 1 located in LAKU (Latitude 04°06.125' ; Longitude 113°49.272'). Burrows were believed constructed by *Hystrix brachyura* species based on research identified by Nor Fahiah, (2008). Both of the areas are classified as secondary forest and are dominated by scattered shrub, fern, sedges and grasses.

4.2 Burrow habitat and distribution

Before measurement of each burrow was taken, every angel of environmental conditions was recorded to reveal any environmental factors that contribute to location of burrows. The factors observed include closest stream availability, terrain ruggedness and surrounding habitat. From the observation, it shows that both areas of Bekenu and LAKU, burrows were situated at about 10-15 meters near the stream. One of the three burrows was constructed on hilly area while the rest were in steeper areas which are under horizontal fallen tree and under tree. All the burrows were located in the area that surrounded by shrub tree, sedges, climber or species believed as their foods sources.

4.3 Burrow morphology

The morphology of burrow was characterized by colour, construction, shape and any environmental conditions surrounding burrows. The morphology of 3 burrows in this study were obviously different between each other because of their different construction which were rocky; Bekenu, entrance 2 (Figure 4), mixed of rocky and soil; Bekenu, entrance 1 (Figure 3) and under fallen tree or soil; LAKU (Figure 5). For all the burrows that have been founded, they have distinguishable color as a reflection from the structure that constructs them. For rocky burrow, the color range from grey to black depending on the colour of rock presented in figure 4 while brownish color is the color of soil burrows (Figure 3 and 5).

The entrance shape between each burrow was different depending on natural ecology of area that constructs them such as hilly, under root tree or under fallen tree. In Bekenu, entrance 1 area, the entrance of burrow at this area was semi circular in shape (Figure 3) and its shape was easily be determined due to the construction of the burrow was from soil. The burrow at this area is covered by climber tree and root tree in front of it (Figure 6). Getting closer to inside the burrow, there were two tunnels which situated at both left and right burrow. The size of the burrow entrance at this area is smaller than the other burrow entrance according to their natural ecology that constructs them. Both ceiling and floor of the burrow were constructed from rock and compact soil respectively.

It was differed with Bekenu, entrance 2, in which the shape of entrance was based on shape of rock and has unclear identified shape (Figure 8). There is a little bit sharp on the angel of entrance reflection from the sharp of rock tips. The availability of

tunnels inside this burrow could not be seen as it has a very furthest inward the burrow. Both of ceiling and floor for this burrow were fully constructed from rock.

Morphological characteristics of burrow in LAKU (Figure 5) were different as the construction of burrow was from fallen tree. In LAKU area, there was no specific shape of burrow itself as burrow was believe modified from fallen tree. The trunk of the fallen tree was naturally becomes as its ceiling while the burrow floor made from soil. The sign of digging can be seen in this burrow area due to the soil condition which is too finer and in granular form (Figure 7). This burrow was classified as recent burrow due to the finer soil texture.

4.4 Burrow parameters

Parameters for each porcupine burrow of *Hystrix brachyura* species were determined and recorded to recognize the data specifically in all locations conducted. The parameters of burrow taken include degree of activeness in burrow either active or not based on any presence of food biting, stretch-mark, footprint or information from villagers, types of burrow (rock, earth or mixed of rock and earth), hole dimension of burrow entrance encompassing height and width for the entrance, entrance direction in term of bearing and back bearing, burrow exposure (North, South, East and West), slope angel (negative), burrow temperature, texture and pH of burrow. For all the locations conducted, each burrow parameters were details described in Table 2.

4.4.1 Kampung Terahad, Bekenu

Study area at Kg Terahad, Bekenu can be classified as secondary forest in which some of the parts were thick bushes that consist of various species such as ferns, herbs (shrub trees) and many plants species. This study site is situated at about 147.5 m from main road. This area is like a crevice hilling area with slope angel 40° faced thick bushes area. About 10 m from burrow entrance, there is a stream flows which might be as water source for porcupines. Two burrow entrances were found at this area in which both of them situated exactly under thick bushes area. The distance between both of burrows was exactly 49.9 m. Both burrows here were believed an active burrow due to the information from villagers and soil covering the hole opening of the entrance (entrance 1). The entrances of burrow were described as entrance 1 and entrance 2.

4.4.1.1 Entrance 1

The height of entrance opening was 20 cm while the width is 40 cm. Slope angel of this entrance was in class C (40-59°) and the entrance exposed to the North. The temperature at the entrance opening was 27°. Soil analysis showed that pH of the entrance was 5.71 while soil texture was clay loam.

4.4.1.2 Entrance 2

The second burrow entrance had 120cm of entrance opening's height and 90 cm of width. Slope angel of this entrance was in class B (20-39°) and the entrance of burrow was exposed to the East. There was no evidence on burrow activeness like soil covering the hole opening detected as this burrow has higher in depth. Likewise, the entrance of this burrow was covered by rock. The temperature at the entrance

opening was 28°C. As this burrow was fully constructed by rocks, soil sample for this burrow was taken near the entrance opening. Soil analysis showed that pH of the entrance was 5.71 while soil texture was clay loam.

4.4.2 LAKU, Bintulu

There only one burrow found at this area. This study area was characterized as a secondary forest with burrow system mainly covered by the shrub trees. This area was considered as steeper area. This burrow was classified an active burrow due to digging sign of finer soil inside burrow (Figure 7). The height of burrow entrance was 95 cm while width was 200 cm. The slope angel for this burrow was in class B (20-39°) and exposed to the East. The soil texture was clay loam with pH and temperature was 4.99 and 26° respectively.

4.5 Burrow system

There are two burrow entrances (entrance 1 and 2) located in Bekenu area shows that there is a burrow system inside the burrow in which one of the burrow entrance may act as their entrance opening and another one may act as exit opening.

Table 2: Parameter of three active burrows in Bekenu and Laku areas.

Parameters	Entrance 1 (Bekenu)	Entrance 2 (Bekenu)	Entrance 3 (LAKU)
Burrow types	Mixed	Rock	Soil
Burrow active	Active	Active	Active
Hole dimension			
1. Height (cm)	20	120	95
2. Width (cm)	21	90	200
Entrance direction			
1. Bearing	220°	328°	328°
2. Back bearing	40°	148°	148°
Exposure aspect	N	E	E
Slope angel	- 40°	- 35°	- 20°
Soil texture	Clay loam	Clay loam	Clay loam
Soil pH	5.71	5.90	4.99
Temperature(°C)	27	28	26

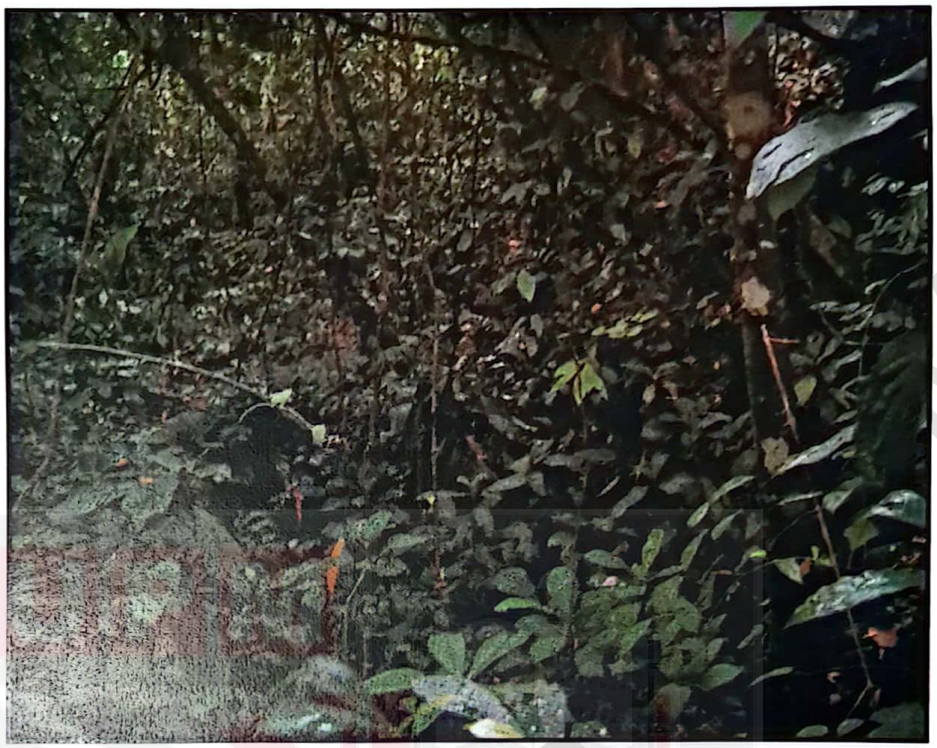

Figure 1: Study area at Bekenu, Miri

Figure 2: Study area at LAKU

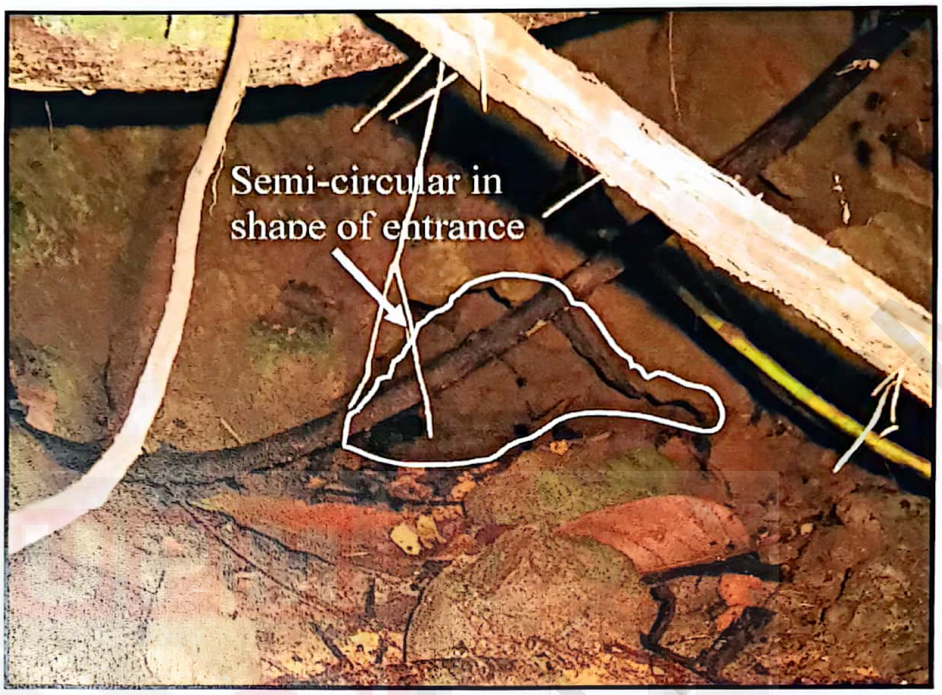

Figure 3: General morphology and characteristic of mixed entrance at entrance 1, Bekenu

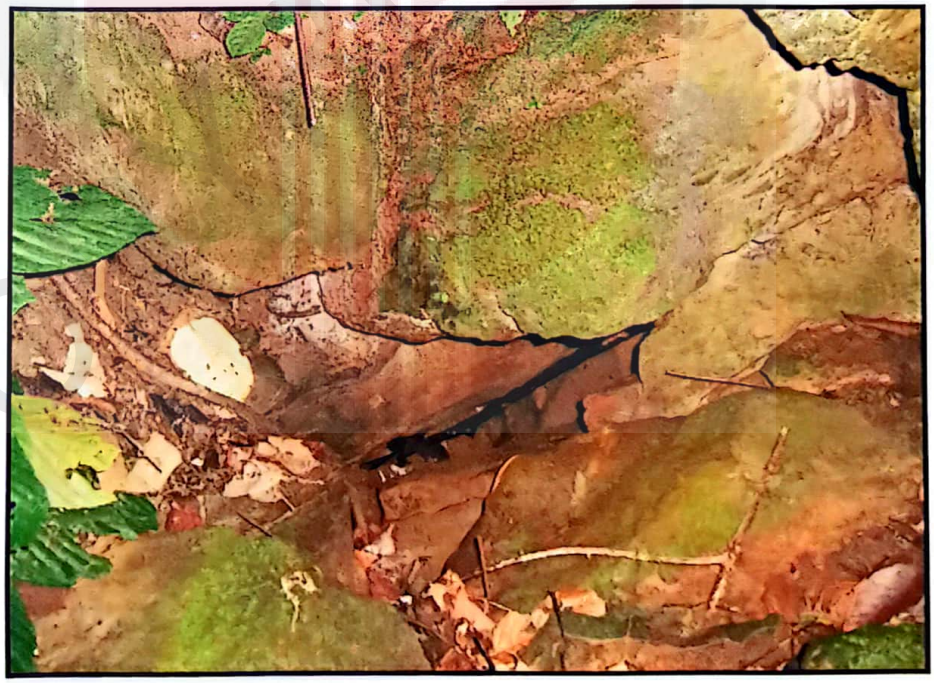

Figure 4: General morphology and characteristics of rocky entrance at entrance 2, Bekenu.

Figure 5: General morphology and characteristics of burrow entrance at LAKU

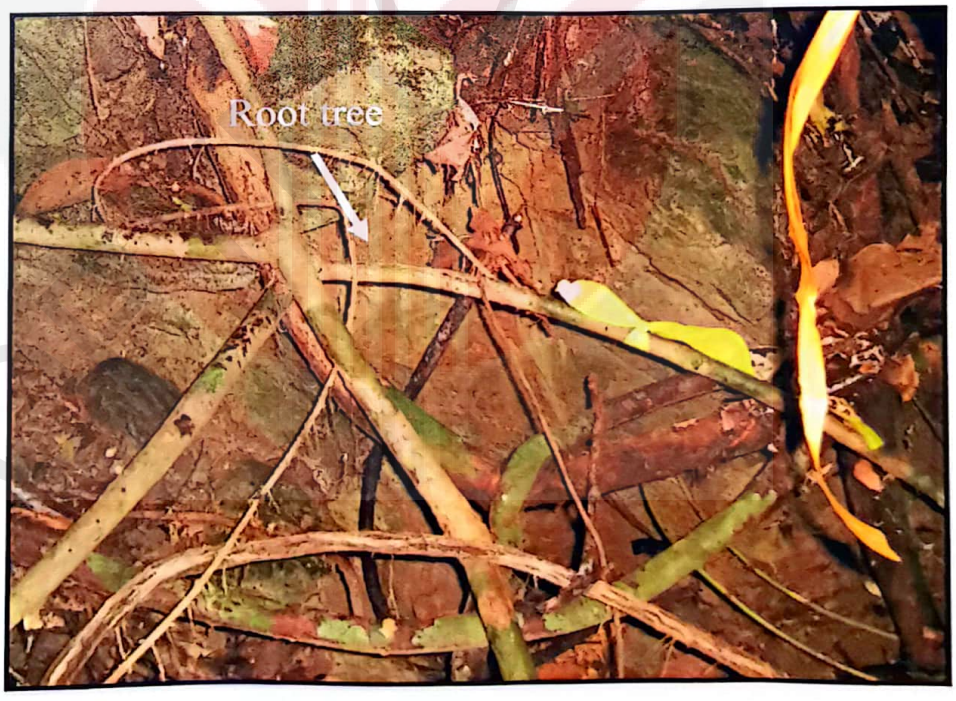

Figure 6: Entrance burrow was surrounded by root tree and climber at entrance 1, Bekenu

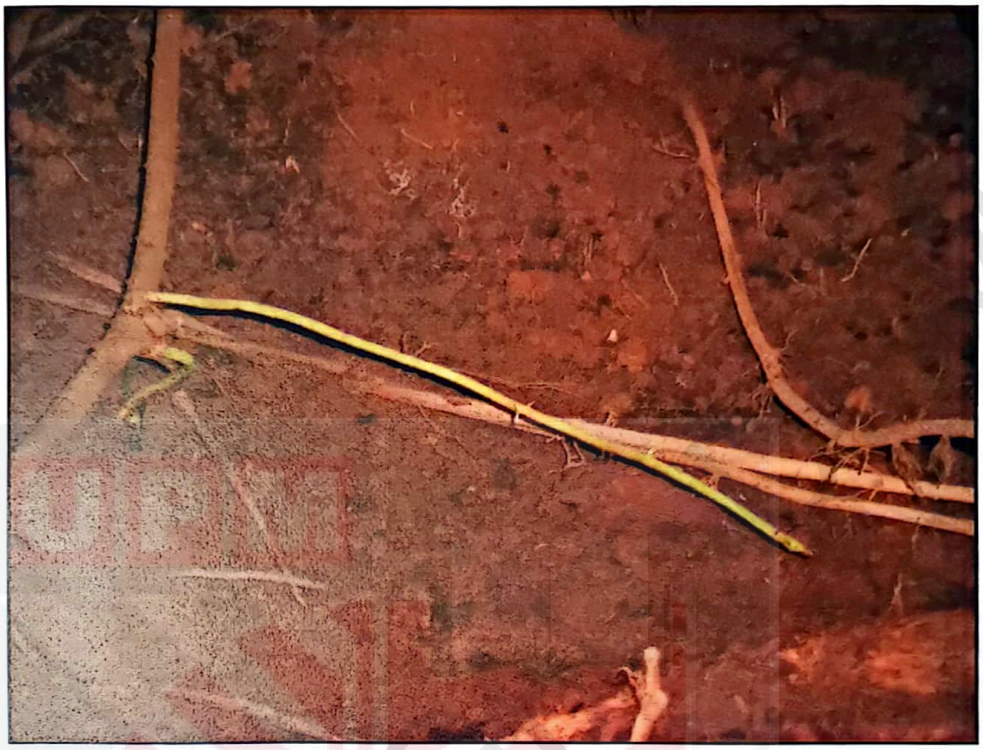

Figure 7: Digging sign of finer particle of soil in LAKU entrance.

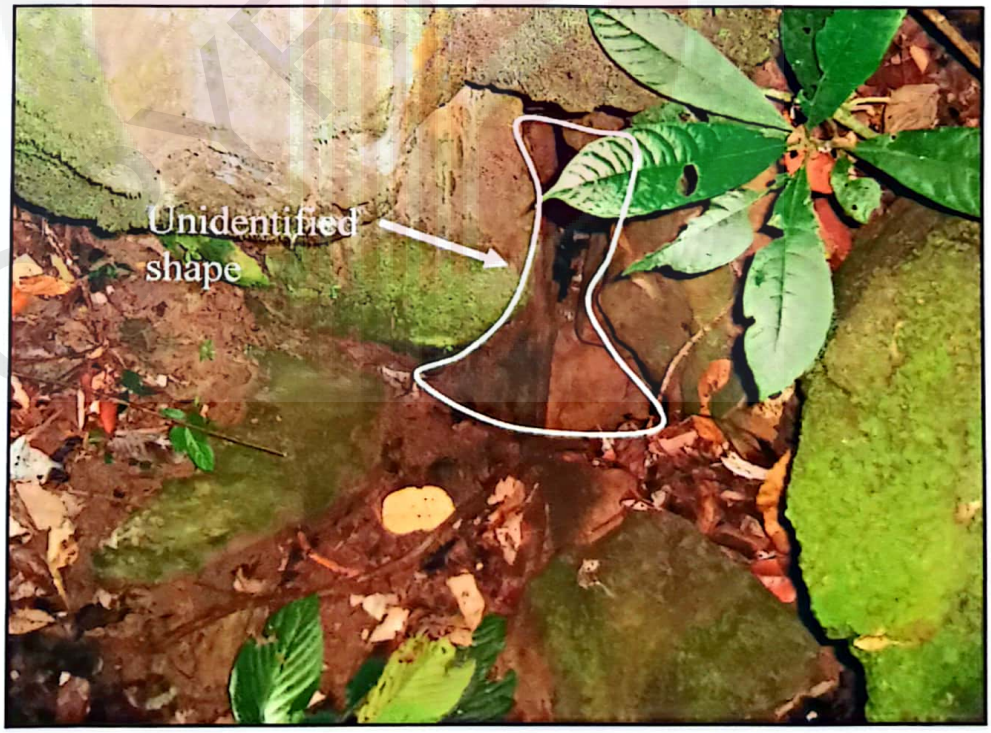

Figure 8: Unclear identified shape of burrow entrance 2, Bekenu.

CHAPTER 5

DISCUSSION

5.1 Burrow habitat

Habitat selection is very important when porcupines want to find the right home as they must considered many aspects such as easy to get food sources, safety from predators and away from bad weather. This study shows that porcupines are preferred to habitat covered by thick vegetation either in secondary forest or reserve forest in which the availability of their food sources is higher. The areas also dominated by scattered shrub, fern, sedges and grasses as vegetative cover is the most important as their food sources to get survive.

According to Henriques and Alho (1991) rodents usually selecting their habitats that positively associated with herbaceous plant, tree and shrub cover of the area. For porcupines, most of them are highly adaptable in variety of habitats and they can be found in all types of forests, plantations, rocky areas, deserts and mountains as well. According to Abramsky *et al.*, (2004) numerous rodents spend less time foraging in patches with less plant cover. Besides, they were closer to the water source. Burrows were purposely constructed closer to water in order to meet the demands of lactation and minimize visibility from predators (White and Cameron, 2008).

In this study, construction of burrow varies in different geographical condition whether on crevice hilling area or steeper slope area. Soil texture of clay loam is preferred for porcupines to dig their burrows as clay loam gives more compactness than sandy soil. Right soil selection needs for porcupines to build their home as soil

can influence vegetation types for that area, affect the ability of predators to excavate and modify burrows and hence, can influence burrows humidity (Kinlaw, 1999).

Moreover, in this study, it reveals that burrows located in rocky area and compact soil in which it will limit a predator's ability to dig them out. In addition, this area is situated quite far from human in order to minimize disturbance and protection from predators like people. Through this study, there were fewer habitats of porcupines found compared to previous research conducted by Nor Fahiah (2008) shows that the porcupine population is decreasing may due to the hunting activity done by human.

It is supported by Kingdon (1974) that man is certainly being as main predator as they are haunted for their meat. An example was recorded in Gabon that porcupines is a species of choice for villagers hunting at night as they have high popularity and market price (Emmons, 1983).

5.2 Burrow morphology

This study revealed that porcupine burrows were constructed in different morphology and characteristic (rocky, soil and mixed of rocky and soil). It is supported by Nowak (1999) that porcupines usually dig their burrow from caves, rock crevices and dead tree. Burrows generally can be found in hollow trees, stumps, logs, under large rocks and the root of overturn trees within caves or rocky ledges. The shape of rocky and mixed burrow was unable to determine because they reflects from the elements that construct them while clear determination of soil burrow presents in this study.

The classes of burrow whether old or recent burrow are based on soil texture presents on the floor burrow. Bragg *et al*., (2005) stated that the different between old and recent burrow can be seen from digging activity. Recent burrow usually happened after the rain while old burrow was prior to the last rain and highly eroded but still a clearly defined digging depending on the freshness and conglomeration extent of the soil excavated by the porcupine. They also stated that, if the soil was hard and coagulated, the burrow was classified as old while if the soil was fine and the particles relatively separated, it was classified as recent as the burrow at Laku area.

In fact, the size of each burrow (Table 2) is different due to the size of their bodies. According to White (2004) he stated that burrows need to be somewhat wider than the animal to accommodate their movement. It is supported also by Nevo (1999) stated that the diameter of any tunnel of burrow was very closely matches the body diameter of its excavator. Tortoise for example, might be expected to have a larger burrow cross section given that they are somewhat more globular than the average mammal (White, 2004).

5.3 Burrow parameters

This study revealed that diameter of porcupines burrow can reach only hundred centimeters (Table 3), based on local body size in which the head and body length of common porcupine is about 60 to 93 cm which identified by Nowak, (1999). It is supported also by a previous research conducted by Nor Fahiah (2008) that burrow diameter of local porcupine is only between 10 – 30 cm (Table 3).

These records were difference compared to burrows in abroad in which the burrows can reach until hundreds in meter and some can vary to only few centimeters. According to Zuri and Terkel (1996) they have stated that modern rodent tunnels can reach length about 30-68 m, some even up to 400 m (Davies and Jarvis, 1986) or 600 m (Begall and Gallardo, 2000). Research by Gobetz (2006) recorded that burrow diameter measured only 13.6 cm from ceiling to floor and 16.7 cm in cross-section.

Burrow diameter is closely related to their body size (Damuth, 1981) and increasing in body size contributed to increasing of burrow diameter (Vleck, 1981). Burrow size of each animals may also purposely constructed based on their needs such as protect from any threat and bad climate. This is supported by White and Cameron (2008) that wider burrow entrances may be preferred because they enable animals to defend themselves and their offspring more effectively from inside the entrance while shorter entrance may prevent access by predators which are generally bigger than animals themselves. In this research also shows that the depth of a burrow is different between others because it is affected by the energetic costs of digging (Vleck, 1981) whereby it is related to the size of animals, soil type, climate and season (Davies and Jarvis, 1986).

In this study exhibits that the range temperature of each burrow recorded that temperature inside the burrow system is quite similar to the ambient temperature (Table 3). It is supported by Kennerly (1964) that burrows and soil temperatures are affected by fluctuation of ambient temperature in both, open and closed burrow systems. In addition, extremely temperature should not exceed the porcupines' native habitat. In addition, all local species of porcupines are from tropical or sub-tropical

climates. According to Bartos (2004) the tropical species should be kept at temperatures ranging from 21-29 °C. It is also noted that, in appropriate climates, these animals can be housed outdoors, but indoor housing allows a better control over the temperature range. Local porcupines are different to Crested porcupines in which Crested porcupines are highly adaptable to a wide range of temperatures provided that they have been properly acclimated (Bartos, 2004). It was slightly different compared to the range of temperature recorded by Johnson (1971) that microclimates within burrow system are cool and stable with an annual temperature ranging from 2 to 14°C due to burrow constructed in area of temperate region.

In contrast, this study exhibited that burrow entrance is more exposed to the East compared to previous study conducted by Nor Fahiah (2008) in which, burrow entrance is more exposed to the South as synchronize with sunset related to its behaviour as a nocturnal animal that active at night for searching their food.

Table 3: Comparison of the parameters between present study with previous study (Nor Fahiah, 2008).

Parameters	Present study					Nor Fahiah, 2008		
Location / Entrance	Entrance 1 (Bekenu)	Entrance 2 (Bekenu)	Entrance 3 (LAKU)	Simpang Bakun	Sepaduk	Kg Lumut	Kg Pejuang	Kg Pahlawan Sibuti
Types of burrow	Mixed	Rock	Soil	Mixed and soil	Soil	Mixed and soil	Mixed and rock	Mixed and rock
Hole dimension								
• Height (cm)	20.0	120.0	95.0	46.4	18.6	53.0	64.5	51.0
• Width (cm)	21.0	90.0	200.0	53.4	32.9	49.0	48.0	95.5
Slope angel (°)	- 40	- 35	- 20	- 27	- 19	- 28	- 20	- 18
Exposure aspect	N	E	E	E / W/ S	N/ W/ E/ S	E / W	N	N/ W
Soil texture	Clay loam	Clay loam	Clay loam	Sandy loam	Clay loam	Loam	Sandy loam	NA
Soil pH	5.71	5.90	4.99	4.00	4.51	4.91	5.97	NA
Temperature (°C)	27	28	26	28	26	26	27	NA

Note: The parameters (height, width, slope angel, exposure, soil pH and temperature) of five locations conducted by Nor Fahiah, (2008) were taken in term of average.
NA: Not applicable

CHAPTER 6

CONCLUSION

The morphology of each burrow entrance is quite difference depends on geographical factor of environment surrounding burrow locations even though they came from same family of Hystricidae. The difference of burrow morphology is explained by different in burrow construction which soil, mixed and rocky. The parameters recorded include hole dimension (height and width), slope angel, temperature, soil pH and soil types which revealed that burrow constructed from rocky has bigger size as well as entrance width and height.

Burrows were constructed mainly at thick vegetation area and near to the water source believed as their diets. They also preferred to dig their burrow at steeper area compared to slope area since gently slope provides facilitation to excavating activity. Floor constructions are mainly from compact soil as it can provide more stability to their burrows while roof constructions are based on the matters that construct them.

Burrow also will provide them with shelter to get protection from any predators that will threat them during their surface and social activity and normally, they build their burrow based on direction towards food sources in the way to ease them get their food source. This study of burrow system should be continuing with other burrowing animals as they provide an interesting architecture to be explored.

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PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "**A study on burrowing system of common porcupines (*Hystrix brachyura*)**" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Science, Universiti Putra Malaysia Bintulu Sarawak Campus and published in the form approved by the faculty.

Nurul Nazira Azaman

Date: 06 / 05 / 09