NUTRIENTS CONTENT OF SOILS IN MUD WALLOW OF BEARDED PIG (*Sus barbatus*) IN DANUM VALLEY, LAHAD DATU, SABAH

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DECLARATION

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

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KANDUNGAN NUTRIEN DI DALAM KUBANG BABI HUTAN (*SUS BARBARUS*) DI LEMBAH DANUM, SABAH

ABSTRAK

Kajian ini adalah mengenai kandungan nutrien dalam kubang babi hutan (*sus barbatus*). Tujuan kajian ini adalah untuk menentukan kandungan nutrien dalam kubang babi hutan dan potensi tanah tersebut sebagai sumber nutrisi semulajadi untuk babi hutan. Sejumlah 64 sampel tanah telah diambil daripada 32 kubang yang berada di hutan primer dan hutan sekunder di sekitar pusat kajian luar Lembah Danum, 5° 0' N, 117° 30' E, Lahad Datu, Sabah. Sampel-sampel tanah tersebut telah diambil pada bulan Jun hingga Julai 2006 daripada bahagian dinding dan bahagian lantai kubang dengan mengunakan alat pensempelan tanah yang diperbuat daripada keluli tahan karat. Kandungan enam elemen nutrien iaitu Natrium (Na), Magnesium (Mg), Kalium (K), Ferum (Fe), Kuprum (Cu), dan Zink (Zn) telah dianalisa dengan mengunakan Spektrometer Serapan Atomik bernyala (FAAS). Nilai pH juga diukur dengan mengunakan meter pH. Antara elemen-elemen yang telah dikaji, Fe didapati mempunyai kandungan yang tertinggi iaitu 29316.880 ± 10252.315 μg/g (min ± sisihan piawai), diikuti oleh K (1659.689 ± 959.663 μg/g), Mg (803.108 ± 199.483 μg/g), Na (199.828 ± 74.300 μg/g), Zn (38.067 ± 19.425 μg/g), dan Cu (25.091 ± 17.979 μg/g). Manakala, nilai min pH untuk kubang adalah 5.012 ± 0.382 (min ± sisihan piawai). Tiada perbezaan yang signifikan ($P > 0.05$) antara kandungan nutrien di bahagian dinding and lantai kubang. Kandungan K dan nilai pH didapati lebih tinggi dengan signifikan ($P < 0.05$) di hutan sekunder berbanding dengan hutan primer. Perbandingan tanah kubang kajian ini dengan kajian tanah kubang terdahulu juga didapati mempunyai kandungan Mg, Fe, Cu, dan Zn yang lebih tinggi daripada tanah kawalan (tanah di luar kubang). Kandungan nutrien yang lebih tinggi di dalam tanah kubang menunjukkan ia mempunyai potensi sebagai sumber nutrisi semulajadi kepada babi hutan dan binatang liar yang lain.

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ABSTRACT

This thesis describes the nutrients content of soils in the mud wallows of bearded pig (*Sus barbatus)*. The purposes are to determine the nutrients content in the mud wallows and the potential of wallows as a source of nutrients for bearded pigs. A total of 64 soil samples were collected from 32 wallows found in the primary and logged forest in and around the Danum Valley Field Center, within the Ulu Segama Forest Reserve 5° 0' N, 117° 30' E, Lahad Datu, Sabah. The soil samples were collected in June – July 2006 from the walls and the bottoms of each wallow using the stainless steel soil auger. Soil samples were analyzed for six elements of nutrients namely Sodium (Na), Magnesium (Mg), Potassium (K), Iron (Fe), Copper (Cu), and Zinc (Zn) using Flame Atomic Absorption Spectrophotometer (FAAS). Soil pH was measured using pH meter. Results showed that among the nutrients analyzed, Fe was the most abundant nutrient in the soil of mud wallows with a mean concentration of 29316.880 ± 10252.315 μg/g (mean ± standard deviation), followed by K (1659.689 ± 959.663 μg/g), Mg (803.108 ± 199.483 μg/g), Na (199.828 ± 74.300 μg/g), Zn (38.067 ± 19.425 μg/g), and Cu (25.091 ± 17.979 μg/g). The mean pH of the soils was 5.012 ± 0.382 (mean ± standard deviation). There were no significant differences ($P > 0.05$) between nutrients content in the wall and bottom of the mud wallows. The comparisons between wallows from logged and primary forest showed that only K and soil pH were significantly higher ($P < 0.05$) in logged forest. Comparisons between control soil (i.e., soils from outside wallows) and soils from the wallows showed that the concentrations of Mg, Fe, Cu, and Zn were higher in wallows' soils. The higher concentrations of nutrients in mud wallows suggest that mud wallows have the potential as the natural source for geophagy (soil eating behavior) for bearded pigs, as well as the other animals.

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LIST OF SYMBOLS

ml	Mililitter
µm	Micrometer
°C	Degree Celsius
kg	Kilogram
°	Degree
′	Minutes
cm	Centimeter
%	Percent
µg	Microgram
±	Plus – minus
g	gram
ppm	Parts per million
mg	milligram
sp.	Species

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Sus barbatus or commonly known as bearded pigs come from family of *Suidea*, is one of the most conspicuous terrestrial mammals inhabiting the tropical lowland rainforest of Sabah. They are very large, long-legged pigs with a long and flowing cheek-beard (Groves, 2001). Adults are 120-152 cm long, usually weigh 57-83 kg, but can reach 200 kg during fruit seasons (Caldecott *et al.*, 1993; Wong *et al.*, 2005). Bearded pigs is distributed in South-east Asia, extending from the large landmass of Peninsular Malaysia, Sumatra and Borneo to Palawan and neighboring islands in west Philippines (Caldecott, 1993). The bearded pigs are found in the areas that dominated by tropical evergreen rainforest and they utilize wide variety of habitat types, ranging from beaches to upper montane cloud forest (Caldecott, 1993).

Bearded pigs are widespread omnivores known to migrate in large herds throughout Borneo (Puri and Meijaard, 2001). They consume roots, fungi, invertebrates in soil and rotting wood, small vertebrates, turtle eggs, carrion, and item

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from at least 50 genera and 29 families of plants (Caldecott, 1993). Bearded pigs migrate during night time at the wild and switch activity during daytime including mud wallowing (Medway, 1969). Bearded pigs are the major seed predator and play a key role in rainforest ecosystem (Curran & Leighton, 2000). The pigs populations are adapted to exploit the regional scale fruiting regimes of Borneo's forest and their populations number will increase explosively during mass fruiting and migrate across large areas to feed on dipterocarp seed, but interestingly, their population will decline dramatically after the end of the mass fruiting season (Caldecott, 1988).

Bennett *et al.* (1995) and Caldecott (1988) remarked that bearded pigs are culturally and economically important to native community in Borneo. Consequently, bearded pigs are being hunted frequently for meat. Besides that, the excessive logging and agricultural activities in the forest had destructed the natural habitat of bearded pigs and caused their population to decline (Caldecott *et al.*, 1993). Unfortunately, due to the complexity in their population dynamics, Hancock *et al.* (2005) reported that there are very few studies focusing on bearded pig population ecology, and no estimates of abundance have been published. As a result, fundamental aspects of the bearded pigs' ecology remain poorly understood, including their spatial distribution, aspects of their habitat and food sources, mechanisms by which bearded pigs aggregate and migrate between different areas, and the driving influences on bearded pigs' migration.

Wild pigs included bearded pigs likes to wallow in the mud to achieve heat reduction and relief from insects and parasites. Wild boar wallow are found in moist sites, i.e. muddy places that may contain stagnant water nearly the whole year round,

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such as edges of flooded areas, dites or muddy depressions in trails (Heinken *et al.*, 2006). Mud wallowing is also observed on Sumatran rhino and elephants but probably varies in their behavioral responses. However, they are few studies particularly on the wallowing behavior of bearded pigs. Though the personal communication with Wong (2006, personal communication), the bearded pigs created numerous mud wallow around the logged and unlogged forest of Danum Valley Conservation Area (DVCA) and bearded pigs have been observed eating soil from mud wallow while wallowing, but the actual functions of mud wallows apart from providing relief from overheating during daylight hour is yet to be studied. One of the potential reasons is the bearded pigs use the soil ingested as a mineral source particularly for the major trace element.

Geophagy or soil ingestion by vertebrates has attracted the attention of many researchers in recent years. This interesting phenomenon is widespread in many kinds of terrestrial vertebrates such as elephants, ungulates, carnivores, primates, birds, humans etc (Mahaney & Krishnamani, 2003). The reasons why so many vertebrates consume soil are remind unknown. However, Krishnamani and Mahaney (2000) had suggested that geophagy always has some medicinal value and is presumed to be important to health and nutrition. They also come out with six hypotheses with are: (1) soils adsorb toxins such as phenolics and secondary metabolites; (2) soil ingestion has an antacid action and adjusts the gut pH; (3) soil act as an antidiarrhoea agent; (4) soils counteract the effects of endoparasites; (5) soils supplement nutrient-poor diets and (6) soils provide extra iron at high altitudes. In addition to these hypotheses, geophagy is also believed may satiate olfactory senses, serve as a famine food and may have no function at all.

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The geophagic soil contains high quantities of clay and fine silt with little sand; it is often clay (>40% clay) or silty-clay to clay loam (27%-40% clay) that indicates a high degree of weathering and great age (Mahaney & Krishnamani, 2003). Clay material are primarily crystalline hydrous aluminosilicates, the component silicon oxide tetrahedral and aluminum hydroxide octahedral sheets, which are associations either in a 2:1 ratio (Si-Al-Si) or a 1:1 ratio (Si-Al). In these associations, the unit layer, are held together tenaciously by oxygen-hydroxyl bonds or only weakly associated through van der Waals forces. However, intermediate and amorphous forms also exist. Krishnamani & Mahaney (2000) found that geophagic soil at tropical-subtropical are well leached that 2:1 (Si-Al-Si) clay minerals are mostly eradicate or exist in a small concentrations, making it difficult to form soil structures that rely on adherence of sticky or expendable clay. Soil eaten by most of the birds, primates, apes and humans is found to be relatively high level of iron content and low level of nitrogen and carbon content, and the soil eaten is serves as food supplement and detoxify the poisonous food ingested (John & Duquette, 1991; Engberg, 1996; Muller *et al.*, 1997; Abrahams & Parsons, 1997; Mahaney *et al.*, 1997; Krishnamani & Mahaney, 2000; Aufreiter *et al.*, 2001; Wakibara *et al.*, 2001; Mahaney *et al.*, 2005). However, geophagy of bearded pigs particularly from mud wallow is yet to be known.

1.2 JUSTIFICATION

The purpose of this research is to study the nutrient contain in the soil of mud wallows. By comparing the nutrients contents in wallows to the nutrient required for animal to grow, it can be explained whether the wallow serve as a geophagic source for bearded

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pigs. This information is important in order to fully understand the feeding habit and ecology of bearded pigs.

1.3 OBJECTIVES

The scopes of this study are as follows:

a. To determine the nutrients (K, Mg, Na, Zn, Fe, Cu) contain in the soil of mud wallow of bearded pigs.

b. To compare the nutrient content in the soils of mud wallows from primary and logged forest.

c. To investigate whether the mud wallow is a potential geophagic source for bearded pigs.

1.4 HYPOTHESES

This study hypothesizes that the soil in mud wallow contains significantly higher levels of essential nutrients and therefore may serve as a source of nutrition supplement for bearded pigs.

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CHAPTER 2

LITERATURE REVIEW

2.1 BEARDED PIG

The study about bearded pig (*Sus barbatus*) is limited. Most of the studies are related to their responses to ecological factor. The lack of information on bearded pigs also have been reported by Hancock *et al*. (2005), who stated that there is very few studies focus on bearded pig's population ecology, and no estimate of abundance have been published, added that the fundamental aspects of bearded pigs' ecology are poorly understood.

The most recent study about bearded pigs was conducted by Wong *et al.* (2005), who look into the impact of fruit production cycles on Malayan sun bear and bearded pigs in lowland tropical rainforest of Sabah. They found that bearded pigs were in emaciation and starvation during the famine period in tropical rainforest of Borneo, and this somehow explained why population of bearded pigs fluctuated in responses to various fruiting scenarios in Bornean forest. The detailed study toward bearded pigs was contributed by Caldecott (1988, 1991, 1993), who provide an

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important qualitative understanding of bearded pigs' ecology including their preferred habitat, reproductive characteristics, diets, social grouping and migration behavior. Besides that, Pfeffer (1959) also noted the migratory behavior in bearded pigs population especially when seeking for food. There were other studies of bearded pigs in Borneo include the investigation of bearded pigs in dipterocarp seeds predation, and seed escape during mast fruiting events due to regional satiation of bearded pig population, which conducted by Curran & Leighton (2000), who found that bearded pigs migrated over considerable distances in Sarawak and east Kalimantan to follow fruiting of illipe nuts (*Shorea* sp.). The status of bearded pig in Sabah, however, is yet to be studied.

2.2 MUD WALLOW

The study in mud wallow is extremely few although mud wallows are the distinctive features of bearded pigs' activity. The only related study regarding mud wallow was conducted by Mokhtar *et al.* (1990) who investigated the elemental composition of rhinoceros wallow soil in Danum Valley, East Malaysia. However, he found that the wallow soil is not the potential source of licks for rhinoceros (*Dicerorhinus sumatrensis*). The mud wallow that created by bearded pigs were forgotten by most of the researchers although the mud wallows one of the distinctive feature for the present of bearded pigs. The study of nutrient contains in the wallow soil of bearded pig can more or less contributes to the understanding of bearded pigs' behavior and feeding habit.

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2.2.1 Types of mud wallow

There are two types of mud wallows found throughout primary and logged forest of Danum Valley. The first type of wallow is known as flat wallow and the second type found are wallows with wall. Flat wallows (Photo 2.1) are wallows that contain a small depression of water on the forest floor while wallows with wall are usually deep inside and have a cave-like shape (Photo 2.2). The active wallows are frequently visited by bearded pigs and deer. This can be showed by the high density of bearded pigs' and deer's foot prints in the mud wallows.

Photo 2.1 A flat wallow on the forest floor with a small depression of water.

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Photo 2.2 A mud wallows with the wall.

2.3 ANIMAL NUTRITION

In 1950, 13 mineral elements were classified as essential; these comprised the major elements (calcium, phosphorus, potassium, sodium, chlorine, sulphur, magnesium) and the micro or trace elements (iron, iodine, copper, manganese, zinc, and cobalt). By 1970, molybdenum, selenium, chromium and fluorine had been added to the list and subsequently arsenic, boron, lead, lithium, nickel, silicon, tin, and vanadium have been included (Scott *et al*., 1972).

The classification of the essential minerals into major elements and trace elements depends upon their concentration in the animal or amounts required in the

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diet. Normally trace elements are present in animal body in the concentration not greater than 50 mg/kg and are required at less than 100 mg/kg diet (Table 2.1).

Table 2.1 Nutritionally important essential mineral elements and their approximate concentration in animals

Major elements	g/kg	Trace elements	mg/kg
Calcium (Ca)	15	Iron (Fe)	20 – 80
Phosphorus (P)	10	Zinc (Zn)	10 – 50
Potassium (K)	2	Copper (Cu)	1 – 5
Sodium (Na)	1.6	Molybdenum	1 – 4
Chlorine (Cl)	1.1	Selenium (Se)	1 – 2
Sulphur (S)	1.5	Iodine (I)	0.3 – 0.6
Magnesium (Mg)	0.4	Manganese (Mn)	0.2 – 0.5
		Cobalt (Co)	0.02 – 0.1

Source: McDonald *et al.*(1996).

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2.4 SOIL EATING OR GEOPHAGY

Geophagy is the consumption of earthy material such as soil, clay, and related mineral substances. Geophagy is observed in many terrestrial animals throughout the world, including human. Primates are widely studied for their geophagic behavior. The most popular information about geophagy among the primates was contributed by Krishnamani and Mahaney (2000), who review on the geophagy activities among the primates that have been reported. After the review on the geophagy observation in primates by various scientist worldwide (detail in Krishnamani and Mahaney, 2000), they come out with six hypotheses regarding the function of soil ingested to the primates, which included: (1) soils adsorb toxins such as phenolics and secondary

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