Diversity of mammalian species at natural licks in rain forest of Deramakot and their conservation

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Abstract Natural licks are an important place for mammals to obtain mineral elements that are deficient in their diets. Although the tropical rain forests of Borneo are known for high mammalian diversity, little is known about the relationship between natural licks and mammals. To understand the use of natural licks by mammals and the role of natural licks to maintain the mammalian diversity and populations in Borneo, we conducted a field study in Deramakot Forest Reserve, Sabah. Twenty-nine species of mammals out of the 37 species known in the forests of Deramakot irrespective of food type were recorded on the natural licks. The mammals came to the natural licks to drink water rather than to eat soil. Analysis of the water from the natural licks showed that the concentrations of calcium, magnesium, potassium, and sodium as well as pH were significantly higher than those of the controls (stream and soil water). Foliar analysis of animal diets showed that potassium was significantly higher than sodium in concentration. This study indicated that the mammals might come for the ingestion of minerals, especially sodium, to maintain internal sodium/potassium balance. The natural licks are hot spots of mammalian diversity in Borneo because a cascade of food web (herbivores to carnivores) is formed.

Abstract for policy-makers

Deramakot Forest Reserve has been employing reduced-impact logging techniques, and was certified as a well-managed forest by the Forest Stewardship Council in 1997. Although the forest vegetation and soils have been studied and the techniques to reduce their impacts were incorporated in the reduced-impact logging guidelines, the wildlife has received little attention in forest management. To better achieve the wildlife conservation and the management of forests in Deramakot Forest Reserve, we focused on natural licks, which were known as mammals' gathering place. Little had been known about the relation of natural licks and mammals in Borneo until we started our analysis. Twenty-nine species of mammals out of the 37 species found in the forests of entire Deramakot Forest Reserve with all food types combined were recorded on the natural licks. This study indicated that the mammals might come primarily for the ingestion of sodium to maintain internal sodium/potassium balance. Therefore, natural licks form hot spots of mammalian diversity in Deramakot and probably in other Forest Management Units in Sabah. We propose that the natural licks should be strictly protected for wildlife.

Keywords Borneo, mammalian diversity, natural licks, tropical rain forest.

Introduction

Bornean tropical rain forests are known to be a region of high mammalian diversity. It is important to study the habitat use of mammals in Borneo to understand the tropical forest ecosystem

and its conservation. We focused on natural licks, which are thought to be mineral-rich places.

Essential mineral elements in an ecosystem are distributed among several compartments such as soils and above-ground vegetation having distinctive roles and turnover rates. Availability of these mineral nutrients is the product of a complex array of interacting processes including microclimate, chemical properties of organic matter, chemical status of the soil, and the activity of animals. Although most essential elements (nitrogen, phosphate, potassium, calcium, and magnesium) are common in plants and animals, sodium is essential for animals only. Therefore, animals need to rely on natural licks or other mineral sources to overcome the deficiencies in essential elements, including sodium. Many studies on the relation of the chemical properties of natural licks and their use by mammals have been conducted (Blair-West *et al.* 1968; Weir 1972; Botkin *et al.* 1973; Emmons and Stark 1979; Tankersley and Gasaway 1983; Risenhoover and Peterson 1986; McNaughton 1988; Knight *et al.* 1988; Moe 1993; Izawa 1993).

In Borneo, it was reported that the distribution of large herbivores, such as Asian elephants (*Elephas maximus*) and tembadau/banteng (*Bos javanicus*), corresponded with that of natural licks (Payne and Andau 1991). However, little is known about the chemical properties of natural licks and the relationship between natural licks and mammals.

The aim of this study was to understand the use of natural licks by mammals and the significant roles of natural licks in Borneo. We conducted a field study for twelve months between May 2003 and March 2005 in Deramakot Forest Reserve, Sabah, Malaysia.

Materials and Methods

Study area

Deramakot Forest Reserve (05°15'-28'N, 117°20'-38'E) is 55,083 ha and is situated at the upper Kinabatangan River in size, centrally located in Sabah, Malaysian Borneo. The climate is humid equatorial with a mean annual temperature of about 27 °C. Being greatly influenced by the Northeast Monsoon (November-February) and the Southwest Monsoon (May-August), the average annual precipitation is about 3500 mm (Kleine and Heuveldop 1993, Huth and Ditzer 2004). The forest of Deramakot Forest Reserve consists of lowland mixed dipterocarp forests dominated by the family Dipterocarpaceae (*Dipterocarpus* spp., *Parashorea* spp., and *Shorea* spp.).

Under the management of the Forestry Department of Sabah, harvesting operations within Deramakot Forest Reserve has been following reduced-impact logging guidelines since 1995 and the reserve was certified as a well-managed forest by the Forest Stewardship Council in 1997. Although the forest vegetation and soils have been studied and incorporated in the reduced-impact logging guidelines, the wildlife has received less attention in forest management.

Mammal survey at natural licks and other places in Deramakot Forest Reserve

We surveyed the mammalian species in Deramakot Forest Reserve, targeting the medium and large, non-volant mammalian species using 1) a 24-hour camera-trap with 15 camera stations, 2) a route census: diurnal direct-observation and identification of prints (footprints and claw marks), and 3) interviews with knowledgeable forestry staff of Deramakot District. Target species were 47 species that have been recorded in lowland forest, Sabah (Yasuma and Andau 2000). Chiroptera (bats), Dermoptera (colugo), Small Insectivora (shrews), Scandentia (treeshrews), and Small Rodentia (squirrels and rats) were excluded from this study.

Camera traps with an infrared triggering mechanism (sensor camera Field note II, Marif, Yamaguchi, Japan) were set up at 15 camera stations, which included 10 animal trails near watering places or on a ridge and five natural licks. Some camera traps were baited with fallen fruits. After completion of the field study, we counted the numbers of individuals photographed. When there were many photographs of the same individual within 30 minutes, only one was counted. When several individuals were photographed in one frame, only one was counted. For the route

census, we established 6 routes with a total of 64 km: a path to get to camera-trapping sites; a 3 km course around the base camp; a 15 km path west of the base camp; a 10 km path north of the base camp; a 30 km path and two 3 km paths east of the base camp. We conducted a route census on foot, by motorbike, or from four-wheel vehicles during the day and night. For interviews, we relied on very knowledgeable Forestry Department employees.

Chemical properties of natural licks and animals foods

The study identified five natural licks within Deramakot Forest Reserve: NL-1 (05°22'N, 117°29'E), NL-2 (05°20'N, 117°30'E), NL-3 (05°21'N, 117°31'E), NL-4 and NL-5 (05°19'N, 117°34'E) (Figure 1); the label number indicating the distance of the natural licks, in kilometers, from the Forestry Department Base Camp. To study the chemical properties of the natural licks, we analyzed the mineral contents of the water from the natural licks. A total of 59 water samples were collected from the natural licks: 13 from NL-1, 13 from NL-2, 11 from NL-3, 13 from NL-4, and 9 from NL-5 at different times and seasons. For comparison, we also collected 18 samples of water, 8 from a pond and 10 from a stream less than 50 m from natural licks NL-1 and NL-4. During each collection, water samples were drawn through a 10 ml pipette from more than 10 points at each natural lick, pond or stream and bulked by site. After thorough mixing to homogenize, about 50 ml of each bulked samples was filtered (syringe filter 0.2 μm pore size, Whatman, USA) and stored at 4 degrees Celsius until the time of the analysis.

To test the chemical properties of the animal diets based on mammal survey at the licks, we collected some creeping herbs (Leguminosae: *Mimosa pudica*), some herbaceous vines (Compositae: *Mikania scandens*), grass (Gramineae: *Paspalum conjugatum*), young leaves of trees (Euphorbiaceae: *Macaranga* spp.), fallen fruits (Moraceae: *Ficus* spp.; Rubiaceae: *Neolamarckia cadamba*), and bark of trees (Sterculiaceae: *Pterospermum* spp.). The plant samples were dried at 60 degrees Celsius to a constant weight and then ground to pass a mesh size of 1 mm using a Thomas Wiley Mill. The ground samples were then digested following the sulphuric acid-hydrogen peroxide method described in Allen (1989).

Total calcium, magnesium, potassium, and sodium concentrations in the filtered water samples and the digested solutions were measured on a GBC atomic absorption spectrometer. Prior to the measurement, the temperature of the water samples was brought to room temperature. All of the analyses were conducted at the Chemistry Section of the Forest Research Centre, Sabah Forestry Department.

Data analysis

Comparisons of the chemical properties of natural licks with controls as well as the sodium and potassium concentrations in vegetative diets of the animals which visited natural licks were statistically conducted through analysis of variance followed by a comparison of means. Data are presented as the mean ± standard deviation.

Results

Mammalian fauna of Deramakot Forest Reserve

Table 1 shows the species of medium-to-large mammals recorded in Deramakot Forest Reserve. Seven orders, seventeen families, and thirty-seven species were recorded during the census. The number of species from this study accounts for 78.7% of the total targeted species (47 species). Large endangered mammals, such as the orang-utan (*Pongo pygmaeus*), the Asian elephant, the clouded leopard (*Neofelis nebulosa*), and the sun bear (*Helarctos malayanus*), were recorded in a wide area. The tembadau/banteng was confined to a relatively small area in the eastern part of Deramakot Forest Reserve. Proboscis monkey (*Nasalis larvatus*) was recorded at the Kinabatangan riverside, in the south and southeastern parts of Deramakot Forest Reserve. Some animals were recorded with their young ones by direct observations, or camera traps or with the evidence of dung. These results showed that

Deramakot Forest Reserve has breeding populations of large endangered mammals.

Mammalian species and their behavior at natural licks

Table 1 also shows that 29 mammalian species (78.4%) out of the 37 in Deramakot Forest Reserve were recorded at natural licks during the census. The number of species accounts for 61.7% of the total number of species (47 species) in Sabah. This survey showed that diurnal and nocturnal, or terrestrial and arboreal mammals with all food-types came to natural licks.

A total of 493 photographs were taken by five camera traps at five natural licks (472 camera-nights). Table 2 shows the top-five mammal species in descending order according to the number and frequency of photographs. The sambar deer (*Cervus unicolor*) (42.8%; n = 211), followed by the bearded pig (*Sus barbatus*) (18.5%; n = 91), was the most commonly recorded species in all photographs (n = 493). The orang-utan, the Asian elephants (*Elephas maximus*), and the tembadau/banteng (*Bos javanicus*) which were endangered species, were also recorded to use a natural lick. (Figure 2-1, 2-2 and 2-3).

The results of camera traps, direct observations and interviews, and the absence of excavation prints suggested that the mammals drink the water rather than eat the soils.

Chemical properties of natural licks and the animal diets

The natural licks of Deramakot Forest Reserve are around 3.5±2.5 m^2, usually contain little water and connected to some animal trails. Although there is variation in the mineral concentrations of natural licks, water samples from natural licks had significantly higher ($p < 0.001$) pH levels and calcium, magnesium, potassium, and sodium concentrations than those from controls did (Table 3). The sodium concentration of NL-4 and NL-5 were significantly higher than that of the other natural licks ($p < 0.001$). Moreover, the NL-4 and NL-5 only has a large colony of leeches in the water. The leeches were thought to be waiting for animals, whereby they cling to the muzzle and suck their blood (interview with local people). Only at the NL-2, calcium demonstrated the highest concentration among minerals. These results indicate that the natural licks could be classified by the mineral concentration and presence of the leeches. The mineral contents of the animal diets indicated that the potassium concentration was the highest of all, except for bark of the tree (Table 4). Moreover, Table 4 shows that potassium was significantly higher than sodium in concentration ($p < 0.001$).

Discussion

Visitation of herbivorous/frugivorous animals to natural licks in Borneo

Mammals of all food types, i.e., herbivorous/ frugivorous, insectivorous, omnivorous, and carnivorous animals, were recorded at natural licks. In addition to the sambar deer, the lesser mouse-deer, and the orang-utan, which were in the top-five species (Table 2), the Asian elephants and the tembadau/banteng were confirmed at all natural licks. These results suggest that these species including endangered species largely depend on natural licks and that their spatial concentrations in the forest must be influenced by the distribution of natural licks.

An analysis of the chemical properties of natural licks and the food available for them showed that 1) the pH of the water was alkaline and 2) the food taken by herbivore/frugivore animals had significantly higher potassium than sodium in concentration. It has been reported that herbivore/frugivore animals suffer from acidosis as a result of the acceleration of fermentation in their stomachs (Kreulen 1985). These results suggest that some of the reasons that herbivore/frugivore animals come to natural licks: 1) to drink alkaline water to avoid acidosis, and 2) to ingest sodium to maintain the internal sodium/potassium balance.

Visitation of omnivorous and carnivorous animals to natural licks in Borneo

Not only herbivorous/frugivorous animals but also omnivorous/carnivorous animals, such as the bearded pig and the Malay badgers (*Mydaus javanensis*), were in the top-five species (Table 2). These omnivorous/carnivorous species can obtain sodium from prey animals. Omnivorous and carnivorous animals have also been recorded at natural licks in Nepal (Moe 1993). The reason for their visiting natural licks is not clear. Considering that natural licks usually have little water, they may not primarily come to drink the water. Rather, they might use natural licks as hunting places. Bearded pigs and Malay badgers generally eat earthworm and insects, although bearded pigs have a varied diet. They might also come to natural licks to forage their food because some insects, such as butterflies, bees, and dung beetles, also use natural licks to ingest mineral water and forage animal dung. Using camera traps, we also recorded small mammals such as bats, treeshrews, squirrels, and rats at natural licks; however, we did not focus on them in this study owing to the difficulty of identifying them in the photographs. They also might come to eat earthworms and insects. Moreover, civets, mongooses, and wild cats were also recorded at natural licks (Table 1). They might come to natural licks to hunt these small animals. These relations suggested that food-chain cascades (soil fauna and insects — small mammals — medium-to-large omnivorous/carnivorous animals) might be formed at natural licks. Further research on the fauna at natural licks would clarify the food chain.

Importance of natural licks in Deramakot and its possibilities

This study suggests that natural licks have the following functions for mammals in Deramakot Forest Reserve: 1) to supply alkaline water, 2) to supply minerals, especially sodium, and 3) probably, to provide a hunting place for predatory mammals. From these, we conclude that natural licks are a hot spot of mammalian diversity in Deramakot and probably elsewhere in Borneo. Results of interviews with local people suggest that such natural licks are not only present in Deramakot Forest Reserve but also in other forest areas in Sabah, Borneo. Therefore, natural licks should be strictly protected as an important habitat to keep mammalian diversity in Deramakot Forest Reserve. At present, Sabah Forestry Department is progressing towards protecting and conserving the identified natural licks.

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Table 1. Medium to large mammal fauna in Deramakot Forest Reserve.

Order	Family	Species (Scientific name)	Main food habit*
Insectivora	Erinaceidae	Moon rat (*Echinosorex gymnurus*)	I
Primates	Lorisidae	Slow loris (*Nycticebus coucang*)	O
	Tarsiidae	Western tarsier (*Tarsius bancanus*)	I
	Cercopithecidae	Red leaf monkey (*Presbytis rubicunda*)	H
		Silvered langur (*Presbytis cristata*)	H
		Proboscis monkey (*Nasalis larvatus*)	H
		Long-tailed macaque (*Macaca fascicularis*)	O
		Pig-tailed macaque (*Macaca nemestrina*)	O
	Hylobatidae	Bornean gibbon (*Hylobates muelleri*)	H
	Pongidae	Orang-utan (*Pongo pygmaeus*)	H
Pholidota	Manidae	Pangolin (*Manis javanica*)	I
Rodentia	Hystricidae	Long-tailed porcupine (*Trichys fasciculata*)	H
		Common porcupine (*Hystrix brachyura*)	H
		Thich-spined porcupine (*Thecurus crassispinus*)	H
Carnivora	Ursidae	Sun bear (*Helarctos malayanus*)	O
	Mustelidae	Yellow-throated marten (*Martes flavigula*)	C
		Malay badger (*Mydaus javanensis*)	C
		Oriental small-clawed otter (*Aonyx cinerea*)	C
	Viverridae	Malay civet (*Vierra tangalunga*)	O
		Otter-civet (*Cynogale bennettii*)	C
		Binturong (*Arctictis binturong*)	O
		Masked palm civet (*Paguma larvata*)	O
		Common palm civet (*Paradoxurus hermaphroditus*)	O
		Banded palm civet (*Hemigalus derbyanus*)	O
		Short-tailed mongoose (*Herpestes brachyurus*)	C
	Felidae	Collared mongoose (*Herpestes semitorquatus*)	C
		Clouded leopard (*Neofelis nebulosa*)	C
		Flat-headed cat (*Felis planiceps*)	C
		Leopard cat (*Felis bengalensis*)	C
Proboscidea	Elephantidae	Asian elephant (*Elephas maximus*)	H
Artiodactyla	Suidae	Bearded pig (*Sus barbatus*)	O
	Tragulidae	Lesser mouse-deer (*Tragulus javanicus*)	H
		Greater mouse-deer (*Tragulus napu*)	H
	Cervidae	Bornean yellow muntjac (*Muntiacus atherodes*)	H
		Red muntjac (*Muntiacus muntjak*)	H
		Sambar deer (*Cervus unicolor*)	H
	Bovidae	Tembadau/Banteng (*Bos javanicus*)	H

*: C: Carnivore; H: Herbivore; I: Insectivore; O: Omnivore
Underlined indicates confirmed mammals at natural lick.

Table 2. Top five species of photographed mammals at the natural licks.

Species (Scientific name)	Number of photographs	Percentage
Sambar deer (*Cervus unicolor*)	211	42.8
Bearded pig (*Sus barbatus*)	91	18.5
Lesser mouse-deer (*Tragulus javanicus*)	37	7.5
Malay badger (*Mydaus javanensis*)	23	4.7
Orang-utan (*Pongo pygmaeus*)	23	4.7

Table 3. Mineral concentrations and pH of the natural licks in Deramakot Forest Reserve.

Locations (Number of Samples)	Minerals: ppm ± *SD*				pH ± *SD*
	Ca	Mg	K	Na	
NL-1 (13)	41.7±4.7	16.5±1.7	6.8±3.2	42.6±10.2	7.9±0.3
NL-2 (13)	94.0±9.3	23.2±1.9	8.4±3.0	38.7±4.6	8.0±0.3
NL-3 (11)	45.1±7.2	15.0±2.0	12.1±3.4	47.2±18.2	8.0±0.2
NL-4 (13)	155.9±51.6	35.1±11.6	29.8±12.6	2710.2±889.1	7.9±0.2
NL-5 (9)	70.5±10.8	13.6±2.4	14.6±17.9	1166.3±253.1	8.2±0.2
Mean of Natural Licks ± *SD*	83.4±50.0	21.4±9.8	14.4±12.6	801.8±1173.5	8.0±0.3
Control-1 (8)	5.6±2.6	2.3±1.1	1.8±0.8	4.6±1.9	7.2±0.6
Control-2 (10)	20.4±4.9	3.1±0.8	1.5±0.2	8.7±0.7	7.9±0.2
Mean of Control ± *SD*	13.8±8.5	2.7±1.0	1.6±0.6	6.9±2.4	7.6±0.5

Table 4. Mineral concentrations of the animal diets.

The diets (Scientific name)	Minerals: mg/g			
	Ca	Mg	K	Na
Creeping herb *Mimosa pudica*	3.26	2.18	16.97	0.09
Herbaceous vine *Mikania scandens*	1.50	1.50	17.08	0.37
Grass *Paspalum conjugatum*	1.91	2.60	20.49	0.11
Young leaf *Macaranga* spp.	5.29	4.10	16.63	0.05
Fruit 1 *Ficus* spp.	14.71	1.99	21.55	0.22
Fruit 2 *Neolamarckia cadamba*	2.05	1.14	15.78	0.11
Bark of the tree *Pterospermum* spp.	15.42	0.76	7.10	0.27
Mean ± *SD*	6.31 ± 6.1	2.04 ± 1.1	16.51 ± 4.7	0.17 ± 0.1

Figure 1. A natural-lick in Deramakot Forest Reserve.

Figure 2-1. Photographed animals at the natural licks. Adult male orang-utan.

Figure 2-2. Photographed animals at the natural licks. Adult female Asian elephant.

Figure 2-3. Photographed animals at the natural licks. Adult male tembadau/banteng.