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Importance of natural licks for the mammals in Bornean inland tropical rain forests

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Abstract An intensive camera-trapping study and a nutrient analysis were carried out to understand how natural licks are important for mammals in inland tropical rain forests where soil cations are usually depleted. Using camera traps, we investigated the fauna, food habits, and the frequency of visitation by species at five natural licks in the Deramakot forest reserve, Sabah, Malaysia. All food-habit types of mammals (carnivore, herbivore-frugivore, insectivore, and omnivore), which included 29 (78.4%) of 37 species known in Deramakot, were recorded at the natural licks. The sambar deer, followed by the bearded pig, the lesser mouse-deer, the Malay badger, and the orangutan were the most commonly recorded species and represented 77.5% in terms of the frequency of appearance in all photographs taken throughout the year. These results indicated that, although the proportion of species recorded at the natural licks relative to the whole mammalian fauna of the forest was high, the frequency of visitation greatly varied among the species, and only a few species dominated. The frequency of visitation seemed to reflect both the density of species and the demand for the minerals, because some endangered, low-density species were more frequently recorded by cameras than expected—for example, the orangutan which was one of the top five species among natural-lick users. The natural licks with greater concentrations of minerals in seepage soil water were significantly preferred by the sambar deer and the bearded pig than those with lower concentrations of minerals. This result suggests that the chemical properties of soil water in natural licks determine the frequency of visitation of these herbivorous species that have strong demand for minerals.

Keywords Borneo · Camera trap · Natural licks · Orangutan · Tropical rain forests

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Introduction

Natural licks are known as mineral-rich places. Although most essential elements (nitrogen, phosphorus, potassium, calcium, and magnesium) are common in plants and animals, sodium is essential primarily for animals only. Plants of inland terrestrial ecosystems, especially in tropical rain forests, do not contain much sodium. Therefore, plant-eating mammals need another source of the minerals (particularly sodium) that are deficient in the plants. Natural licks are one of the mineral sources for such animals. Many studies of the relationship between the chemical properties of natural licks and animals have been conducted, and the roles of natural licks and species diversity have been reported (Emmons and Stark 1979; Kreulen 1985; Izawa 1993; Moe 1993; Clayton and MacDonald 1999; Krishanmani and Mahaney 2000; Montenegro 2004). The mammals have been reported to show a preference for greater concentrations of minerals at licks and/or those in their diets, and the spatial patterns of these mammals reflected the location of mineral sources as well as which animals aggregated at the licks (Weir 1972; Tankersley and Gasaway 1983; McNaughton 1988; Moe 1993). Few of these studies were carried out in Southeast Asia. Although the distribution of natural licks in Southeast Asia seemed to affect the distribution of some mammal species (Payne and Andau 1991; Chanard et al. 1998; Laidlaw et al. 2000), detailed field studies, especially of the visitation frequency of mammals to natural licks and the relationship between the frequency and the mineral concentrations at natural licks, remain to be done.

Tropical soils are known to be depleted of major cations (Jordan 1985). Thus, the plants growing on such soils have a lower foliar concentration of these minerals than plants in the temperate zone (Vitousek and Sanford 1986). Therefore, the mammals of tropical rain forests, especially herbivores and frugivores that are dependent on plants, should supplement minerals from other sources. Bornean tropical rain forests are known to be a region of high mammalian species diversity (approximately 221 species) (Payne et al. 1998) despite the low cation concentrations in soils.

We hypothesized that the visitation of herbivores and frugivores to natural licks was more frequent than that of the other mammals, because they are dependent on plant body for diets. Furthermore, we expected that those species would demonstrate a preference for natural licks with a greater concentration of sodium. We sought to answer these questions through a camera-trapping study of visitation of medium- to large-sized non-volant mammals at five natural licks, comparing the frequency of species visitation between two natural licks with different concentrations of minerals.

Materials and methods

Study area

We conducted a field study at the Deramakot forest reserve, a commercial-logging reserve, in Sabah, Malaysia. Deramakot forest reserve (05°15′–28′N, 117°20′–38′E) is 55,083 ha and is situated at the upper Kinabatangan River, centrally located in Sabah (Fig. 1). The climate is humid equatorial with a mean annual temperature of about 26°C. The mean annual precipitation is approximately 3,500 mm (Kleine and Heuveldop 1993; Huth and Ditzer 2004). Monthly rainfall is somewhat seasonal because the air circulation is influenced by the northeast monsoon from November to February and by the southwest monsoon from May to August. The forest of the Deramakot reserve is composed of lowland mixed dipterocarp forests dominated by the family Dipterocarpaceae (*Dipterocarpus* spp., *Parashorea* spp., and *Shorea* spp.). The forest is regularly harvested for timber with the reduced-impact logging system to minimize the effect on the forest ecosystems (Seino et al. 2006).

Chemical properties of the soil water at natural-licks and the animal diets

We located five spots that local people indicated to us as natural licks in Deramakot. These five putative natural licks were coded as follows: NL-1 (05°22′N, 117°29′E), NL-2 (05°20′N, 117°30′E), NL-3 (05°21′N, 117°31′E), and NL-4 and NL-5 (05°19′N, 117°34′E) (Fig. 1). Mean size of the natural licks was 3.5 ± 2.5 m^2 in diameter (minimum size 1 m^2; maximum size 6 m^2). The results of camera traps, direct observations, interviews of local foresters, and the absence of excavation prints suggested that the mammals drank water rather than eat soil. Therefore, we analyzed the chemical properties of the water at the natural licks. A shallow stagnant water column was formed at each site and this water probably originated from seepage soil water. A total of 59 water samples were collected from the putative natural licks: 13 from NL-1, 13 from NL-2, 11 from NL-3, 13 from

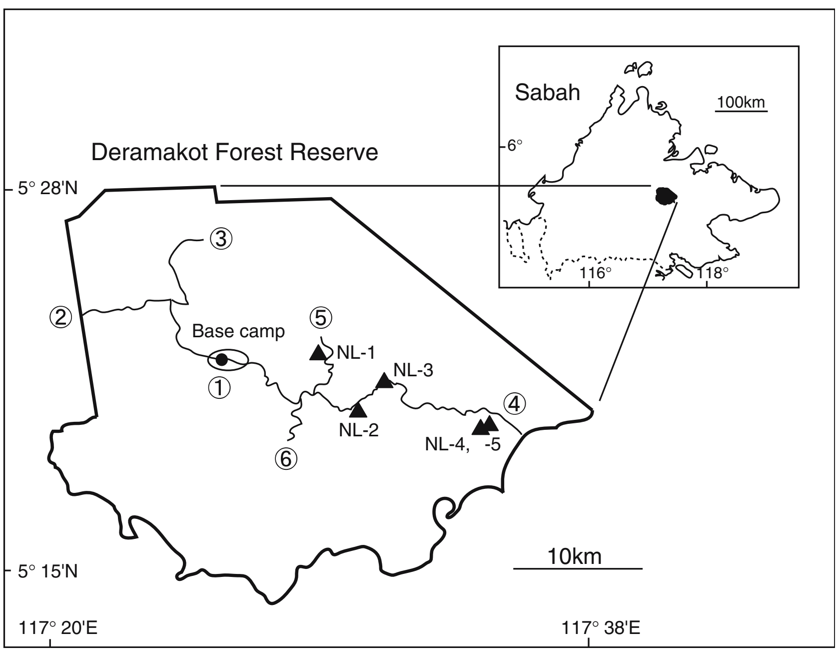


Fig. 1 Location of study area in Deramakot forest reserve, Sabah, Malaysia, North Borneo (*upper right*), and location of study area within the Deramakot. ①–⑥ number of the census routes, ● base camp of Deramakot, Sabah forestry department, ▲ location of the natural licks

NL-4, and 9 from NL-5 at different times and seasons. To know the variation in the season (wet season from November to February and dry season from March to October), we collected the samples from the natural licks during the years 2003 and 2004. To know the background concentration, we collected 18 samples of water—8 samples from a pond and 10 samples from a stream—that were not affected by licks but were less than 50 m from NL-1 and NL-4. During each sampling time, water samples were drawn through a 10-ml pipette from more than ten points at each water column at natural lick, pond or stream and bulked by site. After thorough mixing, about 50 ml of each bulked sample was filtered through a syringe filter of 0.2 μm pore size (Whatman, New Jersey, USA).

To analyze minerals in plants from the representative diets of herbivores and frugivores, we collected materials from the following plants based on mammal's diet survey: 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°C to a constant weight and then ground to pass a mesh size of 1 mm using a Thomas Wiley Mill (Thomas Scientific, New Jersey, USA). The ground samples were then digested following the sulphuric acid-hydrogen peroxide method described in Allen (1989).

The concentration of dissolved calcium, magnesium, potassium, and sodium in the filtered water samples from natural licks and the digested animal diets were determined on a GBC atomic absorption spectrometer. The pH was determined on the filtered water samples with an electrode. All analyses were conducted at the Chemistry Section of the Forest Research Centre, Sabah Forestry Department, Malaysia.

Mammal fauna of Deramakot

We surveyed the mammalian species in the Deramakot forest reserve, focusing on the medium- to large-sized non-volant mammalian species. The following three methods were conducted: (1) a 24-h camera-trap with 15 camera stations, (2) a route census by diurnal, direct observation and identification of prints (footprints and claw marks), and (3) interviews of experienced local forestry staff of the Deramakot district. We focused on 47 species that have been recorded in the lowland forest—Sabah (Yasuma and Andau 2000). Species of Chiroptera (bats), Dermoptera (colugo), small Insectivora (shrews), Scandentia (tree shrews), and small Rodentia (squirrels and rats) were excluded from this study.

Camera traps with an infrared triggering system (Sensor Camera Fieldnote II, Marif Co. Ltd., Yamaguchi, Japan) were set up at a total of 15 camera stations, which included 5 natural licks and 10 animal trails near watering places or on a ridge, for 13 months between June 2003 and October 2005 (981 camera-nights). Some camera traps at the animal trails were baited with fallen fruits. We counted the numbers of individuals photographed. When there were many photographs of the same species within 30 min, only one was counted. When several individuals were photographed in one frame, only one was counted.

For the route census, we established six routes with a total of 64 km, a path to get to camera-trapping sites (Fig. 1). 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 who manage the reserve. We follow the nomenclature of Payne et al. (1998).

Effects of mineral concentrations

The effect of mineral concentrations was investigated at two natural licks (NL-4 and NL-5), which had contrasting mineral concentrations. They were located close to each other (16 m in distance). The other natural licks, NL-1, NL-2, and NL-3, were excluded from this analysis because these were located far away from each other and thus animal visits may co-vary with distance. One camera-trap was placed at NL-4 for 128 days between June 2004 and September 2005. Another camera-trap was placed at NL-5 for 64 days between August 2004 and March 2005. Fallen big branches caused discontinuance of the study at NL-5 after March 2005. The difference in visitation between the two natural licks was tested for the most common users at NL-4 and NL-5.

Data analysis

Differences in the concentration of cations between natural licks and controls, between seasons, and between NL-4 and NL-5 were tested using the *t*-test. Differences in the concentration between potassium and sodium in the animal diets were also tested using this *t*-test. The expectation of a significantly greater ratio of herbivores among the top five species of high visiting-frequency mammals was tested using the χ^2 test (*G*-test). Data are presented as the mean ± standard deviation.

Results

Chemical analyses indicated that the water samples from putative natural licks had significantly higher concentrations of calcium, magnesium, potassium and sodium, and higher pH levels than those from the controls (water of pond and stream nearby) (the minerals, $P < 0.001$; pH, $P = 0.017$) (Table 1). The mean concentration of dissolved sodium in natural-lick water was two orders of magnitude greater than that of the controls, while that of calcium, potassium, and magnesium was one order of magnitude greater. Seasonality of the mineral concentrations and of the pH of natural-lick water was not detected (calcium, $P = 0.682$; magnesium, $P = 0.963$; potassium, $P = 0.5$; sodium, $P = 0.546$; pH, $P = 0.546$).

In the Deramakot forest reserve, 7 orders, 17 families, and 37 species of medium- to large-sized mammals were recorded during the census (Table 2), which accounted for 78.7% of the total focal species (47 species) in Sabah. At the five natural licks, 29 (78.4%) of the 37 species of mammals were recorded. This survey indicated that natural licks were frequently visited by a large proportion of mammal species, including diurnal and nocturnal, terrestrial and arboreal, and any food-habit types. Figure 2 shows the ratio of the main food-habit types of the 37 mammal species recorded in the Deramakot

Table 1 The mean (± standard deviation) concentration of the dissolved minerals in and pH of the water collected from five natural licks in the Deramakot forest reserve—those of the controls are also shown

Locations (number of samples)	Minerals (μg ml^{-1})				pH
	Ca	Mg	K	Na	
KM12 (13)	41.7 ± 4.7	16.6 ± 1.7	6.8 ± 3.2	42.6 ± 10.2	7.9 ± 0.3
KM14 (13)	94.0 ± 9.3	23.2 ± 1.9	8.4 ± 3.0	38.7 ± 4.6	8.0 ± 0.3
KM17 (11)	45.1 ± 7.2	15.0 ± 2.0	12.1 ± 3.4	47.2 ± 18.2	8.0 ± 0.2
KM29-1 (13)	155.9 ± 51.6	35.1 ± 11.6	29.8 ± 12.6	2710.2 ± 889.1	7.9 ± 0.2
KM29-2 (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 (59)	83.4 ± 50.0**	21.4 ± 9.8**	14.4 ± 12.6**	801.8 ± 1173.5**	8.0 ± 0.3*
C-1 (8)	5.6 ± 2.6	2.3 ± 1.1	1.8 ± 0.8	4.6 ± 1.9	7.2 ± 0.6
C-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 (18)	13.8 ± 8.5	2.7 ± 1.0	1.6 ± 0.6	6.9 ± 2.4	7.6 ± 0.5

*Significantly higher than control at $P < 0.05$, and **at $P < 0.001$

Table 2 Medium- to large-sized mammal fauna in the Deramakot forest reserve. *Underlines* indicate mammals recorded at natural licks. *C* Carnivore, *HF* Herbivore-Frugivore, *I* Insectivore, *O* Omnivore

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

[a]Common species in this area

forest reserve and that of the species visiting the five natural licks. The food-habit ratio was quite similar among them, although the area of natural licks was small and restricted. The ratio of herbivores was higher (1.5 times each) than omnivores and carnivores at the natural licks.

A total of 649 photographs were taken at five camera-trap stations of the five natural licks (649 camera-nights). Figure 3 shows the relationship between the frequency of visitation by species and species rank at the natural licks. The sambar deer (*Cervus unicolor* 39.5%; $n = 257$; 0.396 night^{-1}), followed by the bearded pig (*Sus barbatus* 20.1%; $n = 131$; 0.202 night^{-1}), the lesser mouse-deer (*Tragulus javanicus* 7.5%; $n = 49$; 0.076 night^{-1}), the Malay badger (*Mydaus javanensis* 5.5%; $n = 36$; 0.055 night^{-1}), and the orangutan (*Pongo pygmaeus* 4.9%; $n = 32$; 0.049 night^{-1}) (Fig. 4) were the most common. These top five species represented 77.5% in terms of the frequency of their appearance in all of the photographs taken throughout the year, suggesting that a few species visited the licks more frequently than others. The ratio of herbivores-frugivores was shown to be 60% ($n = 3$) of the top five species, but this ratio was not significantly higher than that of omnivores (20%; $n = 1$) or carnivores (20%; $n = 1$) ($\chi = 0.35$, $df = 1$, $P = 0.55$). These results show that the frequency of visitation greatly varied among the species; in particular, large herbivores-frugivores such as the sambar deer, the orangutan, the banteng, and the elephant were high-frequency visitors relative to other visitors. However, against our expectation, herbivores-frugivores were not the sole visitors to the natural licks.

Table 3 shows mineral concentrations of plant diets for herbivores-frugivores. The potassium concentration was the highest of all, except for bark of the tree, and the sodium concentration was the lowest.

Figure 5 shows the relationship of concentration of the minerals and frequency of visitations at the two natural licks. The mineral concentrations at natural lick NL-4 were significantly higher than those at NL-5 ($P < 0.001$ for calcium, magnesium, and sodium; $P = 0.03$ for potassium) (Table 1). The most common users of natural licks NL-4 and NL-5 (the sambar deer and the bearded pig) visited the natural lick NL-4 more frequently than NL-5 (sambar deer $\chi = 21.4$, $df = 1$, $P < 0.001$; bearded pig $\chi = 9.6$, $df = 1$, $P = 0.002$).

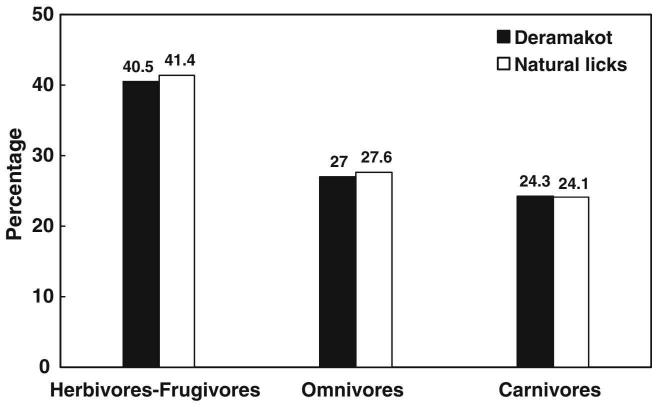


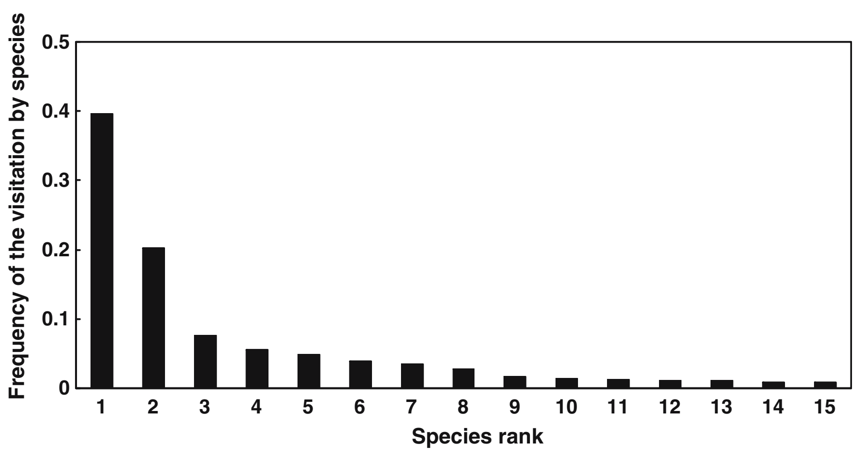
Fig. 2 Ratio of mammalian food-habit in entire Deramakot forest reserve to that at the natural licks

Discussion

This study has clearly shown that various mammals constantly visited natural licks and that the frequency of visitation greatly varied among them. The top five species represented 77.5% in terms of the frequency of the appearance in total photographs. The frequency of appearance could reflect the population density for some animals, but not for others. As low-density rare species (orangutan, banteng, and Asian elephant) are common users of natural licks (Fig. 3), for such species, the demand for minerals is perhaps a plausible factor determining the frequency of the appearance.

We expected that animals would prefer a natural lick with greater concentration of sodium, and this was demonstrated by the sambar deer and bearded pig (Figs. 3 and 5). We suggest that they have a strong demand for minerals, especially for sodium. This is

Fig. 3 Relationship between the frequency of the visitation by species and the species rank at the natural licks. Only those that were photographed more than five times were included. *1* sambar deer, *2* bearded pig, *3* lesser mouse-deer, *4* Malay badger, *5* orangutan, *6* common porcupine, *7* banteng, *8* moon rat, *9* pig-tailed macaque, *10* short-tailed mongoose, *11* common palm civet, *12* Asian elephant, *13* Bornean yellow muntjac, *14* leopard cat, and *15* Malay civet



evidence that such plant-eating large mammals in the inland tropical rain forests use natural licks as a mineral source, and that their ranging pattern may partially reflect the distribution and chemical properties of natural licks. This may be applicable to other plant-eating and low-density rare species such an orangutan.

According to previous studies, the roles of natural licks for animals were thought to be mineral supplementation, adsorption of toxin, and pH adjustment of the gut (Kreulen 1985; Moe 1993; Clayton and MacDonald 1999; Krishanmani and Mahaney 2000; Montenegro 2004). Our analysis of the chemical properties of natural licks showed that the pH of the water was alkaline and sodium content was significantly higher than potassium (Table 1). In addition, analysis of the diets of the herbivores (creeping herb, herbaceous vine, grasses, young leaf, fruits, and bark of the tree) showed significantly higher potassium than sodium concentration (Table 3). Because increased dietary potassium intake results in the excess excretion of sodium through urine (Suttle and Field 1967), a disproportionately greater intake of potassium might be connected with the high demand for sodium.

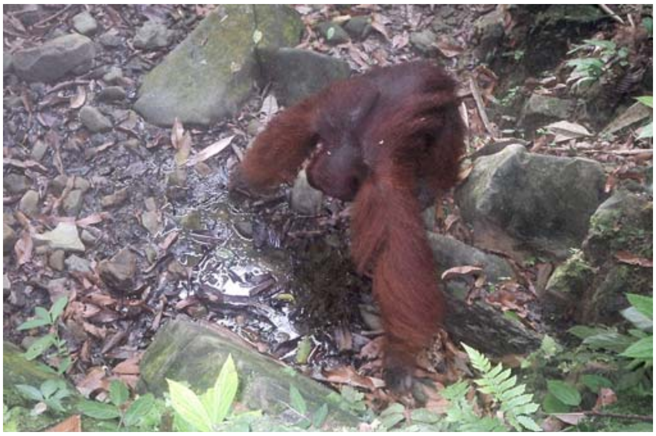


Fig. 4 Camera trapped adult-male orangutan at a natural lick in Deramakot forest reserve

Although most terrestrial herbivorous-frugivorous mammals were recorded at the natural licks, some arboreal species such as leaf monkeys (e.g. *Presbytis rubicunda*) and Bornean gibbons (*Hylobates muelleri*) were not recorded. The reasons for this remain to be solved.

We hypothesized that the visitation of herbivorous-frugivorous mammals to natural licks would be more frequent than that of other mammals. However, the difference was not statistically significant. Carnivores recorded at the natural licks represented 24.1% in the composition of food-habit type (Fig. 2); for example, the leopard cat (*Felis bengalensis* $n = 7$) and the clouded leopard (*Neofelis nebulosa* $n = 4$). Detection of carni-

Table 3 Mean concentration of minerals in the major diets of herbivores

The diets (scientific name)	Minerals (mg g^{-1})			
	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

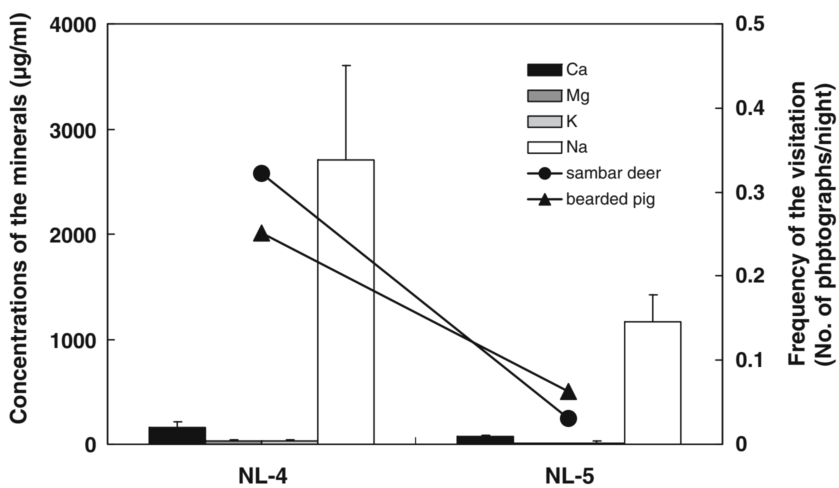


Fig. 5 The relationship between the concentration of minerals and the frequency of the visitations by sambar deer and bearded pig. *Error bars* indicate standard deviation

vores at natural licks was reported in Nepal and Peru (Moe 1993; Montenegro 2004). Considering that carnivores can obtain minerals, especially sodium, directly from their animal prey, these predators might come to natural licks to huntanimals that largely depend on natural licks, rather than to drink the water. Although we do not have any direct evidence from our study site, a cascade of food web (prey animals to predatory animals) might be formed around natural licks.

We conclude the importance of natural licks in the Bornean lowland rain forest, the Deramakot forest reserve. We emphasize that natural lick is not only an essential resource for plant-eating mammals as mineral resources, but also perhaps an essential place for predatory mammals as hunting sites. Ranging patterns of prey species may reflect the distribution and chemical properties of natural licks, and thus natural licks determine the distribution and density of predators. Therefore, natural licks should be considered a high priority in conservation in the forest reserve.

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