*THE RAFFLES BULLETIN OF ZOOLOGY* 2011 **59**(1): 109–115
Date of Publication: 28 Feb.2011


# NATURAL-LICKS USE BY ORANGUTANS AND CONSERVATION OF THEIR HABITATS IN BORNEAN TROPICAL PRODUCTION FOREST

**Hisashi Matsubayashi** and **Abdul Hamid Ahmad**
*Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, LB 2073, 88999, Kota Kinabalu, Sabah, Malaysia*
*Email: matsubayashi_hisashi@yahoo.co.jp (Corresponding author)*

**Nobuhiko Wakamatsu**, **Etsuko Nakazono,** and **Masaaki Takyu**
*Department of Forest Science, Tokyo University of Agriculture, Sakuragaoka 1-1-1, Setagaya, Tokyo, Japan*

**Noreen Majalap** and **Peter Lagan**
*Sabah Forestry Department, LB 68, 90000, Sandakan, Sabah, Malaysia*

**Jum Rafiah Abd. Sukor**
*Sabah Wildlife Department, 5th Floor, B Block, Wisma MUIS, 88100, Kota Kinabalu, Sabah, Malaysia*

***ABSTRACT.* –** The use of natural-licks by orangutans (*Pongo pygmaeus*) was investigated with camera traps in the Deramakot production forest, Sabah, Malaysian Borneo. The results showed that 1) Although orangutans were in the top three species at all the natural-licks, visitation frequency differed at the natural-licks depending on the surrounding environment; 2) Natural-licks use by orangutans was impacted more by human activity than concentration of the minerals; and 3) Visiting proportion of each orangutan class: flanged male, female with infant, and others, showed that flanged male accounted for 31%; female with infant, 17%; and others, 52%; although we had anticipated a bias toward the flanged male. These results suggest that the natural-licks are key habitats for all classes of orangutans and suitable sites for ground monitoring. Therefore, it is strongly recommended that other production forests adopt protection of natural-licks and managed as a monitoring site for orangutan habitat conservation. Furthermore, as orangutans are vulnerable to human activity, it is necessary to manage natural-licks as protected area with buffer zones of reduced human activity.

***KEY WORDS*. –** Camera trap, monitoring site, *Pongo pygmaeus*, sustainable forest management.

## INTRODUCTION

The state of Sabah, Malaysian Borneo, has the highest biodiversity on the island (Hardiono & Alfred, 2005), and the forested area covers about 50% of the state's total land area. However, protected forests represent less than 10%, while production forests (commercial forest reserves) represent over 70% of the forested area at present (Sabah Forestry Department, 2009).

The Deramakot Forest Reserve is one of the production forests located on the upper Kinabatangan River in central Sabah (Fig.1). The Forest Stewardship Council (FSC) certified the Forest Reserve as a well-managed forest in 1997. The Forest Reserve is divided into 135 compartments of various sizes with the use of existing roads and other natural features (rivers, streams, ridges, and foothills) as boundaries (Lagan et al., 2007). The forest management is controlled by principles and criteria of the FSC. For instance, some areas with high biodiversity and frequently used by endangered species must be protected as high conservation value forests (Forest Stewardship Council, 1996).

Natural-licks are mineral-rich sources and are beneficial to large herbivores (Kreulen, 1985). Aggregated distributions of mammals around natural-licks are well known in Africa and Neotropical zones (Weir, 1972; McNaughton, 1988; Montenegro, 2004; Blake et al., 2010; Bravo et al., 2010). In our previous study in the Deramakot Forest Reserve, camera-trap records demonstrated that natural-licks contributed minerals for several mammals, and the findings suggest the importance of natural-licks for sambar deer (*Rusa unicolor*), which are representative terrestrial herbivores not only for daily sustenance but also for reproductive support (Matsubayashi et al., 2007a; 2007b). Since 2008, the Sabah Forestry Department has enacted a rule that prohibits any disturbance within a radius of 100 m of a natural-lick. This regulation applies to high conservation value forests

in the management plan of Deramakot. However, the use of natural-licks by arboreal animals has not been studied much in Borneo. Therefore, it will be necessary for forest management to study the habitats of arboreal animals because these animals are negatively influenced by logging (Meijaard, 2005).

To investigate natural-licks use by arboreal animals in detail, we focused on the orangutan (*Pongo pygmaeus*), a representative arboreal species that is affected by intensity of logging (Felton et al., 2003; Knop et al., 2004; Caldecott & Miles, 2005; Ancrenaz et al., 2008; Husson et al., 2009). More than 60 % of orangutans living in Sabah are distributed in production forests (Ancrenaz et al., 2005). In addition, the orangutan is a high-frequency visitor of the natural-licks in Deramakot (Matsubayashi et al., 2007a).

In this study, we anticipated that, since the orangutan is negatively affected by human activities, their use of natural-licks might be affected. Therefore, we selected four natural-licks, each with a different environment, and investigated the preferences of the high-frequency visitors with camera-trapping. We also anticipated that more flanged males might visit natural-licks because they generally spend more time on the forest floor than females and younger individuals (Cant, 1987); in addition, we assumed that females with infants might be rare because of their wariness of ground predators (Galdikas, 1988). Therefore, we divided the orangutan into three classes (flanged male, female with infant, and others such as unflanged male or female without infant) and investigated natural-licks use by orangutans in detail.

## MATERIALS AND METHODS

***Study site*. –** This study was conducted from March 2008 to March 2010 in the Deramakot Forest Reserve. The Deramakot Forest Reserve (05°14'–05°28'N 117°20'–38'E) is located on the upper Kinabatangan River in central Sabah (Fig. 1). The reserve covers 55,083 ha including 4,000 ha of conservation area, and it ranges from 20 m to 350 m above sea level. The climate is humid equatorial with a mean annual temperature of about 26°C. The mean annual precipitation is approximately 3,500 mm (Kleine & Heuveldop, 1993). 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 Deramakot Forest Reserve is mainly composed of lowland mixed dipterocarp forests dominated by the family Dipterocarpaceae (*Dipterocarpus* spp., *Parashorea* spp., and *Shorea* spp.). Monitoring of the orangutan population has been conducted by aerial line census using a helicopter since 1999 by the Sabah Forestry Department.

The locations of natural-licks in the Deramakot Forest Reserve are better known than those in other production forests because the condition of each compartment was thoroughly surveyed before the Sabah Forest Department made a forest management plan. We have identified natural-licks by mineral analysis and have used camera traps since 2003 to record mammals at the sites (Matsubayashi et al., 2007a; 2007b). Eleven natural-licks have been identified. Four natural-licks each with a different environment, with similar sizes, D1 (05°19'N 117°28'E), D2 (05°21'N 117°29'E), D3 (05°21'N 117°31'E), and D4 (05°19'N 117°34'E), were selected for this study. The natural-licks were approximately 1 $m^2$, and small amounts of water seeped from the soil and rocks. The seepage water supply is stable all year round.

***Mineral analysis of the natural-licks*. –** A shallow stagnant water pool was formed at each natural-lick. To determine the background concentration of minerals, we collected 15 samples from the natural-licks, and three samples from a pond that was not affected by natural-licks but was less than 10 m from them. During each sampling time, water samples were drawn through a 10 ml syringe from more than five points at each water column. After thorough mixing, about 50 ml of each bulked sample was filtered through a syringe filter with 0.2 μm pore size (Whatman, New Jersey, USA). The concentrations of dissolved calcium, magnesium, potassium, and sodium in the filtered water samples were determined on an atomic absorption spectrometer (GBC Scientific Equipment Pty Ltd, Victoria, Australia). All analyses were conducted at the Chemistry Section of the Forest Research Centre, Sabah Forestry Department.

***Environmental characteristics of each natural-lick*. –** The environment around each natural-lick was characterised as human influence, 1) distance from the main roads with heavy traffic and, 2) distance from the villages, and natural influences, 3) distance from the main rivers, 4) altitude and, 5) above-ground biomass of forest around the natural-licks. We digitized geographical information maps (boundary of forest compartments, roads, rivers, and villages) and drew a contour map using three-seconds-mesh data of (about 90 m) called SRTM-3 (Shuttle Radar Topography Mission-3). The distributions of main roads and rivers were described on the basis of the map of the Sabah Forestry Department and the SPOT images. The distributions of four villages in and around the forest reserve were mapped on the basis

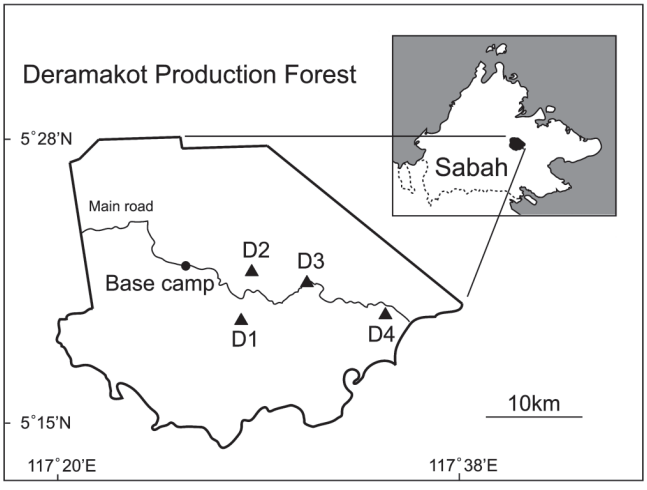


Fig. 1. Location maps of Deramakot Forest Reserve in Sabah, Malaysian Borneo (D1 to D4: natural-licks).

of a field survey. Distances from the nearest objects to the natural-licks and altitude were calculated on the basis of the digitized geographical information maps and the contour map. The above-ground biomass of the forest was estimated by the canopy water-contents calculated by Landsat ETM band 4 (near-infrared 0.75–0.90 μm) and band 5 (shortwave IR 1.50–1.75 μm) rectifying from data of ground observation. Three mesh size, 30, 150 and 210 m including natural-licks were selected for this calculation (210 m was the maximum available data because of the cloud influence).

***Camera-trap monitoring at the natural-licks*. –** Camera traps with an infrared triggering system (Capture, Cuddeback, CA, USA) were set up at a total of five camera stations, which included four natural-licks (D1 to D4) and one small pond around 10 m near D1 as a control. A camera was tied by belt on the trunk 50 cm above the ground at 2 to3 m apart from a natural-lick. As animals tend to stay at natural-licks longer than at other places, such as on an animal trail, the time delay was set to 15 minutes to reduce flash impact on animals and to extend battery life. Maintenance involved replacement of the cameras every two months. Moreover, to confirm whether orangutans consume the water or the soil, video traps (NoFlash, Cuddeback, CA, USA) were set up with a 15-minute time delay, and each recording was 30 or 60 seconds long at D1 and D4.

For comparing the frequency of visitation among species, we counted the numbers of individuals photographed (O'Brien, et al. 2003). When there were many photographs of the same species within one hour, only one was counted. In orangutans, we set three apparently distinguishable classes, flanged male, female with infant, and others, such as unflanged male or female without infant, and investigated the frequency of visitation of each class. To analyse the visiting proportion and the visitation time of each orangutan class, when the same individual was continuously photographed more than 1 hour, only the first photo was counted. In this study, we follow the nomenclature of International Union for the Conservation of Nature and Natural Resources (IUCN; 2010).

***Statistical analyses. – C***omparison of the visitation frequency among the natural-licks was made with a Kruskal-Wallis test. Fisher's exact test was used to compare the length of stay at natural-licks of the three orangutan classes. A comparison of the visitation frequency of orangutans between the morning (0400 to 1100 hrs) and afternoon (1200 to 1800 hrs) was made with a Mann-Whitney U test. Statistical significance for all tests was set at $p<0.05$ or $p<0.01$. Data are presented as the mean ± standard deviation.

## RESULTS

***Chemical analysis and environmental characteristics of the natural-licks*. –** Table 1 shows the result of chemical analysis and environmental characteristics of the natural licks. The results of the chemical analysis showed that the concentration of minerals of the four natural-licks were significantly higher than those of the control ($p<0.05$). D4

Table1. Concentrations of the minerals and environmental characteristics of the natural-licks.

| Locations (No. of Samples) | Minerals (μg/ml) | | | | pH | Distance (m) | | | Above-ground biomass of forest | Altitude (m) | No. of photos | Camera days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | K | Na | | Main road | River | Village | | | | |
| D1 (4) | 45.8±4.5 | 9.5±0.9 | 20.1±6.1 | 154.3±4.6 | 8.4 | 1,300 | 900 | 6,600 | 388.4±2.7 | 217 | 656 | 494 |
| D2 (3) | 28.2±2.0 | 5.9±1.5 | 28.8±14.4 | 106.7±9.2 | 7.5 | 2,400 | 500 | 6,200 | 247.6±112.5 | 185 | 670 | 432 |
| D3 (4) | 67.3±7.7 | 24.2±5.9 | 10.4±1.6 | 46.8±12.1 | 8.1 | 200 | 700 | 10,100 | 322.3±2.1 | 212 | 242 | 366 |
| D4 (4) | 125.6±51.2 | 30.8±10.7 | 21.5±9.0 | 2622.7±1177.2 | 7.7 | 500 | 100 | 4,400 | 323.8±43.3 | 144 | 1839 | 363 |
| Control (3) | 10.7±7.7 | 2.5±0.9 | 1.3±0.4 | 17.6±12.3 | 7.6 | 1300 | 900 | 6,600 | 388.4±2.7 | 217 | 14 | 212 |

Table 2. Camera trapped medium to large mammals at the natural-licks.

| Order | Family | Common name (Scientific name) |
|---|---|---|
| Eulipotyphla | Erinaceidae | Moonrat (*Echinosorex gymnura*) |
| Primates | Hominidae | Bornean orangutan (*Pongo pygmaeus*) |
| | Cercopithecidae | Pig-tailed macaque (*Macaca nemestrina*) |
| Rodentia | Hystricidae | Malayan porcupine (*Hystrix brachyura*) |
| | | Long-tailed porcupine (*Trichys fasciculata*) |
| Carnivora | Ursidae | Sun bear (*Helarctos malayanus*) |
| | Mustelidae | Yellow-throated marten (*Martes flavigula*) |
| | | Oriental small-clawed otter (*Aonyx cinerea*) |
| | Mephitidae | Malay badger (*Mydaus javanensis*) |
| | Viverridae | Malay civet (*Viverra tangalunga*) |
| | | Otter-civet (*Cynogale bennettii*) |
| | | Common palm civet (*Paradoxurus hermaphroditus*) |
| | Herpestidae | Collared mongoose (*Herpestes semitorquatus*) |
| | | Short-tailed mongoose (*Herpestes brachyurus*) |
| | Felidae | Sunda clouded leopard (*Neofelis diardi*) |
| | | Leopard cat (*Prionailurus bengalensis*) |
| Proboscidea | Elephantidae | Asian elephant (*Elephas maximus*) |
| Cetartiodactyla | Suidae | Bearded pig (*Sus barbatus*) |
| | Tragulidae | Lesser mouse-deer (*Tragulus kanchil*) |
| | | Greater mouse-deer (*Tragulus napu*) |
| | Cervidae | Bornean yellow muntjac (*Muntiacus atherodes*) |
| | | Sambar deer (*Rusa unicolor*) |
| | Bovidae | Banteng (*Bos javanicus*) |

had the highest concentration of calcium and sodium among the natural-licks. Natural-licks closer to human activity, such as heavy traffic and village were D3 (200 m from the road) and D4 (500 m from the road and 4,400 m from the village), while those with less human activity were D1 (1,300 m from the road and 6,600 m from the village) and D2 (2,400 m from the road and 6,200 m from the village). Above ground biomass around the natural-licks was not significantly different ($p>0.05$), and each altitude was similar. D4 was the closest to the river which is recognisable by the SPOT image.

***Mammal fauna at the natural-licks and visitation frequency of the top three species. –*** In total, 23 species of medium to large mammals were recorded at four targeted natural-licks (3,407 photos; 1,655 camera-days; 205.9 photos per 100 camera-days; Table 2). The sambar deer (2,468 photos; 149.1 photos per 100 camera-days), the orangutan (483 photos; 29.2 photos per 100 camera-days; Fig. 2), and the bearded pig (*Sus barbatus*; 274 photos; 16.6 photos per 100 camera-days), were the most commonly recorded species and represented 94.7% in terms of the frequency of appearance in all photographs. At the control site, only seven species were photographed (14 photos; 212 camera-days; 6.6 photos per 100 camera-days), and orangutans were not recorded.

In all the natural-licks, the top three species were the same; sambar deer, orangutans, and bearded pigs. Fig. 3 shows proportion of visitation frequency by category at each natural-lick. The visitation frequencies of three species were significantly different at the four natural-licks ($p<0.01$ each). For orangutans, the highest frequency was recorded at D1. In contrast, sambar deer and bearded pigs had the highest frequency at D4.

Fig. 2. Two pairs of females with infants drink the seepage water at a natural-lick.

## NATURAL-LICKS USE BY ORANGUTANS

***Orangutan behaviour at the natural-licks*. –** From video traps, 51 movies of orangutans were recorded at D1 (49 movies per 73 days) and D4 (two movies per 22 days). The video trap results show that orangutans drank water directly rather than obtaining it by eating soil at the natural-licks and they sometimes removed stones at a site to obtain access to water.

***Visiting proportion of each orangutan class at the natural-licks*. –** Fig. 4 shows visiting proportion of each orangutan class: flanged male, female with infant, and others. The flanged male accounted for 31%; female with infant, 17%; and the others, 52%. Occasionally, all three classes were sometimes recorded within one day, and different individuals were recorded in the same frame or within short proximity, i.e., 15 minutes (Fig. 2).

***Duration of orangutan visits at the natural-licks*. –** Fig. 5 shows duration of the visits by each orangutan class. More than 70% of orangutans stayed less than 15 minutes at the natural-licks. 77.2% of females with infants stayed less than 15 minutes, and none of them stayed more than one hour. In others, 82.9% stayed less than 15 minutes, and a stay in excess of one hour was recorded only once. On the other hand, 55.2% of flanged males stayed less than 15 minutes, and 9.1% of them stayed more than one hour, and the longest stay was 2 hrs 27 minutes. The percentage of flanged males staying more than 15 minutes was significantly higher than that of females with infants and others ($p<0.05$).

***Visitation time of orangutans at the natural licks*. –** Fig. 6 shows visitation time of each orangutan class to the natural-licks. Females with infants and others tend to visit more in the afternoon (1200 to 1800 hrs) than in the morning (0400 to1100 hrs) ($p=0.05$ and $p<0.05$ each), while flanged males showed no such tendency ($p=0.15$). In flanged males, the earliest visit was 0452 hrs; the latest, 1734 hrs; and no peak visitation was established. In females with infants, the earliest visit was 0719 hrs; the latest, 1734 hrs; and the peak was at 1500 hrs. In others, the earliest visit was 0541 hrs; the latest, 1805 hrs; and the peaks were at 0600 hrs and 1600 hrs.

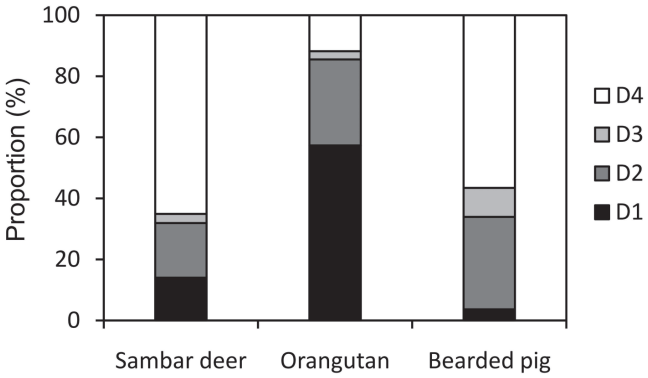


Fig. 3. Proportion of visitation frequency of top 3 species among the natural-licks.

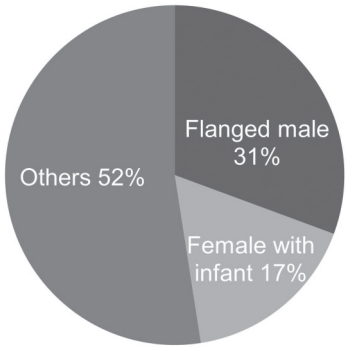


Fig. 4. Visiting proportion of each orangutan class: flanged male, female with infant, and others.

## DISCUSSION

***Differences in the use of natural-licks among the top three species*. –** This study shows that orangutans were high-frequency visitors to natural-licks and among the top three species of all natural-licks, which supports the results of a previous study (Matsubayashi, et al. 2007a). High-frequency visitation of orangutans was also confirmed in the Malua

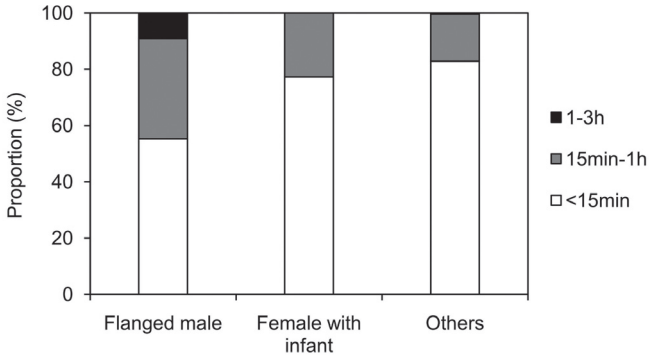


Fig. 5. Duration of the visit of each orangutan class to the natural-licks.

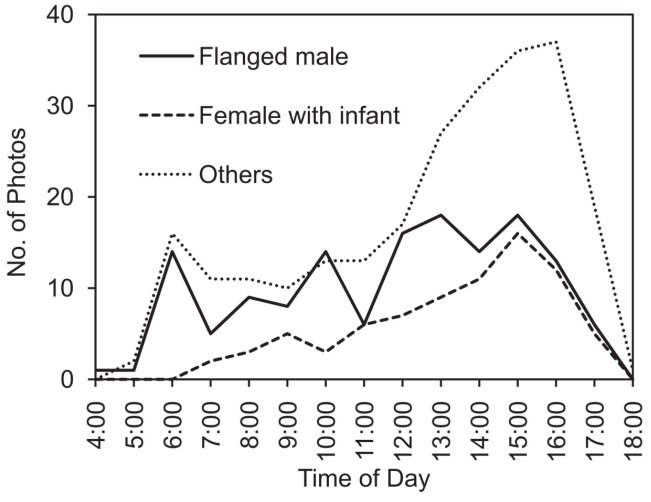


Fig. 6. Visitation time of each orangutan class to the natural-licks.

Forest Reserve, which is a production forest located on opposite side of the Deramakot; the two are divided by the Kinabatangan River (Matsubayashi et al. unpublished data). Therefore, frequent use of natural-licks by orangutans is a common behaviour in Sabah.

The frequency of visits by orangutans differed among the natural-licks, and D1 had the highest frequency. D1 was relatively far from the main roads and did not show apparently higher concentrations of minerals than other natural-licks (Table 1). D1 was also farthest from the river which is recognisable by a SPOT image, but there were some streams. Therefore, the area has some other water sources in addition to D1. On the other hand, D4 with the highest concentration of sodium and close to the main roads showed fewer visits by orangutans, and the highest frequency was noted by sambar deer and bearded pigs (Fig. 3). The results indicate that the close proximity of a main road leads to a decline in orangutan visits; however, sambar deer and bearded pigs are more likely to be influenced by sodium concentrations. The preference for higher sodium concentrations by sambar deer and bearded pigs supports the findings of our previous study (Matsubayashi et al. 2007a). These results seem to be dependent on species characteristics such as a high mineral demand and/or degree of wariness.

***Natural-licks use by orangutans*. –** The video traps show that the animals drank water directly rather than obtaining it by eating soil at the natural-licks. However, it is still difficult to distinguish if they consumed the soil in very small quantities because MacKinnon (1974) reported geophagy of orangutans in Sabah.

We had anticipated that the flanged male would be more likely to visit the natural-licks. However, flanged males accounted for only 31% of the total visits, and females with infants, who were assumed to have a higher degree of wariness, accounted for at least 17% of the visits. This result suggests that natural-licks are important for all orangutan classes as a mineral source. Furthermore, several individuals used natural-licks simultaneously. Evidences in this study include four individuals recorded in the same frame (two pairs of females with infants in Fig. 2), and all orangutan classes were recorded on the same day. In addition, recently, a female with an infant was recorded coupling with an adult male at D2. These results suggest that environs of the natural-licks have secondary function as a communication site.

Although the proportion of flanged male visits was lower than anticipated, flanged males did tend to stay longer than the members of the other classes. This result suggests that the physiological requirement for minerals of the flanged male is much higher and/or that he is at less risk while making the visit than the members of the other classes.

Females with infants and others tended to visit the natural-licks in the afternoon rather than in the morning. This suggests that they tended to visit after foraging, although the reason remains unclear. Early morning visitation (before 0719 hrs) of females with infants had not been recorded until now. This may be because females with infants are more vulnerable to ground predators (Galdikas, 1988) and the risk of descending to the forest floor is too high in the darkness of the early morning.

***Natural-licks as monitoring sites in production forests*. –** This study shows the importance of natural-licks for all orangutans regardless of their class. In addition, natural-licks are very useful as monitoring sites of orangutans, especially of females with infants, who have a high degree of wariness. More than 60% of orangutans living in Sabah occur in production forests (Ancrenaz et al., 2005). Therefore, it is strongly recommended that other production forests protect their natural-licks and manage them as monitoring sites for orangutan habitat conservation. This study also shows that the decisions of orangutans to visit natural-licks are affected more by human activity than by the concentration of minerals at the site. Therefore, for more efficient conservation of orangutans, it is necessary to manage nature-licks as protected area with buffer zones where human activity is restricted (for example reducing number of logged tree or setting skid trails far from the zone).

## ACKNOWLEDGEMENTS

We express our gratitude to Mr. Rawinder-Ajon (Kampung Bundu Tuhan) for supporting our fieldwork. We are grateful to Datuk S. Mannan, Mr. A. Ahmad, Mr. A. Bagoi, Mr. I. Sunjoto, Mr. S. Intang, Mr. J. Torimo (Sabah Forestry Department), Dr. T. Kanamori, Dr. H. Samejima, Dr. K. Kitayama (Kyoto University) for their encouragements to our work. This study was supported by the Global Environmental Research Aid (F-071) of the Japanese Ministry of Environment, and was also supported by a Grant-in-Aid for Young Scientists B (No. 20710182) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

## LITERATURE CITED

Ancrenaz, M., O. Gimenez, L. Ambu, K. Ancrenaz, P. Andau, B. Goossens, J. Payne, A. Sawang, A. Tuuga & I. Lackman-Ancrenaz, 2005. Aerial surveys give new estimates for orangutans in Sabah, Malaysia. *Plos Biology*, **3**: 1–8.

Ancrenaz, M., A. Marshall, B. Goossens, C. van Schaik, J. Sugardjito, M. Gumal & S. Wich, 2008. *Pongo pygmaeus*. In: IUCN 2010. *IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland. Http://www.iucnredlist.org [accessed 22 Apr.2010].

Blake, J. G., J. Guerra, D. Mosquera, R. T. Bette, A. Loiselle & D. Romo, 2010. Use of mineral licks by white-bellied spider monkeys (*Ateles belzebuth*) and red howler monkeys (*Alouatta seniculus*) in Eastern Ecuador. *International Journal of Primatology*, **31**: 471–483.

Bravo, A., K. E. Harms & L. H. Emmons, 2010. Puddles created by geophagous mammals are potential mineral sources for frugivorous bats (Stenodermatinae) in the Peruvian Amazon. *Journal of Tropical Ecology*, **26**: 173–184.

Caldecott, J. & L. Miles, (eds.) 2005. *World Atlas of Great Apes and their Conservation*. Prepared at the UNDP World Conservation Monitoring Centre. University of California Press, Berkeley, USA.

Cant, J. G. H., 1987. Positional behavior of female Bornean orangutans (*Pongo pygmaeus*). *American Journal of Primatology*, **12**: 71–90.

Felton, A. M., L. M. Engström, A. Felton, A., & C. D. Knott, 2003. Orangutan population density, forest structure and fruit availability in hand-logged and unlogged peat swamp forests in west Kalimantan, Indonesia. *Biological Conservation*, **114**: 91–101.

Forest Stewardship Council, 1996. FSC international standard, FSC principles and criteria for forest stewardship. Forest Stewardship Council A. C., Bonn.

Galdikas, B. M. F., 1988. Orang utan diets, range and activity at Tanjung Putting, Central Borneo. *International Journal of Primatology*, **9**: 1–31.

Hardiono, M. & J. R. Alfred, 2005. *Borneo*: Treasure Island at Risk. WWF Germany

Husson, S. J., S. A. Wich, A. J. Marshall, R. D. Dennis, M. Ancrenaz, R. Brassey, M. Gumal, A. J. Hearn, E. Meijaard, T. Simorangkir & I. Singleton, 2009. Orangutan distribution, density, abundance and impacts of disturbance. In: Wich, S.A., S. S. U. Atmoko, T. M. Setia & C. P. van Schaik. (eds), *Orangutans*. Pp. 77–96.

IUCN, 2010. *2010 IUCN Red List of Threatened species*. www.iucnredlist.org.

Kleine, M. & J. Heuveldop, 1993. A management planning concept for sustained yield of tropical forests in Sabah, Malaysia. *Forest Ecology and Management*, **61**: 277–297.

Kreulen, D. A., 1985. Lick use by large herbivores: a review of benefits and banes of soil consumption. *Mammal Review*, **15**: 107–123.

Knop, E., P. I. Ward & S. A. Wich., 2004. A comparison of orangutan density in a logged and unlogged forest on Sumatra. *Biological Conservation*, **120**: 183–188.

Lagan, P., S. Mannan & H. Matsubayashi., 2007. Sustainable use of tropical forest by reduced-impact logging in Deramakot Forest Reserve, Sabah, Malaysia. *Ecological Research*, **22**: 414–421.

MacKinnon, J., 1974. The behavior and ecology of wild orangutans (*Pongo pygmaeus*) *Animal Behavior*, **22**: 3–74.

Matsubayashi, H., P. Lagan, N. Majalap, J. Tangah, J. R. A. Sukor & K. Kitayama, 2007a. Importance of natural licks for the mammals in Bornean inland tropical rain forests. *Ecological Research*, **22**: 742–748.

Matsubayashi, H., P. Lagan, J. R. A. Sukor & K. Kitayama, 2007b. Seasonal and daily use of natural licks by sambar deer (*Cervus unicolor*) in a Bornean tropical rain forest. *Tropics*, **17**: 81–86.

McNaughton, S. J., 1988. Mineral nutrition and spatial concentrations of African ungulates. *Nature*, **334**: 343–345.

Meijaard, E., D. Sheil, R. Nasi, D. Augeri, B. Rosenbaum, D. Iskandar, T. Setyawati, M. Lammertink, I. Rachmatika, A. Wong, T. Soehartono, S. Stanley & T. O'Brien, 2005. *Life after logging*. Center for International Forestry Research.

Montenegro, O. L. 2004., Natural licks as keystone resources for wildlife and people in Amazonia. PhD dissertation, University of Florida, Gainesville, Florida.

O'Brien, T. G., M. F. Kinnaird & H. T. Wibisono, 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, **6**: 131–139.

Sabah Forestry Department, 2009. Annual report 2008. Sandakan.

Weir, J. S., 1972. Spatial distribution of elephants in an African National Park in relation to environmental sodium. *Oikos*, **23**: 1–13.