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NOTE AND COMMENT

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Natural licks are required for large terrestrial mammals in a degraded riparian forest, Sabah, Borneo, Malaysia

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Abstract Although the importance of natural licks for terrestrial mammals is widely acknowledged, we report here for the first time its importance for large terrestrial mammals in a degraded riverine forest in Borneo. Our results clearly demonstrated that various mammals, including bearded pig, sambar deer, and endangered orang-utans, were using the natural lick, though large arboreal/avian herbivore/omnivore animals were not attracted to the natural lick. In addition, the diversity of mammal species recorded in this study was lower than those recorded in the dry lowland forest. Possible reasons for this difference between the different forest types are discussed.

Keywords Bearded pig · Camera-trap · Mineral · Orang-utan · Sambar deer

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Introduction

To meet their nutritional requirements, various animal taxa exploit natural mineral licks, which are mineral-rich deposits (e.g., Emmons and Stark 1979; Klaus et al. 1998; Krishnamani and Mahaney 2000; Holdø et al. 2002; Brightsmith and Munoz-Najar 2004; Ayotte et al. 2008). In contrast to Africa and the Neotropics, few studies have been conducted on natural licks in Southeast Asia (Matsubayashi et al. 2007a). Matsubayashi et al. (2007a) presented the first comprehensive study based on data from camera traps set at natural licks in the Deramakot Commercial Forest Reserve, a dry lowland mixed dipterocarp forest in Sabah, Borneo, Malaysia. Their study showed that various mammals, especially herbivores, exploited natural licks with a higher visitation frequency by sambar deer (*Cervus unicolor*) during the wet season, possibly because of their higher mineral requirements during pregnancy and/or lactation (Matsubayashi et al. 2007b). In addition, these researchers also showed that natural licks were key resources for the orang-utan and suitable sites for their ground monitoring (Matsubayashi et al. 2011). This information reinforces the need to protect all sites containing a natural lick under the high conservation value forest (i.e., HCVF) concept.

In contrast, very little information is available about the value (e.g., to biodiversity) of licks in highly disturbed and degraded habitats in Borneo (Payne and Davies 2013), although recent developments in camera trapping techniques allow animal usage of licks to be monitored more easily (Ancrenaz et al. 2012). Therefore, using camera traps, we investigated the visitation frequency of wildlife to a natural lick located in a highly degraded riparian forest along the Kinabatangan River, Sabah (see Abram et al. 2014 for details on study site). Our hypotheses were as follows:

1. Various animal species will exploit a natural lick in a degraded riverine forest.

2. Large terrestrial and arboreal animals and birds with plant-based diets will use the natural lick at a higher frequency than will smaller animals.
3. Animals will visit the natural lick more often when mineral concentrations are higher, i.e., seasonal changes in visitation frequency will occur.

Methods

Study site and natural lick

We conducted a field study from February 2010 to January 2012, in the riparian forest along the lower Kinabatangan River in Sabah, Malaysia. The mean minimum and maximum temperatures were approximately 24 and 32 °C, respectively (Matsuda et al. 2009), and annual precipitation in the study area was approximately 2,800 mm during the study period. Seasonal flooding usually occurs at the end of the year during the Northeast monsoon (continued for 1–3 months), although there was no strict seasonality such as a dry season (< 100 mm/mo). We located a natural lick following interviews with local community members. This lick was about 0.3–1.5 m in diameter depending on rainfall, under a limestone hill that was approximately 90 m away from the nearest riverbank of the Kinabatangan River (N5°36.2′ E118°20.3′).

Data collection

Water sampling and chemical analysis

To assess the chemical properties of the natural lick, we collected three samples of water every month from June, 2010, to January, 2012, at two sites: the natural lick (experimental sample) and the river (control). We determined the concentrations of dissolved calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) in filtered water samples using an atomic absorption spectrometer (GBC Scientific Equipment Pty Ltd, Victoria, Australia). The pH of the filtered water samples was determined using an electrode at the Forest Research Centre, Sandakan, Sabah.

Camera trap monitoring

Digital camera traps (Capture™ 3.0, Cuddeback, Green Bay, WI, USA) were used from 27 February 2010 to 31 January 2012 to photograph animals visiting the natural lick. In addition, from 17 June 2010 to 27 October 2010, we placed a camera at a point on the riverbank nearest to the natural lick as a control. The cameras remained continuously activated, except when batteries failed or other malfunctions occurred. We set the cameras with a minimum time of 30 s between photographs. When many photographs of the same species were taken within 30 min, only one was counted.

Survey of the river stretch along the natural lick

Once per week from March 2010 to February 2011 in the late afternoon (16:00–18:00), we performed a boat survey along the Kinabatangan River to document spatio-temporal fluctuations in the distribution of primate species in this region following Goossens et al. (2002). The survey route was 3 km downstream and upstream from the natural lick, for a total length of 6 km. Whenever the observers found primates or other animal taxa, the species name and location was recorded.

Data analysis

The Shannon–Wiener index of diversity (H') using visitation frequencies (Pielou 1966) was calculated to compare the diversity of animals visiting the natural lick and the control points. Multiple regression analysis was also conducted to examine whether the monthly visitation frequencies of the animals, particularly bearded pig and sambar deer, to the natural lick were affected by monthly variations in mineral concentrations. Data for visitation frequencies of bearded pig and sambar deer, concentrations of K and Mg, and monthly precipitation were normalised. Akaike information criterion for small samples (AICc value; Burnham and Anderson 2002) was used to find a good-fitting model (ΔAICc < 2). All statistical analyses were conducted using R-3.0.1 (R Development Core Team 2013).

Results

As shown in Table 1, chemical analyses indicated that water samples from the natural lick had significantly higher concentrations of Ca, Mg, and Na and higher pH levels than those from the control. The concentration of each dissolved mineral in water, especially Ca and Na, from the natural lick was more than ten times that of the control. The monthly concentration of minerals at the lick varied with monthly precipitation; concentrations of all minerals, except Ca, correlated negatively with monthly rainfall (two-tailed Pearson's correlation coefficient, K $r = -0.62$, $P < 0.01$; Na $r = -0.66$, $P < 0.01$; Mg $r = -0.57$, $P < 0.01$; Ca: $r = 0.049$, $P = 0.84$), indicating that rainfall lowered concentrations of these minerals.

During the study period, 193 (670 camera-nights) photographs were taken at the camera trap station at the natural lick (visitation frequency = 0.3 night^{-1}). The camera trap captured 11 different animal species, including eight mammal and three bird species (see Table S1 for details). Of these 11 species, two (i.e, bearded

Table 1 Mean (±standard deviation) concentrations of dissolved minerals and pH of the water collected from natural licks and those of controls

	Mineral (μg ml^{-1})				pH
	Ca	Mg	K	Na	
Natural lick	81.5 ± 18.9	5.7 ± 1.4	2.2 ± 1.1	109.6 ± 29.9	7.3 ± 0.5
Control	7.1 ± 3.0	3.9 ± 1.0	3.6 ± 0.9	8.3 ± 7.0	6.8 ± 0.6
P value	1.9×10^{-6}	1.9×10^{-6}	8.2×10^{-5}	1.9×10^{-6}	3.2×10^{-4}

pig and sambar deer; 0.14 and 0.09 $night^{-1}$, respectively), contributed >80 % of the total number of visiting animals to the natural lick.

Twenty-six animal species, including five primate species, were detected during our boat-based surveys, but only seven of these were also photographed at the natural lick (Table S1). In addition, during the river survey, some animal species (i.e., long-tailed and pig-tailed macaques, proboscis monkey, silvered langur, and hornbill) were frequently found at riverside trees within a 200-m radius of the natural lick (Fig. 1), although the natural lick was visited only by two macaque species.

The camera trap at the control point near the river captured 13 different animal species (39 photographs in 430 camera-nights, i.e., 0.09 $night^{-1}$). Although the number of species captured by the camera at the control point was higher than that by the camera at the natural lick, the Shannon–Wiener index of the diversity index (H') of animals visiting the natural lick ($H' = 0.76$) was clearly higher than that at the control point ($H' = 0.30$).

The visiting frequency to the natural lick was significantly higher for bearded pigs (two-tailed $P < 0.0001$ using the exact Wilcoxon signed-rank test) and sambar deer ($P < 0.01$) compared with that at the control point, indicating that these two species were attracted to the natural lick to drink the mineral water. However, the visitation frequency to the natural lick was significantly lower compared with that at the control point for long-tailed macaques ($P < 0.01$). In addition, we found no significant difference in the visitation frequency of the other animals between the natural lick and control points; the sample size for several species such as orang-utan was too small to perform a statistical analysis.

Only one model was selected by the AICc after multiple regression analysis to predict seasonal changes in the monthly visitation frequency of bearded pigs to the natural lick. The model indicated that concentrations of K (positive) and Mg (negative) were significant factors (coefficient and SE: 0.40 ± 0.17 for K and −0.53 ± 0.20 for Mg, $R^2 = 0.31$, adjusted $R^2 = 0.23$, $F = 3.83$, $P = 0.042$). The best-fit model was considered to predict the frequency of bearded pig at the natural lick; the second-best model was the null model. The model for the monthly visitation frequency of sambar deer to the natural lick and concentrations of the other four minerals were not significant.

Discussion

The present study clearly showed that a natural lick located in a riparian forest was used by various mammal species, including endangered ones such as orang-utans, as already noted for dry lowland forest in the Deramakot Commercial Forest Reserve (Matsubayashi et al. 2007a). Surprisingly, however, our study showed that large arboreal/avian herbivore/omnivore animals, i.e, some primates and hornbills, were not attracted to the natural lick, even though these species were present nearby. In addition, the diversity of mammal species recorded in this study was lower than that recorded at the Deramakot reserve, i.e., 8 vs. 29, species (Matsubayashi et al. 2007a).

A possible explanation for the lower diversity of animals visiting the natural lick in this study may be differences in food plant quality, particularly leaves, between those forest types. A comparison of the leaf nutrition of common plant species between secondary riverine and inland primary forests in Borneo showed not only a higher protein–fibre ratio (indicative of leaf quality for folivorous primates; Chapman and Chapman 2002), but also higher levels of crude ash (minerals) (Matsuda et al. 2013). Since folivorous animals inhabiting riverine forests may obtain minerals more easily from plant foods than those inhabiting inland forests, animals in the riverine forest may not have to use a natural lick or visit it only infrequently.

The visitation frequency of sambar deer was rather low in this study (0.09 $night^{-1}$) probably because of heavy hunting pressure (M.A. pers. obser. and results from our interviews with local hunters). On the other hand, the visitation frequency of bearded pig was relatively high (0.14 $night^{-1}$), since the communities are of Muslim faith do not hunt this species. These differences in species abundance in our study site compared to Deramakot (sambar deer, 0.40 $night^{-1}$; bearded pig, 0.20 $night^{-1}$: Matsubayashi et al. 2007a) could explain the different visitation frequencies to natural licks. In addition, although orang-utan abundances in Deramakot and in this study (Lower Kinabatangan area) were comparable (Ancrenaz et al. 2004, 2005), the visitation frequency to the natural lick was much lower in this study (this study 0.003, Deramakot 0.049). Although the reasons for this difference are unclear, we hypothesize that the natural lick may be relatively

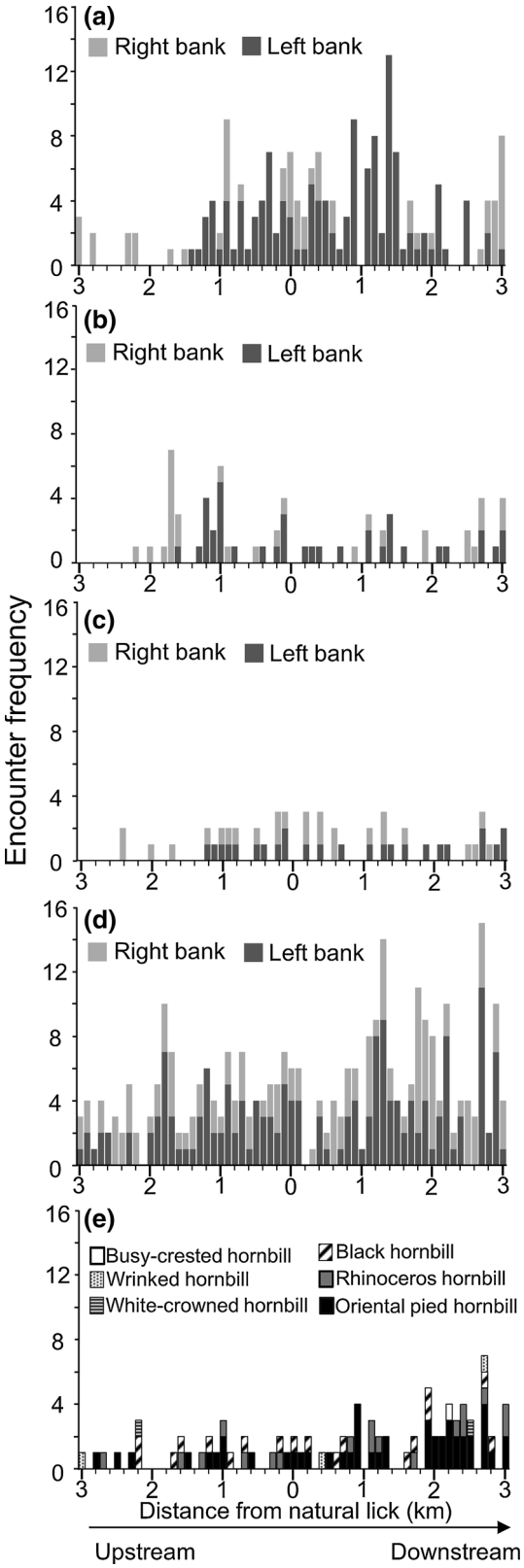

Fig. 1 Frequency of encountering a primate group or hornbills during a river census conducted along the Kinabatangan River, from a point 3 km downstream and upstream to a point on the riverbank nearest to the natural lick (i.e., total census length of the river, 6 km), **a** proboscis monkey, **b** silvered langur, **c** pig-tailed macaque, **d** long-tailed macaque, and **e** hornbills

inaccessible to orang-utans or that they obtain sufficient minerals from their diets.

Seasonal changes were found in the visitation frequency only in bearded pigs. Our current results indicate that variations in concentrations of Mg (negative effect) and K (positive effect) influenced their monthly visitation frequencies, although a previous study showed that sambar deer and bearded pig generally prefer natural licks with greater concentrations of Na (Matsubayashi et al. 2007a). Further study of the detailed ecological traits of the animals, e.g., their diets, rut cycles, and/or female lactation statuses (Holdø et al. 2002; Matsubayashi et al. 2007b; Ayotte et al. 2008; Ping et al. 2011), is required to better understand the seasonal differences in their visitation frequency to natural licks.

Payne and Davies (1987) suggested that the distribution of large Bornean mammals may be more linked to the distribution of natural licks than to forest type or degradation. Our study indicates that the importance of natural licks for sustaining mammalian communities needs further investigation and that it is essential to identify all these sites, to declare them as high conservation value forest, and to protect them to sustain wildlife.

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