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ORIGINAL ARTICLE

Use of Mineral Blocks by Terrestrial Mammals in the Inobong Substation of the Crocker Range Biosphere Reserve: A Preliminary Assessment

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ABSTRACT - Artificial saltlicks are typically created for monitoring terrestrial mammals, although those made solely with mineral blocks are rarely utilized for this purpose by researchers. This trend is evident in Sabah, in which the effectiveness of mineral block-based artificial saltlicks in attracting the given species in local inland forests remains largely unexplored. To bridge this gap, a camera trapping survey was conducted at the Inobong Substation within the Crocker Range Biosphere Reserve. A total of 10 sampling points were placed in the local hill dipterocarp forest, encompassing five artificial saltlicks (with mineral blocks) and five control points (without mineral blocks). A total of 320 independent detections of 22 terrestrial mammal species were recorded across these points over 675 nights of camera trapping. Only seven detections of the southern pig-tailed macaque (*Macaca nemestrina*) and southern red muntjac (*Muntiacus muntjak*) involved them consuming the mineral blocks (4.3 %) at these saltlicks, whereas most sightings (n = 155 or 95.7 %) showed terrestrial mammals engaged in other activities. Hence, the relatively lower mammalian detection frequency, along with the significantly higher species richness and evenness found at the artificial saltlicks compared to the control points, were unlikely to be resulted by the presence of the mineral blocks. The present findings indicate that the design of the artificial saltlicks is ineffective in attracting local terrestrial mammals, thereby emphasizing the necessity for further refinement, while supported by pertinent scientific data, before it can be applied for ongoing terrestrial mammal monitoring in Sabah.

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INTRODUCTION

A saltlick, whether naturally occurring or artificially created in the wild, can attract frequent visits from a diverse array of terrestrial mammal species [1–3]. Saltlicks contain adequate essential minerals and trace elements to support species with fiber-based diets, while also serving as a hunting ground for species with protein-based diets [4–6]. This discovery has driven researchers to apply artificial saltlicks for monitoring terrestrial mammals in the wilderness [7–9]. As a result, there has been an increase in number of studies conducted in the inland forests of West Malaysia in recent years, mainly focusing on artificial saltlicks that mimic natural wet licks, in which various species have been observed using these saltlicks [2; 8; 10]. The process of installing such saltlicks involves adding bags of coarse salts into shallow soil pits, which develop into artificial wet licks when exposed consistently to precipitation [7]. Alternatively, artificial saltlicks can also be established by only installing mineral blocks at designated spots, where this design needs less site modification compared to the establishment of wet licks [11-13]. However, despite their simplicity, these blocked artificial saltlicks are rarely used in wildlife studies in West Malaysia, thereby leading to a limited understanding of their effectiveness to attract local terrestrial mammals.

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The areas chosen for creating artificial saltlicks may have originally served as pathways for navigation and resource acquisition by wildlife [14; 15]. As a result, particular species might visit artificial saltlicks for purposes unrelated to ascertaining minerals from local mineral-rich earth materials [1; 16; 17]. While past studies in West Malaysia revealed that the effectiveness of these saltlicks in attracting terrestrial mammals was dictated by species richness and other related indicators, they did not investigate these aspects when using artificial saltlicks to monitor local mammal species [2; 8; 18]. This gap in research has contributed to a limited understanding of these issues at present. In Sabah, East Malaysia, research on the utilization of artificial saltlicks for monitoring terrestrial mammals is limited [19; 20], as most studies have focused on natural saltlicks and their adjacent areas [1; 5; 16; 21]. This lack of research hinders the understanding of which terrestrial mammal species may consume mineral-rich materials at artificial saltlicks, a behavior known as "geophagy", and in turn, the number of species visiting these manmade features in Sabah.

To address the aforementioned research gaps, this study established artificial saltlicks solely by using mineral blocks at the Inobong Substation of the Crocker Range Biosphere Reserve (CRBR) for monitoring local terrestrial mammals. The local forest is home to a variety of terrestrial mammal species, but research on these species is currently limited [22–24]. As a result, this area offers an ideal setting for this research to use camera traps in identifying the terrestrial mammal species present and evaluating the effectiveness of mineral blocks in attracting these species to designated areas within the site. Based on the results from past studies [2; 8; 10], areas with mineral blocks were expected to show higher species evenness, richness, and detection frequencies, and vice versa for areas without mineral blocks. The results of this study would subsequently offer valuable insights into the response of terrestrial mammals to mineral blocks installed in the inland forest of Sabah.

MATERIALS AND METHODOLOGY

Study Site

The Crocker Range Biosphere Reserve is one of the largest total protected areas in Sabah that spans nine districts within the state. While managed by Sabah Parks, this reserve aims to promote and demonstrate a harmonious relationship between humans and biosphere via conservation efforts [25]. To facilitate access across this 350,584-ha conservation area, 11 strategically located substations enable Sabah Parks staffs to efficiently reach different parts of the reserve. Out of these substations, the Inobong Substation is situated at the north-western boundary of the reserve, within the Penampang District. The region is characterized by steep, undulating hill mainly covered by hill dipterocarp forest, with elevations ranging from 350.0 m to 800.0 m above sea level [23]. In addition, the site experiences an average annual precipitation of about 2251.0 mm and an average annual temperature of approximately 26.0°C. While established in 2003, this substation is open to the public for recreational activities, where a paved road provides access only to the basecamp, while the local forest could be reached via the Bansadon Trail, Waterfall trail, and Salt Trail.

A total of 10 sampling points were established in this study, where the points were installed at least 5.0 m from the edges of the forest trails in the Inobong Substation, according to the Sabah Parks regulations. In addition, these points were positioned parallel to the trails and at least 200.0 m apart from each other. Mineral blocks were installed at five points to create artificial saltlicks, while the other five points were left without mineral blocks, serving as control points, as depicted in Figure 1. The 2.0 kg Boslic Mineral Block (N.A.M. Pharma Sdn. Bhd.) was used in this research, as it contains an adequate mix of different essential elements and trace minerals, which makes it suitable for establishing blocked artificial saltlick. Moreover, these artificial saltlicks were established by placing a mineral block on a cement block above the ground surface, covering it with a plastic cover, and securing all three components to the ground applying a 0.9 m metal bar, as displayed in Figure 2. This design, which was adapted from the approaches used by [12] and [13], revealed in the preliminary results that the mineral blocks last over 70 days without being relocated by wildlife, highlighting that the design was feasible for monitoring terrestrial mammals at the site.

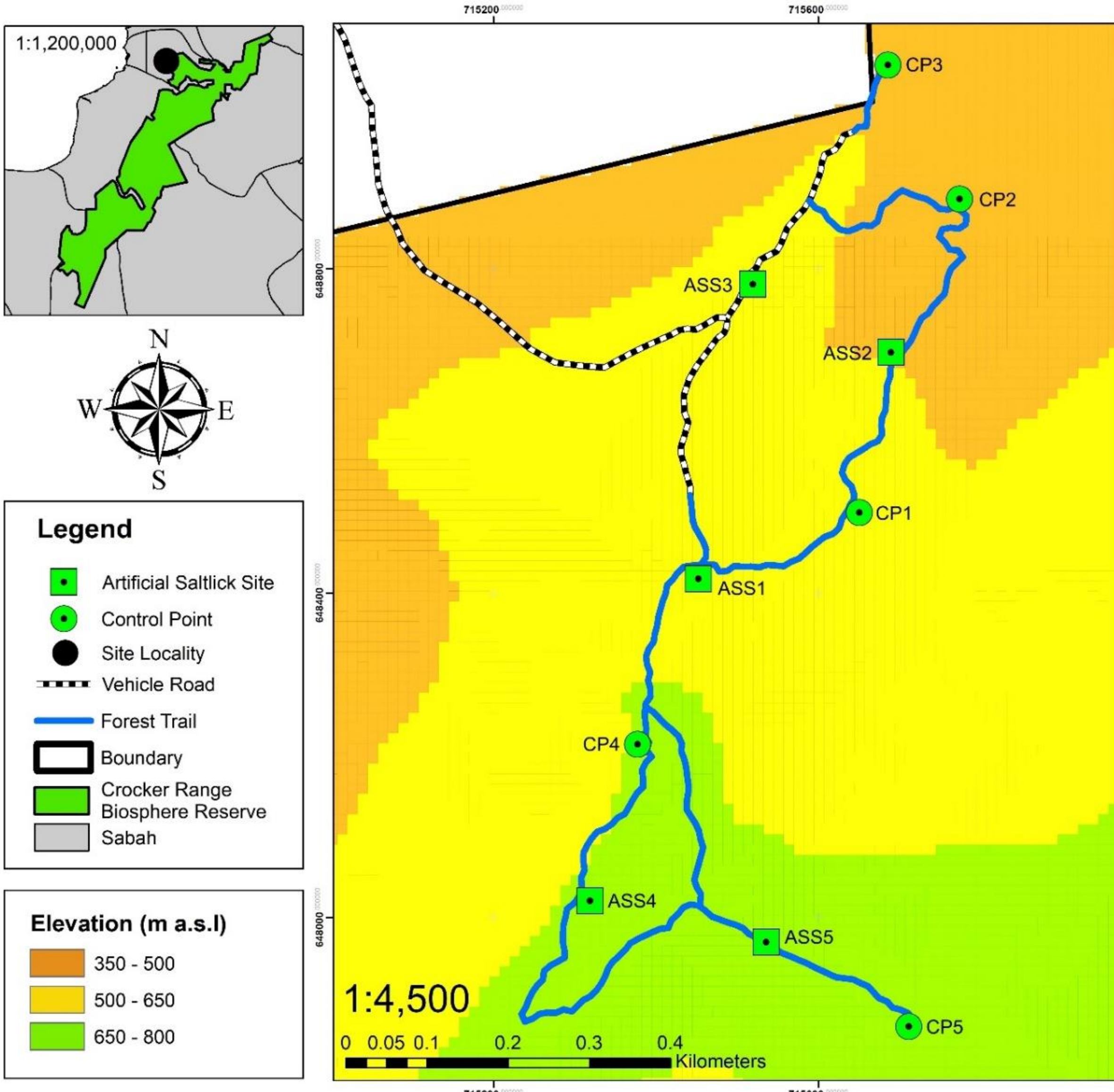

Figure 1. Locations of the ten sampling points within the Inobong Substation of the Crocker Range Biosphere Reserve

Data Collection

All sampling points were surveyed for approximately 9 to 10 weeks, from January 17th to April 25th, 2024. At each point, a Ka Shi H7 camera trap with passive infrared motion sensors (Zhen Shi Jie Ke Ji Co., Ltd.) was mounted onto a vertical tree stand, situated 0.5 m to 1.5 m above the ground and 2.0 m to 5.0 m from either the nearest mineral block (for artificial saltlick) or the targeted forest floor (for control point). Upon activation, the cameras captured three consecutive photographs and one 10-sec video, with a 60-sec delay before reactivating [24]. This setting was applied primarily to capture the activities of terrestrial mammals during their visits to the artificial saltlicks, as proposed by [5] and [9]. Once every three weeks, the camera traps were maintained by removing any view-blocking objects and replacing memory cards and batteries, to ensure their continued functionality during the entire sampling period.

Figure 2. Design of the blocked artificial saltlicks established within the study site

Data Analysis

Photographs and videos without identifiable mammalian individuals were omitted from the data analysis. Subsequently, species, IUCN Red List status, and feeding guild were verified for each recorded individual utilizing relevant secondary sources [22; 26]. A 30-min time interval was used to distinguish between two successive detections of the same species at a sampling point [24]. Based on this assumption, the number of independent sightings was regarded as detection frequency of the species at specific types of sampling points. The recorded footage was also applied to identify the frequency of different activities performed by recorded species during their visits to the artificial saltlick. Furthermore, species evenness and richness at both the control points and artificial saltlicks were evaluated applying Simpson's diversity index (1-D) and Shannon's diversity index (H'), respectively [24]. Non-parametric tests were used in this study, due to the non-normal distribution of the processed camera trap data (Shapiro-Wilk test: $p < 0.05$). Henceforth, the variability in mammalian detection frequency, and also in species richness and evenness, between control points and artificial saltlicks were examined using Mann-Whitney U test and diversity-t test, respectively. Moreover, variations in the frequencies of different activities performed by recorded species were verified utilizing Kruskal-Wallis test, followed by Mann-Whitney U tests for post-hoc comparisons. All statistical analyses were performed using PAST ver. 3.25 [27], with a confidence level of 95.0 % ($p = 0.05$).

RESULTS

Within 675 camera trap nights, 320 independent sightings of 22 distinct terrestrial mammal species were observed across the 10 sampling points, as shown in Table 1. The majority of the sighted individuals were validated as least concern species (15 species or 68.1 %) and omnivores (15 species or 68.1 %). Henceforth, carnivores (3 species or 13.6 %) and herbivores-frugivores (4 species or 18.1 %), and also near-threatened species (3 species or 13.6 %), vulnerable species (2 species or 9.1 %), and endangered species (2 species or 9.1 %), comprised the minority. Over half of the recorded individuals were found at both types of sampling points (18 species or 81.8 %), apart from the long-tailed macaque (*Macaca fascicularis*) that was observed exclusively at control points, as well as the leopard cat (*Prionailurus bengalensis*), thick-spined porcupine (*Hystrix crassispinis*), and banded civet (*Hemigalus derbyanus*) that were only observed at the saltlicks. Moreover, among the 22 recorded species, the long-tailed porcupine (*Trichys fasciculata*: n = 84 or 26.3 %), northern long-footed treeshrew (*Tupaia longipes*: n = 43 or 13.4 %), and southern pig-tailed macaque (*M. nemestrina*: n = 34 or 10.6 %) were the most frequently observed in this study. Conversely, the long-tailed macaque, banded civet, and leopard cat were each detected only once (0.3%), thereby making them the least observed species.

Table 1. Terrestrial mammal species sighted across 10 sampling points within the Inobong Substation of the Crocker Range Biosphere Reserve

Scientific Name	Common Name	FG	IUCN	AS (n)	CP (n)	Overall (n)
Callosciurus notatus	Plantain squirrel	O	LC	15	2	17
Callosciurus prevostii	Prevost's squirrel	O	LC	13	2	15
Echinosorex gymnure	Moonrat	C	LC	1	12	13
Hemigalus derbyanus	Banded civet	C	NT	1	0	1
Hystrix crassispinis	Thick-spined porcupine	HF	LC	2	0	2
Leopoldamys sabanus	Sabah giant rat	O	LC	5	2	7
Lutrogale perspicillata	Smooth-coated otter	O	VU	0	2	2
Macaca fascicularis	Long-tailed macaque	O	EN	0	1	1
Macaca nemestrina	Southern pig-tailed macaque	O	EN	17	17	34
Martes flavigula	Yellow-throated marten	O	LC	1	3	4
Maxomys whiteheadi	Whitehead's Sundaic maxomys	O	VU	19	1	20
Muntiacus atherodes	Bornean yellow muntjac	HF	NT	1	1	2
Muntiacus muntjak	Southern red muntjac	HF	LC	8	14	22
Mydaus javanensis	Sunda stink-badger	O	LC	2	1	3
Paradoxurus hermaphroditus	Common palm civet	O	LC	3	7	10
Prionailurus bengalensis	Leopard cat	C	LC	1	0	1
Trichys fasciculata	Long-tailed porcupine	HF	LC	11	73	84
Tupaia gracilis	Slender treeshrew	O	LC	1	1	2
Tupaia longipes	Northern long-footed treeshrew	O	LC	35	8	43
Tupaia tana	Large treeshrew	O	LC	11	3	14
Viverra tangalunga	Malay civet	O	LC	14	7	21
Urva semitorquata	Collared mongoose	O	NT	1	1	2

***Note:** FG = Feeding Guild (HF = Herbivore-Frugivore; C = Carnivore; O = Omnivore); IUCN = IUCN Red List Status (LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered); n = number of independent sightings; AS = Artificial Saltlick; and, CP = Control Point

Of the 162 independent sightings of 20 species at artificial saltlicks, the Whitehead's Sundaic maxomys (*Maxomys whiteheadi*: n = 19 or 11.7 %), northern long-footed treeshrew (n = 35 or 21.6 %), and southern pig-tailed macaque (n = 17 or 10.5 %) were the most frequently observed species. In contrast, the leopard cat, banded civet, yellow-throated marten (*Martes flavigula*), moonrat (*Echinosorex gymnure*), Bornean yellow muntjac (*Muntiacus atherodes*), collared mongoose (*Urva semitorquata*), and slender treeshrew (*T. gracilis*) were detected once each (0.7 %), thereby making them the least detected species at artificial saltlicks. Moreover, among the 158 independent sightings of 19 species at control points, the Sunda stink-badger (*Mydaus javanensis*), Bornean yellow muntjac, slender treeshrew, long-tailed Macaque, collared mongoose, and Whitehead's Sundaic maxomys were the least sighted species (n = 1 or 0.6 %). Conversely, the southern pig-tailed macaque (n = 17 or 10.8 %), southern red muntjac (*M. muntjak*: n = 14 or 8.9 %), and long-tailed porcupine (n = 73 or 46.2 %) stood out as the most frequently observed species at control points. Ultimately, terrestrial mammals showed lower detection frequencies at control points compared to artificial saltlicks, although the difference was statistically insignificant ($U = 213.5$, $p = 0.505$). Conversely, species richness and evenness at the artificial saltlicks (H' = 2.477; 1-D = 0.8925) were significantly higher than at control points (H' = 1.998, $t = 3.820$, $p < 0.001$; 1-D = 0.7532, $t = -4.127$, $p < 0.001$). These results suggest that terrestrial mammals inhabiting the Inobong Substation of CRBR used both the control points and artificial saltlicks with similar frequencies, although the artificial saltlicks were more evenly used by a wider range of species than the control points.

At artificial saltlicks, the 20 recorded species were sighted engaging in four different types of activities, with passing through the mineral blocks comprising the highest number of detections (n = 79 or 48.8 %), followed by foraging near these blocks (n = 67 or 41.4 %), sniffing the blocks up close (n = 9 or 5.6 %), and lastly, engaging in geophagy (n = 7 or 4.3 %), as depicted in Table 2. Additionally, among these species, 12 (60.0 %) were majorly detected passing through the blocks (n > 50), four (20.0 %) were mainly observed foraging near the blocks (n > 50), and two (10.0 %) were majorly found sniffing the blocks up close (100.0 %). In contrast, the thick-spined porcupine was observed foraging and sniffing the blocks once each (50.0 % each), while the southern red muntjac was found engaging in geophagy and passing through the blocks at similar frequencies (n = 3 or 37.5 % each). Henceforth, the variability in detection frequencies between the given four activities were validated to be statistically significant ($X^2_3 = 19.92$, $p < 0.001$). Specifically, geophagy occurred significantly less often compared to both foraging ($U = 102.0$, $p = 0.012$) and passing ($U = 60.5$, $p < 0.001$), whereas sniffing happened significantly less frequently than passing ($U = 74.0$, $p = 0.002$). Additionally, only the southern red muntjac (n = 3) and southern pig-tailed macaque (n = 4) were sighted consuming mineral blocks at the artificial saltlicks, whereas five species were detected sniffing the blocks up close without engaging in geophagy. These species included the yellow-throated marten (n = 1), collared mongoose (n = 1), Malay civet (*Viverra tangalunga*: n = 2), thick-spined porcupine (n = 1), and long-tailed porcupine (n = 1). Ultimately, blocked artificial saltlicks were determined to have consistently experienced minimal use throughout the sampling period, thereby indicating their limited effectiveness in attracting visits from terrestrial mammals residing within the study site.

DISCUSSION

This study documented 22 terrestrial mammal species, surpassing the species count recorded by [24] with 20 species and [28] with 13 species. These prior studies were conducted in smaller forest areas (less than 10,000 ha) in Western Sabah, in contrast to the larger forest area examined in this study. Moreover, [28] focused solely on small mammals, utilizing cage traps in both trail and non-trail areas, while [24] and this research applied camera traps to sample terrestrial mammals of various sizes along human pathways and adjacent forested areas, respectively. This can clarify the high similarity in species count and composition observed in this research and those reported by [24], and also the greater variability when compared with [28]. However, this study recorded a similar, albeit lower, species count compared to previous studies that utilized camera traps for sampling terrestrial mammals in other divisions of Sabah [1; 16; 29]. These prior studies covered both trail and non-trail areas in large, contiguous forests, thereby facilitating the sighting of multiple shy and elusive threatened species often found in forest interiors [22; 30]. This suggests that a higher species count could be achieved in this research through increasing the number of sampling points in forest areas farther from human pathways at the study site, as well as expanding the sampling area to include other substations of CRBR.

Both control points and artificial saltlicks exhibited high species evenness, thereby indicating that the large, contiguous hill dipterocarp forest at the Inobong Substation was evenly utilized by a diverse array of terrestrial mammal species, likely stemmed from its ability to support their needs impartially [23; 24; 31]. This finding could be driven by the fact that terrestrial mammals inhabiting relatively undisturbed inland forests in Borneo tend to show high diversity (H' > 1.5) and even distribution (1-D > 0.5), as mentioned by prior research [16; 30; 32; 33]. Moreover, the disturbance-tolerant leopard cat, Sunda stink-badger, and long-tailed macaque were rarely detected (n < 4), while many disturbance-intolerant species were sighted with similar frequency in this study. Disturbance-intolerant species are generally more abundant in both undisturbed and least disturbed habitats, whereas disturbance-tolerant species tend to thrive more within disturbed habitats, likely caused by the variability in food availability across these habitat types [24; 30]. Interspecific competition for resources such as food, water, shelter, and minerals could also cause smaller species to avoid areas frequented by larger competitors [3; 28; 34]. Ultimately, these situations may help elucidate the lower sightings of the smaller-sized Bornean yellow muntjac (16.0 kg to 20.0 kg), long-tailed macaque (3.0 kg to 7.0 kg), common palm civet (*Paradoxurus hermaphroditus*: 2.0 kg to 3.0 kg), and the banded civet (2.0 kg to 3.0 kg) in areas frequented by the larger-sized southern red muntjac (20.0 kg to 28.0 kg), southern pig-tailed macaque (4.0 kg to 9.0 kg), and Malay civet (3.0 kg to 5.0 kg), respectively, both in this research and in other inland forests of Sabah, as noted in previous studies [22; 24; 34; 35].

Table 2. Frequencies and percentages of activities performed by 20 terrestrial mammal species during their visits to the artificial saltlicks established within the Inobong Substation of the Crocker Range Biosphere Reserve

Species	Foraging		Passing		Geophagy		Sniffing	
	n	%	n	%	n	%	n	%
Banded civet	0	0	1	100.0	0	0	0	0
Bornean yellow muntjac	0	0	1	100.0	0	0	0	0
Collared mongoose	0	0	0	0	0	0	1	100.0
Common palm civet	0	0	3	100.0	0	0	0	0
Large treeshrew	2	18.2	9	81.8	0	0	0	0
Leopard cat	1	0	0	100.0	0	0	0	0
Long-tailed porcupine	2	18.2	8	72.7	0	0	1	9.1
Malay civet	7	50.0	5	35.7	0	0	2	14.3
Moonrat	0	0	1	100.0	0	0	0	0
Northern long-footed treeshrew	23	65.7	12	34.3	0	0	0	0
Plantain squirrel	10	66.7	5	33.3	0	0	0	0
Prevost's squirrel	11	84.6	2	15.4	0	0	0	0
Sabah giant rat	2	40.0	3	60.0	0	0	0	0
Slender treeshrew	0	0	1	100.0	0	0	0	0
Southern pig-tailed macaque	1	5.9	10	58.8	4	23.5	2	11.8
Southern red muntjac	1	12.5	3	37.5	3	37.5	1	12.5
Sunda Stink Badger	0	0	2	100.0	0	0	0	0.0
Thick-spined Porcupine	1	50.0	0	0	0	0	1	50.0
Whitehead's Sundaic Maxomys	6	31.6	13	68.4	0	0	0	0
Yellow-throated Marten	0	0	0	0	0	0	1	100.0
Total	**67**	**41.4**	**79**	**48.8**	**7**	**4.3**	**9**	**5.5**

***Note:** n = number of independent sightings; and, % = Percentage

The detections of the Sabah giant rat (*Leopoldamys sabanus*), moonrat, banded civet, large treeshrew (*T. tana*), Whitehead's Sundaic maxomys, and thick-spined porcupine emphasize the favorable conditions of the forest habitat within the study site that support their survival [5; 28; 30]. These species primarily inhabit inland forests with minimal anthropogenic disturbance, where the local vegetation structure and composition offer abundant food and shelter, thereby enabling them to thrive in the area [22; 29; 33]. In addition, several species that can be found within the inland forests of Western Sabah, such as the Sunda pangolin (*Manis javanica*), bearded pig (*Sus barbatus*), mousedeer (*Tragulus* spp.), and small-toothed palm civet (*Arctogalidia trivirgata*) [28], were not recorded in this study. Their absences could be related to their tendency to avoid hunting pressure by steering clear from areas easily and frequently accessed by nearby human communities [36–38]. Moreover, the established sampling points were located near forest trails close to the site boundaries, indicating high human accessibility. As a result, these species may have avoided the sampling points and instead occupied more interior segments of the extensive forested area of CRBR, although further study is necessitated to validate this inference in the future.

The significant differences in species richness and evenness between the artificial saltlicks and control points were not associated with the engagement of terrestrial mammals in geophagy, as this activity only accounted for 4.3 % (n = 7) of the mammalian sightings recorded at the saltlicks. Past research mentioned that natural saltlicks in Sabah mainly consisted of wet licks, where terrestrial mammals acquired minerals from local spring water [1; 3; 16]. Additionally, artificial wet licks established in the inland forests of West Malaysia were determined to be frequented by various terrestrial mammal species [1; 2; 18]. Therefore, it is possible that terrestrial mammals in Malaysia have developed a preference for wet licks, which indicates a tendency to obtain minerals from local spring water, rather than mineral blocks [2; 16; 31]. Streams and fig trees are present near particular sampling points, and while these resources are scarce at the study site, they may act as alternative mineral sources for local terrestrial mammals [14; 37; 39]. Moreover, a fruiting event occurred during the sampling period, which increased the abundance of mineral-rich fruits with low concentrations of secondary plant compounds at the site [31; 40]. Since natural saltlicks have not yet been validated at this site, it is likely that local terrestrial mammals have adapted to rely on alternative sources for regular mineral intake, which explains their rare engagement in geophagy at the five artificial saltlicks created in this research [17; 21]. In addition, wildlife might take time to adapt to newly introduced foreign objects, with the adjustment time allowing wildlife to gradually recognize their purpose and eventually use them more regularly [41; 42]. This situation could help explain the nine detections of terrestrial mammals sniffing the mineral blocks up close without making physical contact (5.5 %), thereby denoting that some individuals remain wary as they are in the process of recognizing the purposes of these blocks. However, data supporting these interpretations remains scarce, both at this study site and in other inland forests in Sabah, which underscores the necessity for further research to bridge this gap.

An effective design usually allows research to achieve its objectives with a high success rate [8; 30; 43]. Nonetheless, the artificial saltlicks established in this study proved ineffective in attracting local terrestrial mammals, which makes it unsuitable for long-term monitoring of these species in Sabah. This potentially explains the preference of researchers for creating artificial saltlicks that mimic natural wet licks, instead of blocked artificial saltlicks, for monitoring terrestrial mammals in Malaysia [1; 2; 18]. Moreover, the ten sampling points created in this study showed similar environmental conditions, including their locations in hill dipterocarp forest, proximity to human settlements and forest trails, and high human accessibility. Under these circumstances, local terrestrial mammals may adopt similar utilization patterns across these points during the sampling period [1; 3; 16]. Henceforth, the lack of significant differences in mammalian detection frequencies between control points and artificial saltlicks further highlighted the ineffectiveness of blocked artificial saltlicks for monitoring terrestrial mammals, and also elucidated their frequent use as mineral supplements for domesticated animals instead [8; 13; 31].

Consequently, the significant variations in species evenness and richness of terrestrial mammals noted in this study are likely driven by the variations in specific environmental conditions between the artificial saltlicks and control points [17]. The ease of movement and resource acquisition in a particular area for a species with certain behavioral, morphological, and identity traits are dictated by factors such as weather (illumination, temperature, and precipitation), anthropogenic disturbance (hunting pressure and human visitation intensity), vegetation (density, diversity, and canopy openness), and topography (topographic position, elevation, slope steepness, and terrain ruggedness) [5; 31; 35; 44; 45]. Hence, the spatial impacts of these biotic and abiotic factors can trigger terrestrial mammals to frequent specific areas with favorable environmental conditions, and vice versa [1; 29; 31], which supports the present results. However, as this study did not examine the impacts of these explanatory factors on species detection frequencies, evenness, and richness at the ten sampling points, it is essential for future research to explore this topic holistically.

In summary, the present results imply that the employed artificial saltlick design is not suitable for the long-term monitoring of terrestrial mammals, not only at the study site, but also in other forest habitats of Sabah. This indicates the need for additional scientific data to enhance the design, particularly in terms of understanding how various explanatory factors and design types could affect the effectiveness of artificial saltlicks in attracting terrestrial mammals to designated spots. In addition, the physiochemical properties of various types of mineral blocks can vary, which may dictate how quickly and easily terrestrial mammals become habituated to using these blocks frequently for mineral intake [12; 13; 41]. Henceforth, this factor should be incorporated into future research to enhance the accuracy and precision of the findings as well. Consequently, these efforts would help refine the blocked artificial saltlick design by enhancing its ability to attract terrestrial mammals, thereby improving its feasibility for long-term monitoring of these species within the inland forests of Sabah [8; 30; 43].

CONCLUSION

Present findings suggest that blocked artificial saltlicks are ineffective in attracting terrestrial mammals to designated spots within the study site. This is supported by the fact that terrestrial mammals are primarily passing through or foraging close to the mineral locks during the sampling period, with only the southern pig-tailed macaque and southern red muntjac ingesting the blocks at similarly low frequencies. Therefore, the lack of significant variations in detection frequencies, as well as the significant differences in species richness and species evenness, between artificial saltlicks and control points are unlikely to be resulted by the introduction of these mineral blocks to the study site. Instead, these outcomes are more likely caused by the existing environmental conditions, such as anthropogenic disturbance, topography, vegetation, and weather, which dictate the ease of movement and acquiring resources for local terrestrial mammals at the 10 sampling points. However, the impacts of these abiotic and biotic factors on the utilization patterns of different native species at these points remain uncertain, due to the exclusion of these explanatory factors from the data analysis. Above all, the low effectiveness of the established artificial saltlicks emphasizes the necessity to refine the design, while supported by relevant scientific data, before applicable for monitoring these species within the inland forests of Sabah over long-term. Ultimately, these limitations present an opportunity to pursue additional research in the future.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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