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Cover: Watercolour illustrations—Striped Tiger *Danaus genutia*, Common Silverline *Cigaritis vulcanus*, Tamil Lacewing *Cethosia mahratta*. © Mayur Nandikar.

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COMMUNICATION

Identification and chemical composition analysis of salt licks used by Sumatran Elephants *Elephas maximus sumatranus* in Tangkahan, Indonesia

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Abstract: A crucial aspect of successful conservation strategies is the identification of critical aspects of local habitats required for species preservation in a given region, such as salt licks. Tangkahan is adjacent to the Gunung Leuser National Park in North Sumatra, Indonesia. The park collaborates with the Indonesia Conservation Response Unit using captive Sumatran Elephants *Elephas maximus sumatranus* for forest patrols, mitigation of human-elephant negative interactions, public education, and ecotourism in the area. An initial study on the daily activities of captive Sumatran Elephants revealed their search for salt licks, which are essential for maintaining their optimal daily sodium intake. Information on salt licks in Tangkahan is limited and deserves further investigation. Ethical clearance is deemed unnecessary, as the research employs a non-invasive approach, exclusively observing the natural behaviors, and daily activities of elephants. The well-being of the elephants takes precedence over invasive technologies, with continuous monitoring ensuring their care throughout the research process. The study utilizes a descriptive-analytic methodology, tracking the daily movements of Sumatran Elephants to identify the locations of salt licks in the area. Four salt licks—Encepan-1, Encepan-2, Namo Cencen, and Hot Spring—were identified by participating in the elephants' territorial exploration. Although the salt licks were located adjacently, Encepan-1 was most frequently visited by the elephants. The salt licks were characterized as waterholes containing Na^+ (Sodium ion) rich waters from springs. However, according to the atomic absorption spectrophotometry (AAS) method, the sodium concentration in these salt licks ranged 34–55 ppm, which is estimated to be insufficient for the physiological requirements of the elephants. Therefore, further investigations are needed to explore other complementary salt licks and the incidence of geophagy to support the mineral needs of Sumatran Elephants in the Tangkahan region.

Keywords: Asian Elephant, geophagy, mineral lick, sodium.

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INTRODUCTION

The Sumatran Elephant *Elephas maximus sumatranus* is classified as 'Critically Endangered' by the IUCN Red List of Threatened Species, with habitat conservation being a priority, and conflict mitigation requiring strict management by local conservation sites in Indonesia (Gopala et al. 2011). The Conservation Response Unit (CRU) Tangkahan, located in the Langkat Regency of North Sumatra, part of Gunung Leuser National Park, is a conservation area dedicated to protecting Sumatran Elephants in Indonesia. CRU Tangkahan focuses on supporting the conservation of wild elephant habitats and bridging positive intervention programs with local communities through various involvement in conservation activities such as forest patrol, human-elephant negative interaction mitigation, public education, and ecotourism. CRU Tangkahan has played an instrumental role in facilitating deeper investigations into captive, trained, and wild elephants, leading to a greater understanding of their behavior within the conserved region.

The survival of the Sumatran Elephant greatly depends on its habitat, which includes forest vegetation, open areas, water sources, salt licks, and resting places. This megaherbivore consumes various plant species, but is highly selective depending on the area, weather, and ecosystem where it lives (Pla-ard et al. 2022). Studies conducted on Bornean Elephants *Elephas maximus borneensis* have shown that they consume around 182 plant species, without preference for larger or smaller species (English et al. 2014). Unlike other forest elephants, Bornean Elephants prefer plant species from the Poaceae family rather than other types such as gingers, palms, lianas, and woody trees (English et al. 2014). These differences may reflect their adaptability to different ecological niches.

Elephants have a high feeding rate to meet their energy needs based on body size, age, and sex. During the wet season, both African & Asian elephants tend to graze and spend more time feeding, while during the dry season, they feed less, and are characterized more as browsers (Mohapatra et al. 2013; Greene et al. 2019). Studies have suggested that seasonal deterioration in grass quality may lead to browsing behavior in Asian and African elephants (Weir 1972; Owen-Smith & Chafota 2012; English et al. 2014). The feeding activity of elephants aims to meet their nutritional needs, both qualitatively and quantitatively (Berliani et al. 2018). However, elephants are also known to have difficulty digesting plants with high levels of tannin and other digestive enzyme inhibitors (Karasov & Douglas 2013).

Salt licks are locations that contain essential minerals where animals regularly visit to supplement their diet by licking the soil or water. The presence of animal footprints at these natural deposits consistently confirms their significance to the animals (Sompud et al. 2022). Even endangered species like Asian Elephants and orangutans have been observed visiting these areas (Matsubayashi & Lagan 2014). Therefore, elephants tend to consume mineral-rich soils, also known as geophagy, to feed on essential minerals. There are four primary hypotheses explaining the habitual and intentional soil-eating behavior in animals and people: geophagy, therapeutic, detoxification, and buffering gastric pH (Houston et al. 2001). The most prevalent geophagy hypothesis is the nutrient complementation and/or sodium hypothesis (Dudley et al. 2012). Herbivores consume soil because their typical diets, such as plant leaves, and grasses, lack sufficient mineral concentrations, particularly sodium, to meet their dietary requirements.

The geophagic behavior displayed by elephants and other animals is likely an adaptive practice to remedy a physiological response to mineral nutrient deficiencies in their environment. The therapeutic hypothesis of geophagy is based on the high clay content in some soils, which is known to alleviate gastrointestinal distress & upsets (Risenhoover & Peterson 1986; Tawa et al. 2023). Clay in geophagic soils has also been found to detoxify plant secondary compounds, particularly alkaloids, that are present in many tropical forest trees, counteracting the effects of lactic acidosis. The clay mineral composition has also been found to relate to that of Kaopectate™ used in human medical practice to alleviate various gastroisntestinal disorders such as diarrhea, heartburn, indigestion, and nausea. In contrast, some wild herbivores lick from the deposits for detoxification of elements that are widespread in their habitats or taken up through ingestion (Panichev et al. 2017). Finally, studies have shown that geophagic soil benefits animals by buffering stomach pH and helping them mechanically grind food, which is common for most bird species (Dudley et al. 2012).

Elephants consume minerals as a strategy to detoxify harmful phytochemicals and meet their nutritional requirements due to metabolic constraints (Middleton et al. 2016). Although terrestrial plants, other than halophytes, do not typically accumulate sodium, herbivores still require adequate sodium intake (Cheeseman 2015). It has been hypothesized that mineral lick sites, such as salt licks with Na^+-rich waters, generally provide sodium to supplement the low Na^+

intake of herbivores (Risenhooever & Peterson 1986). Sodium, or Na^+, is the dominant cation found in salt licks, along with other essential minerals such as calcium, magnesium, and potassium. However, the concentration of these minerals may vary considerably depending on the natural conditions of different habitats worldwide (Klaus et al. 1998). For example, in five salt licks in the Amazon Basin, the concentration of Na could range from as low as 29 mg/kg to as high as 1,361 mg/kg (Molina et al. 2013). Interestingly, the mineral concentration in waterholes utilized by elephants may be higher compared to other sites that were not used by elephants (Metsio-Sienne et al. 2013). Elephants intentionally search and allocate some of their energy to locate these mineral hotspots as part of their daily behavior (Berliani et al. 2019).

The majority of studies on salt licks have focused on geophagy by African Elephants *Loxodonta africana*, examining their behavior, populations, and the mineral properties of the licks (Weir 1969; Stark 1986; Ruggiero & Fay 1994; Holdø et al. 2002). Mineral requirements are influenced by several factors, including reproduction, age, sex, growth rate, and physiological condition. Therefore, wild animals, particularly herbivores, require periodic access to mineral sources at salt licks, which elephants often visit in search of mineral-rich salts. The natural characteristics of salt licks thus support wild animals, especially herbivores, in addressing nutritional deficiencies in their diets (Lameed & Adetola 2012).

In the tropical region of North Sumatra, salt licks may take the form of waterholes or sodium-rich waters, which remain understudied despite being a crucial element for the conservation dynamics of Sumatran Elephants. This study aims to characterize a series of salt licks and their mineral composition located around the CRU Tangkahan region inside Gunung Leuser National Park, providing baseline information to support conservation efforts and management by officials. Ethical clearance is deemed unnecessary due to the prioritization of elephant well-being over invasive methodologies and the continuous monitoring of their care throughout the research process.

METHODS

Study Area

Tangkahan is situated in the northern part of Sumatra (03.414°N, 98.040°E) and is one of the ecotourism sites in Langkat Regency, North Sumatra. This study was carried out in Tangkahan, which is famous for its herd of rescued Sumatran Elephants that are trained to patrol the forests with their mahouts. The CRU Tangkahan area is a buffer area zone of Gunung Leuser National Park. Tangkahan is home to virtually untouched forests inhabited by wild orangutans, with waterfalls, caves, and hot springs to explore. The area features a diverse range of flora & fauna, including a variety of food plants that are important for the Sumatran Elephants' diet. The climate in Tangkahan is characterized by its tropical rainforest climate, with high humidity, and significant rainfall throughout the year. The luxuriant vegetation and favorable climatic conditions render Tangkahan an optimal habitat for a myriad of wildlife, notably featuring the 'Critically Endangered' Sumatran Elephants.

Sampling procedure and behavioral observation

To locate salt licks in the region, exploration was carried out by observing the daily behavior of Sumatran Elephants. Four salt licks were selected for this study: Encepan-1 (03.4110°N, 98.0412°E), Encepan-2 (03.411°N, 098.0414°E), Namo Cencen (03.4175°N 098.0423°E), and Hot Spring (03.4129°N, 98.0418°E) (Figure 1). During May–July, Na^+ rich water samples (100 ml) were collected from the CRU Tangkahan area and stored in borosilicate bottles to analyze mineral concentration and composition. Atomic absorption spectrophotometry (AAS) was used to analyze samples for the concentration of Boron (B), Sulfur (S), Phosphorus (P), Potassium (K), Calcium (Ca), Sodium (Na), Magnesium (Mg), Aluminium (Al), Copper (Cu), Zinc (Zn), Iron (Fe), and Manganese (Mn). Dissolved organic C content and pH were measured using digital instrumentation.

RESULTS AND DISCUSSION

Characteristics of salt licks in Tangkahan

Based on the findings of this study, each of the salt licks in the Tangkahan area had distinct characteristics and different sulfuric odors (Table 1). The Sumatran Elephants were observed to periodically visit these four salt licks for drinking or performing geophagy to fulfill their nutritional requirements (Image 1). The salt licks were primarily composed of limestone, and the water temperature ranged 20–58 °C. Sulphuric gas was detected in all salt licks at varying levels, with the highest levels found at Hot Spring due to the natural weathering of minerals such as sulfur (S), which released the sulfuric odors around the licks. Encepan-2 had the highest organic C content, while the lowest was found

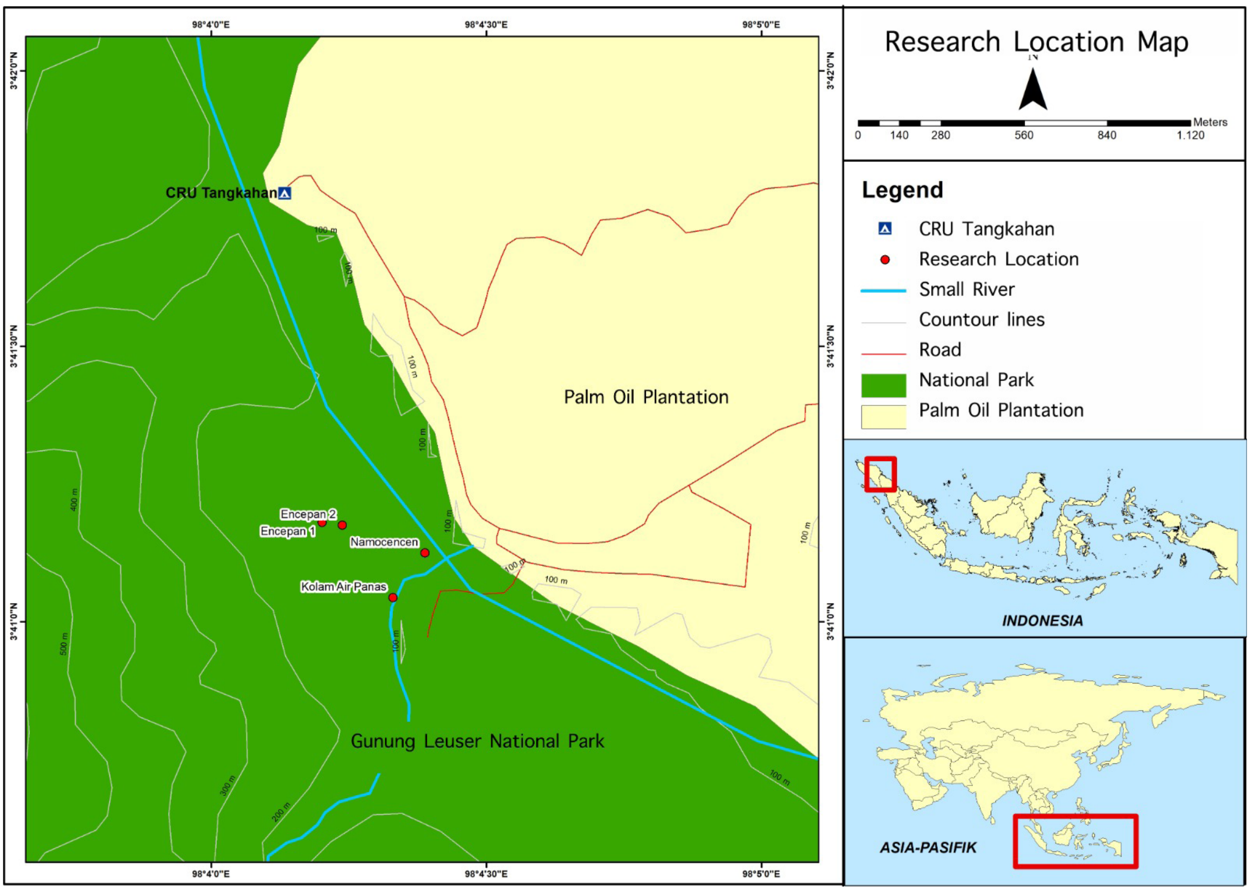

Figure 1. Study area shows the salt licks area in the CRU Tangkahan region, North Sumatra.

at Hot Spring. The water pH in each of the salt licks was stable and fell within the range of 7.35–7.59. These characteristics of salt licks are significant for elephants and the ecosystem in several ways. Salt licks provide essential minerals which are necessary for the elephants physiological functions, including nerve function, and muscle contraction. The existence of salt licks is not only important for elephants but also for a wide range of other wildlife species.

Encepan-1, situated along the patrol route for elephants in the CRU Tangkahan, stands out as the most frequently visited salt lick, given its proximity to the patrol pathway. The structure of Encepan-1 was primarily composed of sandstones mixed with clays from nearby riparian soils. The waterhole at Encepan-1 was fed by springs that emerged from the ground and mixed with the river flow passing through the area. The mineral composition of the sand fraction of soils can affect the long-term potential fertility of the area due to the weathering of the material (Molina et al. 2013). Further investigation into the geomorphological formation of the region may help determine the mineralogical composition of specific clay materials and their relation to the characteristics of the salt licks (Table 2).

The high organic C content found in Encepan-2 (924.61 ppm) may be attributed to the natural decomposition of litter in the salt lick. Additionally, the high level of organic C content could be due to the chelation of essential minerals such as Cu, Fe, Al, and Mn dissolved in the soil materials (Cambardella & Elliott 1992; Obi 1999). Moreover, the waterholes formed in this salt lick may provide sufficient nutrients for the elephants to maintain their dietary intake of minerals. The salt and mineral composition are presented in Table 2, which shows the dominant and less dominant elements in the salt licks. A high concentration of sulphur was detected in both Encepan-1 and Namo Cencen, whereas Hot Spring had a comparatively lower concentration of sulfur, which was unusual in this study. Animals need to receive an appropriate and balanced diet that meets their nutritional requirements, including sulfur, without exceeding safe levels. Sulfur is a component of certain amino acids, vitamins, and coenzymes that play crucial roles in various physiological processes. It is particularly

Table 1. Characteristics of salts licks in CRU Tangkahan area.

Characteristics	Salt Licks			
	Encepan-1	Encepan-2	Namo Cencen	Hot Spring
Structure	Sandstone	Limestone	Limestone	Limestone
Temperature (°C)	44	30	20	58
Sulphuric gas	+++	++	+	++++
Formation	Notched	Notched	Notched	Notched
Water clarity	Clear	Clear	Clear	Clear, covered with moss
Depth (cm)	10	20	40	100
Litter	Absent	Present	Present	Absent
Organic C content (ppm)	109.94	924.61	594.99	1.12
pH	7.59	7.57	7.38	7.35

Table 2. Salt and mineral composition in salt licks in CRU Tangkahan.

Parameter(s)	Concentration (ppm) at salt licks			
	Encepan-1	Encepan-2	Namo Cencen	Hot Spring
Boron (B)	0.33	1.09	3.68	4.56
Sulphur (S)	100.51	18.18	185.08	55.11
Phosphorus (P)	0.98	0.96	3.16	2.26
Potassium (K)	50.22	41.25	94.15	75.92
Calcium (Ca)	49.48	58.99	405.43	28.34
Sodium (Na)	34.02	43.70	55.55	44.20
Magnesium (Mg)	39.57	35.20	349.38	64.78
Aluminium (Al)	18.10	16.96	26.89	22.77
Copper (Cu)	0.08	0.08	0.43	0.34
Zinc (Zn)	0.44	0.40	1.60	0.97
Iron (Fe)	11.6	12.38	12.74	12.58
Manganese (Mn)	0.32	0.27	2.43	2.47

important for the synthesis of proteins, the formation of connective tissues, and the maintenance of the structural integrity of hair, skin, and hooves. Salt-licks can supply a variety of nutrients including iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), selenium (Se), calcium (Ca), phosphorus (P), potassium (K), sodium (Na), sulfur (S), and chlorine (Cl). Naturally occurring salt-licks (NSs) are therefore considered significant landscape resources. Studies in the Segaliud–Lokan Forest Reserve, Sandakan, Sabah, Malaysia, have shown that they have an impact on the density & composition of fauna in the vicinity, and appropriateness for salt-lick tourism (Lim & Mojiol 2022; Chaiyarat et al. 2023).

The salt concentration ranged from 34–55 ppm. The ideal Na^+ intake is known to be correlated with the body mass of the studied animals, revealing a dynamic measurement for some species (Belovsky & Jordan 1981). In addition, a study of a 5,000 kg African Elephant in Zimbabwe showed the importance of Na^+ rich water, which supplied about 112 g of daily sodium intake from 200 l of water from the Sinamatella River (Holdø et al. 2002). However, it is noteworthy that the sodium supply from these salt-licks in Tangkahan may not be sufficient to meet the daily requirements of the elephants due to the limited access to waterholes and resources. The incidence of geophagy or soil consumption with high minerals by the elephants may require further investigation as another strategy to fully satisfy their requirements. Some researchers also argue that the phenomenon of salt-licks may only become valid in a Na^+-balance experiment using fecal Na^+ as an indicator to reflect the connection between the movement and habitat-use patterns of elephants (Holdø et al. 2002).

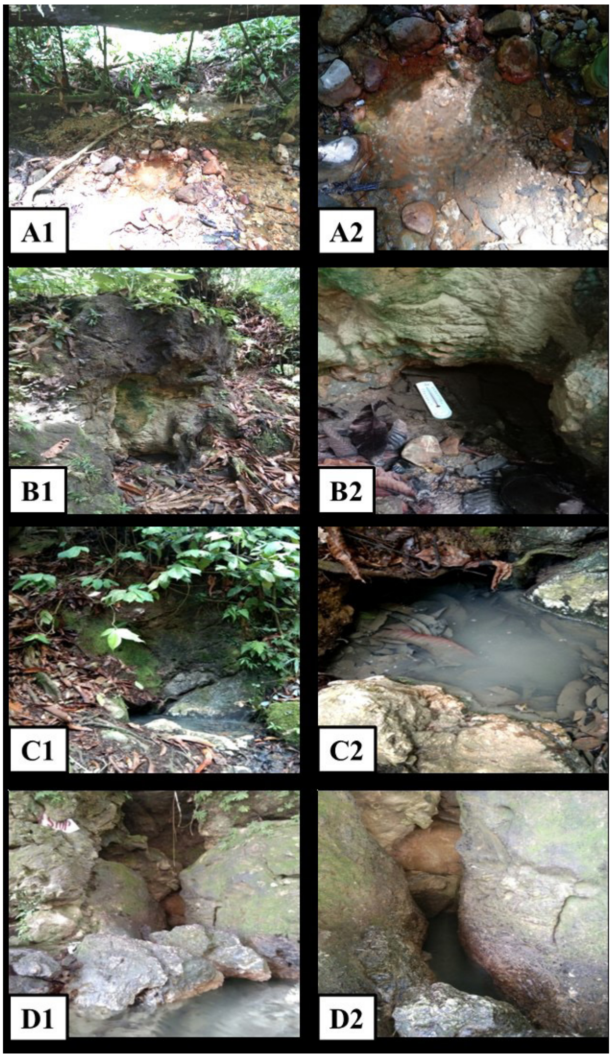

Image 1. Salt licks located in the CRU Tangkahan area: A1—Encepan-1 | A2—Water Spring | B1—Encepan-2 | B2—Small cave | C1—Namo Cencen | C2—Puddle | D1—Hot Spring | D2—Crevice.

CONCLUSION

The findings of our study confirm the presence of salt-licks for Sumatran Elephants in Tangkahan, highlighting the importance of conservation efforts in the area. With a better understanding of the elephants' use of salt-licks, officials can focus on protecting these sites and potentially identify additional ones in the deeper forest regions. Maintaining salt-licks as essential components of the forest's ecological functions will contribute to the long-term sustainability of the elephant population in CRU Tangkahan. This study was conducted within a specific timeframe, limiting the understanding of seasonal variations or long-term patterns. Investigating the broader ecological impact of salt-licks on the biodiversity, and functioning of the surrounding forest ecosystem, and exploring the relationship between salt-lick locations and human-elephant negative interactions to develop mitigation strategies are recommended for future and collaborative research.

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Abstract : Aspek penting dari strategi konservasi yang sukses adalah identifikasi mikrohabitat yang signifikan untuk pelestarian spesies di wilayah tertentu. Proses menggaram menyediakan mineral penting dan mendukung perilaku hewan yang berbeda dari lingkungan sekitarnya. Tangkahan, yang berbatasan dengan Taman Nasional Gunung Leuser di Sumatera Utara, Indonesia, bekerja sama dengan Indonesia Conservation Response Unit, menggunakan gajah Sumatera (*Elephas maximus sumatranus*) yang ditangkarkan untuk patroli hutan, mengurangi konflik antara manusia dan gajah, edukasi publik, serta ekowisata. Studi awal mengenai aktivitas harian gajah ini mengungkapkan pencarian mereka terhadap penggaraman, yang penting untuk menjaga asupan natrium yang optimal. Namun, penemuan penggaraman di Tangkahan masih terbatas dan perlu penelitian lebih lanjut. Penelitian ini tidak memerlukan izin etik karena menggunakan pendekatan non-invasif, hanya mengamati perilaku alami dan aktivitas harian gajah. Kesejahteraan gajah diutamakan dengan pemantauan terus-menerus selama proses penelitian. Metodologi yang digunakan adalah deskriptif-analitik, dengan melacak pergerakan harian gajah Sumatera untuk mengidentifikasi lokasi jilatan garam. Empat lokasi jilatan garam—Encepan-1, Encepan-2, Namo Cencen, dan Sumber Air Panas—diidentifikasi melalui penjelajahan teritorial gajah. Meskipun lokasi-lokasi ini berdekatan, Encepan-1 adalah yang paling sering dikunjungi. Penggaraman ini dikarakterisasi sebagai lubang air yang mengandung air kaya Na+ dari mata air. Namun, analisis dengan spektrofotometri serapan atom (AAS) menunjukkan konsentrasi natrium di jilatan garam ini berkisar antara 34 hingga 55 ppm, yang kemungkinan tidak mencukupi kebutuhan fisiologis gajah. Oleh karena itu, diperlukan investigasi lebih lanjut untuk mengeksplorasi jilatan garam tambahan dan kejadian geofagi guna mendukung kebutuhan mineral gajah Sumatera di wilayah Tangkahan.

Keywords: *Elephas maximus sumatranus*, geofagi, penggaraman, natrium.

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