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Monitoring of the habitat usage of Tembadau (*Bos javanicus lowi*) around salt lick in a forest plantation of Sabah, Malaysia

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Abstract. *Enn HS, Musta B, Sarjadi MS, Maid M, Muning M, Kodoh J, Goh C, Jonalius M, Sompud J. 2022. Monitoring of the habitat usage of Tembadau (*Bos javanicus lowi*) around salt lick in a forest plantation of Sabah, Malaysia. Biodiversitas 23: 6062-6069.* Tembadau (*Bos javanicus lowi*) is a wild cattle endemic to Borneo Island, especially in Sabah, Malaysia. Their population is declining due to habitat loss and illegal hunting. Previous researchers have reported that hunting pressure and forest fragmentation due to the conversion of natural forests into oil palm plantations are driving the species into the looming extinction of this species. Tembadau is well known for using the salt lick in its habitat. Salt licks are rich in minerals, or feeding sites are important as critical temporal use for wildlife, including Tembadau. The lack of data on the ecological behavior of Tembadau in salt lick areas caused difficulties in monitoring their population in the forest. It may undermine their conservation, especially in the forest plantations. The habitat usage of the Tembadau in this study was expressed in the detection rate and activity pattern. This study aimed to compare Tembadau's detection rate at salt and non-salt lick areas in a forest plantation situated at the Segaliud Lokan Forest Reserve, Sandakan, Sabah. The activity pattern of Tembadau between a salt lick and non-salt lick areas was also determined. A camera trap survey was carried out from 2 November 2019 to 6 September 2020 to collect the presence, absence and activity pattern of Tembadau. The results show that the detection rate of Tembadau was higher in salt licks, especially salt lick C59SL (n: 171, U: 3187.5, p: 0.003). Tembadau at the salt licks expressed all diurnal, nocturnal and crepuscular behavior but was primarily active at night (n: 12, 43% of nocturnal behavior). Salt licks are beneficial for wildlife to provide the essential elements of intake, health and reproductive success. These findings are helpful information for the monitoring and further conservation work for the species, especially in forest plantation areas. It also provides essential baseline data for lawmakers to make policies for the total protection of salt licks in forest plantations.

Keywords: Activity pattern, Bornean banteng, Bovidae**,** camera-trapping, detection rate

Abbreviations: SLFR: Segaliud Lokan Forest Reserve, SL: Salt lick, NSL: Non-salt lick, FMU: Forest Management Unit, RIL: Reduced Impact Logging

INTRODUCTION

Tembadau (Bovidae: *Bos javanicus lowi*), or Bornean banteng, is a wild cattle type endemic to Borneo Island, especially in Sabah, Malaysia. Like other wild cattle, Tembadau is essential as an herb seed disperser (Matsubayashi et al. 2007). They can also crossbreed with domestic cattle, producing hybrids that survive under harsh environmental conditions in the wild (Matsubayashi et al. 2014). Tembadau has white buttocks, distinguished from other cattle, such as water buffalo and domestic cattle. The lower part of the legs is white in color, generally described as "legs with stockings". They have sexual dimorphism, where an adult male is black or blackish in color, and the adult female is reddish brown. The male calf is reddish brown in color, like female adults. The height of an adult Tembadau at shoulder level is between 120 and 170cm; its weight is between 400 and 900kg. Females often have smaller bodies and horns (Phillipps and Phillipps 2016). They seldom appear in the daytime, especially when they are highly threatened by predators or poachers (Gardner et al. 2014, 2016). Tembadau will come out in an undisturbed forest at dawn or early morning to forage and socialize (Gardner et al. 2016).

Unfortunately, the Tembadau population is declining due to forest fragmentation caused by habitat loss and illegal hunting for their meat or horns (Gardner et al. 2016). They are currently categorized on the International Union for Conservation of Nature Red List as endangered animals. Tembadau is listed in Schedule 1 as "Totally Protected" in the Sabah Wildlife Conservation Enactment 1997. This legislation forbids illegal activities such as hunting, consuming, possessing, or selling Tembadau and its parts. Gardner et al. (2021) have singled out that hunting pressure is the driving force causing the species' imminent extinction in Sabah. In 2015 in Sabah, only 87 individuals were recorded at Tabin Wildlife Reserve and Malua Forest Reserve. Deforestation and conversion to monoculture oil palm plantations play a significant role in forest fragmentation (Lim et al. 2021). In connection with the

forest fragmentation issue, Brodie et al. (2015a) proposed several wildlife corridors throughout Borneo that supports the survivability and sustainability of the existing mammalian community. Lim et al. (2021) presented spatial modeling on the habitat and movement of the wild Tembadau in Sabah that can be used to reconnect fragmented forests to conserve the species population. The critical role of salt licks as the vital habitat for Tembadau has been highlighted by Lim et al. (2021) in their spatial modeling for Tembadau.

According to the Sabah Wildlife Conservation Enactment 1997, natural salt lick must be protected. Mineral springs, ground containing salt, or any other mineral is considered a salt lick. It can be found in tropical and temperate regions, especially in South-East Asia (Lazarus et al. 2021; Maro and Dudley 2022; Pla-ard et al. 2022). Salt lick can provide mineral sources and animal feeding sites (Tawa et al. 2022). Identifying these sites for critical temporal use can be protected, managed, and monitored to avoid further human disturbances such as logging operations (Matsubayashi et al. 2007; Lim et al. 2022). Nevertheless, this crucial habitat is being exploited for tourism purposes (Wahab et al. 2020; Lim et al. 2022), which may have detrimental long-term effects on wildlife populations (Adewale and Alarape 2020) if not adequately deliberated (Moorhouse et al. 2017).

Tembadau is known to use the salt lick habitat (Matsubayashi et al. 2007; Gardner et al. 2014). Nevertheless, the lack of research on the in-depth habitat usage of *Bos javanicus lowi* in salt lick areas may cause difficulties in monitoring the forest species' population, undermining the species' conservation efforts. Lim et al. (2021) have underlined the importance of studying the habitat usage of Tembadau to conserve endangered species. This study provides information on what kind of habitats are preferred by Tembadau (especially in salt licks) that can be used for the conservation of this species in the wild. It is hypothesized in this research that Tembadau has no habitat usage preference across the selected areas in the forest plantation of Sabah.

MATERIALS AND METHODS

Study area

The research was carried out on a forest plantation in a Forest Management Unit (FMU 19(B) in the Segaliud Lokan Forest Reserve (Figure 1), Sandakan District, Sabah, Malaysia (5°20' N and 5°27' N; 117°23' E and 117°39' E). Segaliud Lokan Forest Reserve (SLFR) is a commercial forest reserve (Class II) and has been logged since 1952. The vegetation in this SLFR is generally logged over Dipterocarp forest, with a land area of 57,247ha and mainly dominated by Meranti (*Parashorea* sp.). Other species such as Seraya majau (*Shorea leptoclados*), Kapur (*Dryobalanops lanceolata*) and Keruing (*Dipterocarpus caudiferus*) can also be found in the forest (SIRIM QAS International 2015). KTS Plantation is currently managing this Forest Plantation. In 1993, Sabah State Government gave a permit to KTS Plantation Sdn. Bhd. to manage FMU in SLFR, with a 96 years occupation lease. In 1998, KTS Plantation began to practice Reduce Impact Logging (RIL) methods in its forest management. RIL is the application of forest harvesting techniques that have a low impact and maintain the forest's productivity (Edwards et al. 2012). SLFR's forest management plan (FMP) was constructed and revised in the second and third FMPs to achieve sustainable forest management (SIRIM QAS International 2015; KTSP 2019). The company also received Malaysian Criteria and Indicators for Sustainable Forest Management and Environmental Management System ISO 14001:2015 (Kee et al. 2018). Tembadau has been reported by Kee et al. (2018) to inhabit the forest plantation managed by the company. However, their studies were concentrated on wildlife surveys that did not specifically target Tembadau. Several identified salt licks in SLFR serve as critical temporal use. However, there was little research on the ecological behavior of Tembadau in salt lick areas. As such, SLFR was chosen as the study site for this study.

Procedures

Camera trap survey

A purposive sampling was conducted using camera traps to collect the presence or absence and activity pattern of Tembadau. The camera traps were set up in four selected salt lick (C59SL, C60SL, C56SL, and C50SL) and three non-salt lick areas (C56NSL, C50NSL, and C59_60NSL) from 2 November 2019 to 6 September 2020. Non-salt lick areas served as a control for comparing Tembadau detection rates between stations with and without salt lick. Areas with no salt lick were paired with salt lick areas near to or located in the same compartment: i) C59SL and C59_60NSL; ii) C60SL and C59_60NSL; iii) C56SL and C56NSL; iv) C50SL and C50NSL). Each station was placed with a camera trap with passive infrared sensors to record the image of Tembadau. They were positioned at nearby trees at salt licks or wildlife trails in non-salt lick areas. The camera trap was set at about 1m height, corresponding to Tembadau's height. The camera traps operated for 24 hours and were set to capture one image for each detection (Prosser et al. 2016) with 30 minutes time interval, as the animal may stay longer at salt lick areas (Matsubayashi et al. 2014). Each camera trap condition and its batteries were checked each month, where possible, to ensure they were functioning.

Tembadau's detection rate and activity pattern

The images captured from seven camera traps were analyzed and identified based on library references (Phillipps and Phillipps 2016). The behavior of Tembadau was observed and recorded. In this study, only one event was counted when multiple events occurred within 30 minutes. This is to obtain sufficient data set for analyzing and proving the presence and absence of Tembadau within the monitoring period. Tembadau records' presence-absence was used to calculate the detection rate for each camera trap. The detection rate is the total number of Tembadau events divided by trap nights (the number of days multiplied by the number of functioning camera traps) (Meek et al. 2012).

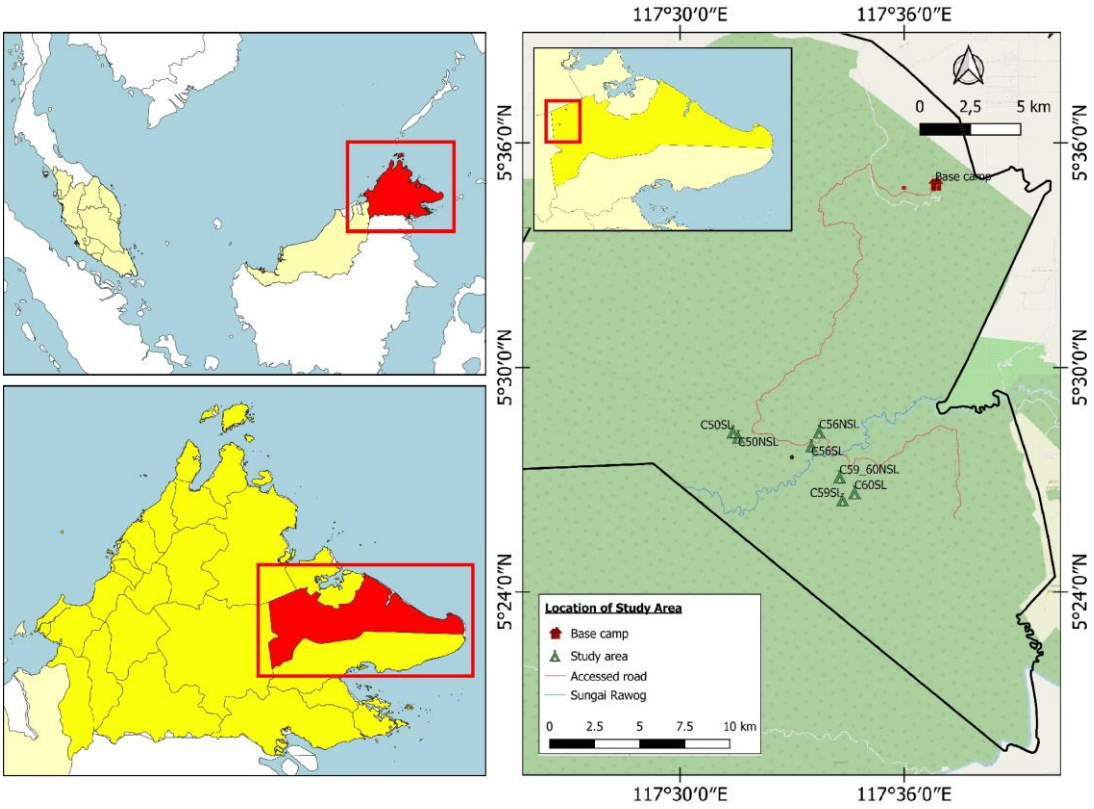

Figure 1. Map of Segaliud Lokan's FMU and camera trap stations labelled as C59SL, C60SL, C59 and 60NSL, C56SL, C56NSL, C50SL, and C50NSL

The frequency of visitation to the salt lick and non-salt lick areas per trap night was obtained through the number of images captured in two-hour intervals divided by the total number of images (Gardner et al. 2014). The activity pattern's categorizations are based on Hon and Shibata's study (2013), which categorized the time between 1900 to 0459 were nocturnal, 0700 to 1659 hours were diurnal, 1700 to 1859 hours and 0500 to 0659 hours were crepuscular.

Data analysis

The physical characteristics of the salt licks were systematically recorded and compared visually using photographs to understand more about the habitat usage of Tembadau in the study areas. A Mann-Whitney U test (U) was used to determine the significant difference in Tembadau event between a salt lick and non-salt lick areas. A Euclidean distance hierarchical cluster analysis was used to show the Tembadau event's dissimilarities in all salt and non-salt lick areas using PAleontological STatistics (PAST) software (Hammer 2020). The algorithm used for the dendrogram was UPGMA (unweighted pair group method with arithmetic mean).

$$d(p,q) = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2}$$

Where:

p,q: two points in Euclidean n-space

q_1, p_1: Euclidean vectors, starting from the origin of the space (initial point)

n: n- space

RESULTS AND DISCUSSION

Results

Habitat usage

The camera trap active days varied for each station. This was due to the camera running out of batteries, battery failure, or ants building nests around the camera, causing malfunction. Camera trap days in this study ranged from 15 to 96 days. Through this study, three types of salt lick were observed and defined as active, moderate, and less active. The active salt lick was categorized primarily based on the Tembadau events collected during the camera trap survey and then classified based on the total number of other ungulates events captured in the area (Table 1). The ungulates species that were detected were the bearded pig (*Sus barbatus*), Borneon pygmy elephant (*Elephas maximus borneensis*), and sambar deer (*Rusa unicolor*).

Active salt lick in this study is referred to as the salt lick area with the highest number of Tembadau events and the total number of other ungulates events, such as C59SL (26 Tembadau events, 302 other ungulates events). Hootprints of the ungulates can be seen throughout the muddy and flat land in C59SL, indicating that this camera trap station was frequently visited by wildlife (Figure 2A). The moderate level is referred to as salt lick areas with at least one

Tembadau event. Multiple events of other ungulates were recorded in the station, such as C60SL and C50SL. Although C60SL has the lowest total number of other ungulates events (50 events), it has detected one Tembadau event. The multiple hootprints in the area also indicated that it was moderately visited by other ungulates (Figure 2B). C50SL has also detected one Tembadau event with 79 other ungulates events (Figure 2C). The less active salt lick in this study was referred to as salt lick with no Tembadau events and multiple other ungulates events around the area. C56SL was considered a less active salt lick, as there was no Tembadau recorded in this station. However, it was visited by other ungulates (Figure 2D). The detection rate of Tembadau was highest in C59SL (0.2708), followed by C60SL (0.0667), C50NSL (0.0400), and C50SL (0.0256). C59_60NSL, C56SL, and C56NSL have the lowest detection rate (0.000), as no Tembadau events were recorded (Figure 3). The results show Tembadau has a higher habitat usage preference in salt lick areas than non-salt lick.

The Euclidean distance hierarchical cluster analysis (Figure 4) shows that active salt lick areas differed from non-salt lick areas in Tembadau events. It has shown that C59SL, with the highest Tembadau event, was the most distinct and furthest away from other stations. C60SL, C50NSL, C50SL, C59_60NSL, C56SL and C56NSL were in one cluster, but C60SL, C50NSL, and C50SL were in the sub-cluster as they each detected one Tembadau event. C59_60NSL, C56SL and C56NSL were similar to a sub-cluster with no Tembadau event detected.

Table 1. The number of Tembadau events and the total number of ungulates events for each camera trap station with a salt lick

Camera trap station	Number of Tembadau events	Total number of other ungulates events
C60SL	1	50
C59SL	26	302
C56SL	0	67
C50SL	1	79

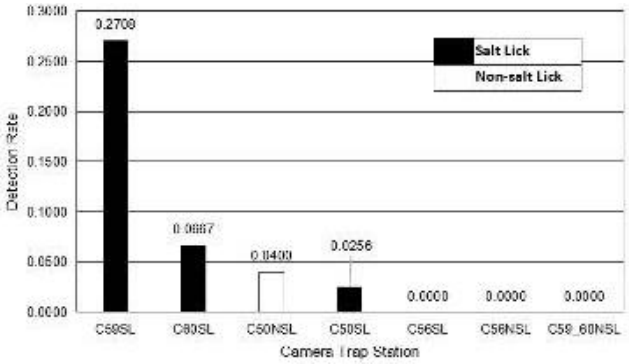

Figure 3. The detection rate of Tembadau at the seven stations

Figure 2. The four salt licks compare the wildlife tracks imprinted on the surrounding area. A. The salt lick at C59 which was biggest size and flat; B. The salt lick at C60; C. The salt lick at C56; D. The salt lick at C50. Based on the visual comparison from the photographs, Tembadau frequently uses a flat area with no boulder obstructions, easy access and free from interference

The Tembadau habitat usage at SL was significantly higher than those at NSL (Table 2). The result was statistically very significant, especially between camera trap station C59SL and C59_60NSL (U: 3187.5, p=0.003**). The results for station C60SL (moderately active salt lick) and C59_60NSL was also statistically significant (U: 525.0, p=0.025*). The comparisons for other stations showed no significant difference (U: 1303.5, p>0.05).

The results indicated that active salt lick has a higher detection rate of Tembadau than non-salt lick areas, especially compared between C59SL (0.2708) and C59_60NSL (0.000), which was statistically very significant. Moderately active salt lick with the non-salt lick areas (C60SL and C59_60NSL) was also statistically significant. Tembadau events were higher in active and moderate salt lick areas than in non-salt lick areas. Based on the visual comparison of the physical characteristics of salt licks and the statistical analysis results, it shows that Tembadau prefers salt licks that is a flat area with no boulder obstructions, easy access, and free from interference.

Activity pattern

The highest frequency of activity of Tembadau in salt lick was between 1800 to 1859 hours with four events (Figure 5), followed by 0200 to 0259 hours and 1200 to 1259 hours (three events). The Tembadau was primarily nocturnal in salt lick areas, as 12 events (43%) occurred at night. During the daytime, Tembadau events were also recorded (n: 9, 32%), and they also showed crepuscular behavior (n: 7, 25%). The Tembadau visitation in non-salt lick areas was between 1900 to 1959 hours with one event only. The overall results indicated that Tembadau expressed nocturnal, diurnal and crepuscular behavior in SLFR, where nocturnal behavior was expressed the most.

Table 2. Mann-Whitney U test for station comparison between salt lick and non-salt lick

Station comparison	*n*	Mann-Whitney U (*U*)	p-value
C59SL and C59_60NSL	171	3187.5	0.003**
C60SL and C59_60NSL	90	525.0	0.025*
C56SL and C56NSL	112	1303.5	1.000
C50SL and C50NSL	64	1303.5	1.000

Note: **Very significant; *significant

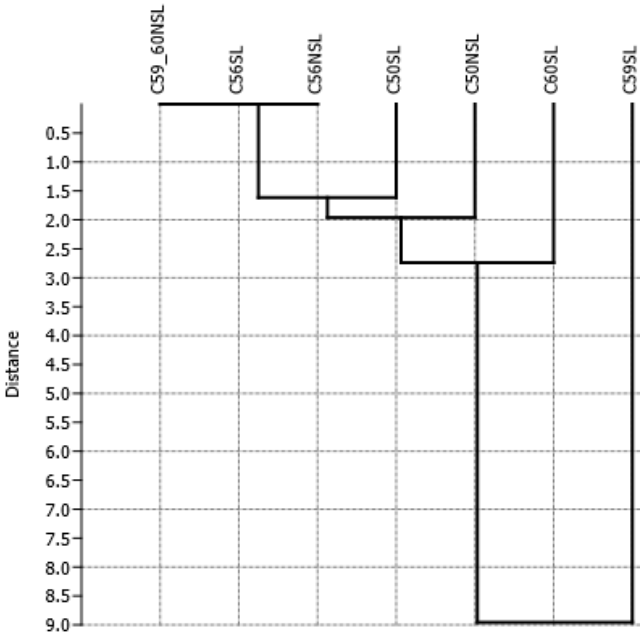

Figure 4. The similarity for each station based on Tembadau event using Euclidean distance hierarchical cluster analysis. The results show that the habitat usage by Tembadau was not consistent across the salt licks and non-saltlicks areas

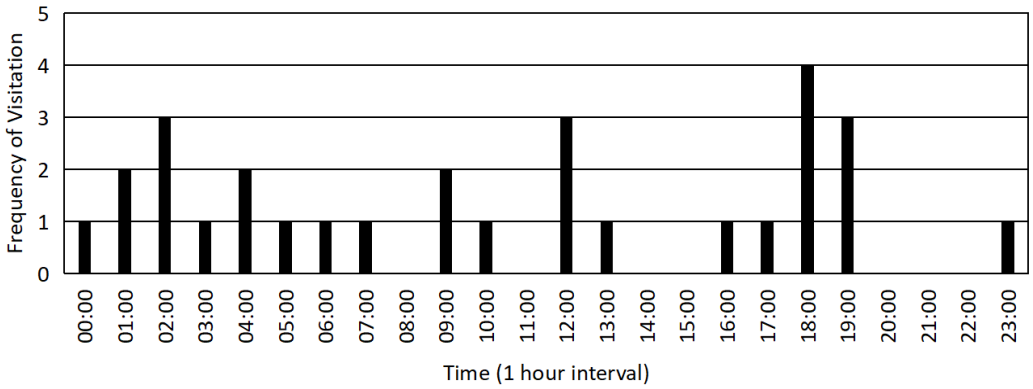

Figure 5. The temporal habitat usage based on the frequency of visitation in the one-hour interval by Tembadau at salt lick areas

Discussion

Based on this study, Tembadau has higher habitat usage in salt lick than in non-salt lick. In addition, the habitat usage by Tembadau was not similar in all the salt licks. Salt lick, especially C59SL, has a higher detection rate of Tembadau than non-salt lick areas. Mojiol and Lim (2022) conducted research at the same study site and reported high visitation of Tembadau at C59 salt lick. Sompud et al. (2022) reported that the salt lick at C59SL is also preferred by the Bornean pygmy elephant (*Elephas maximus borneensis*). They further suggested that the physical attributes of the salt lick, which is undulating flat and large in size compared to all four salt licks, attract wildlife to it. Lazarus et al. (2021) and Razali et al. (2022) reported that the topographic variable of salt licks does affect the habitat usage of wildlife in that area.

Tembadau is a frequent salt lick visitor in the forest (Phillipps and Phillipps 2016). Natural salt licks may serve as nutrient supplementation sites for nutrient deficiency and stabilize rumen pH for large herbivores (Matsubayashi et al. 2007; Chew et al. 2014) such as Tembadau. This habitat usage behavior increases their chances of survival in the forests. Herbivores such as Tembadau may consume nutrients in salt licks when surrounding plants are low in minerals, especially sodium, which is seldom found in plants (Matsubayashi et al. 2014). This behavior may occur in SLFR, as it is a tropical inland forest where plants may be low in major cations such as sodium due to the distance from sodium supply sites such as the ocean and high rainfall that cause leaching (Dudley et al. 2012).

By consuming carbonates in salt licks, herbivores (Lavelle et al. 2014) such as Tembadau may be able to stabilize rumen pH and prevent acidosis, especially when they produce less saliva during seasonal forage changes or weather changes. Saliva is an essential buffering solution with bicarbonates and phosphates that neutralize the rumen's acids. Rumen and blood pH of the wildlife may decrease when there is a decrease in saliva, which can cause eating disorders such as anorexia and diarrhoea (Lavelle et al. 2014). Salt lick with high carbonate content may help ruminants (Molina et al. 2014), such as Tembadau, increase buffering capacity and adjust rumen pH. These functions of salt lick may be the primary purpose of Tembadau using the habitat at salt licks. It requires further study by examining salt licks' chemical content, Tembadau feeding behavior, and nutrients of Tembadau's food sources in SLFR. Mojiol and Lim (2022) reported that salt licks at SLFR have different concentrations of minerals available in those salt licks. However, one of the stations with a salt lick, C56SL, did not have any Tembadau events. This observation may have been caused by other environmental characteristics that were not favorable to Tembadau, such as distance to the river, the accessed road and the mineral contents in the lick.

Tembadau did not use only one salt lick (C56SL) in this current study. This observed result might be because it was nearer to the accessed road and the Sungai Rawog than the other salt licks. The primary road was the main road built across the forest reserve, allowing KTSP staff to access different compartments to carry out forest operations or monitoring (KTSP 2019). Compartment 56 is categorized as a protection zone under the current management of KTSP. The low Tembadau events indicate that the species may still be affected by the previous harvesting operations or other factors that have not been identified. In this study, Tembadau was also detected using the non-salt lick area (C50NSL) but at a much lower frequency. The non-salt lick areas may serve as a part of the pathway to travel to salt licks and food for forage. Matsubayashi et al. (2007) reported that Tembadau often visits areas with available food sources, such as grasses or herbs, that the species prefer. Brodie et al. (2015b) conducted a wildlife survey in selectively logged forests in Borneo and presented that in the absence of hunting, disturbed forests become an important conservation area for endangered and vulnerable species. The Tembadau population in SLFR was able to persist, indicating that the hunting is at a minimal level here due to the active manned gate stationed at the entry point of the concession by KTS Plantation.

Tembadau, in this study, expressed all diurnal, nocturnal and crepuscular behavior in SLFR, especially in salt lick areas. These findings were similar to the previous study by Gardner et al. (2014) on Tembadau, where they found the species to be present day and night. Whereas there was only a one-night event showing Tembadau was foraging in non-salt lick areas. The activity pattern results may require further study as they may not represent a good comparison between a salt lick and non-salt lick areas since non-salt lick areas only detected one event.

In this study, Tembadau appeared during the day but was less active. Tembadau activity frequency is affected by temperature (Lim et al. 2021). There was less activity frequency of Tembadau during higher temperatures. Gardner et al. (2016) reported that Tembadau would forage in the daytime when there was a low human disturbance in the forest. The access road for most of the southern part of SLFR is no longer accessible. During our visit to C59SL and C60SL, the roads were also covered by dense vegetation indicative of low human disturbances through the access road. Tembadau also showed crepuscular behavior (1700 to 1859 hours and 0500 to 0659 hours), where the highest frequency of activity was between 1800 to 1859 hours. Similar findings were reported by Lim et al. (2021). Another study by Rahman et al. (2019) on Javan Banteng also reported similar crepuscular behavior, active between 1700 to 1900 hours. Tembadau appears nocturnal in Sabah and seldom appears in the daytime in places with high human disturbance (Gardner et al. 2014, 2016). Between the 1950s and 1990s, SLFR was continuously harvested using conventional logging. The land around the forest was converted into oil palm plantations, altering the area's ecology (KTSP 2019). Due to the previous human disturbance, Tembadau may still be affected. This study has shown that Tembadau mainly expresses nocturnal behavior. Their nocturnal behavior can be due to previous human disturbances in the area.

Salt licks are beneficial for wildlife's essential elements intake, health, and reproductive success. Tembadau prefers salt lick, which has a flat area with no boulder obstructions, easy access and is free from interference. As such, salt licks

with these physical characteristics need special protection as they are very critical habitat for Tembadau species conservation. These findings are important for policymakers to make informed decisions for the total protection of salt licks, especially in forest plantations. The management authorities should use recent advanced remote technologies, including IR4.0, IoT and UAV, for monitoring and as an advanced warning system to alert ground rangers to protect Tembadau's population in SLFR. Forest managers can identify buffer zones that must be protected, managed, and monitored from human disturbances. In depth studies should be done on habitat structure, extreme weather patterns and environmental factors that may affect the detection rate and activity patterns of Tembadau. It is also recommended that further research on anthropogenic activities and poaching should be conducted to understand their relationship with Tembadau's presence around salt lick areas.

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