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DAILY ACTIVITY OF EARLESS MONITOR *Lanthanotus borneensis* STEINDACHNER, 1878 IN A CAPTIVE ENVIRONMENT

Amat Ribut[1], Evy Arida[2*], and Riyandi[1]

[1]*Department of Biology, Faculty of Mathematics and Natural Sciences, Tanjungpura University, Jalan Prof. Dr. Hadari Nawawi, Pontianak, West Kalimantan, Indonesia*
[2]*Research Center for Applied Zoology, National Research and Innovation Agency (BRIN), Soekarno Science and Technology Park, Jalan Raya Jakarta - Bogor km. 46, Cibinong 16911, West Java, Indonesia*
[*]*Corresponding author: evya001@brin.go.id*

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ABSTRACT

The earless monitor (*Lanthanotus borneensis* Steindachner, 1878) is a rare and endemic species of lizard to the island of Borneo. Individuals of this species were often culled to supply the international pet market and have been kept in captivities, also in the northern temperate areas. This study aimed to describe the daily activities of *L. borneensis* at the reptile house of Museum Zoologicum Bogoriense (MZB), a live animal research facility of the former Indonesian Institute of Sciences (LIPI) – now merged into BRIN. Focal animal sampling was used to observe *L. borneensis* behavior for two hours per individual in the morning (09:00–11:00) and afternoon (15:15–17:15) with the assistance of surveillance cameras (CCTV), resulting in a total observation time of 16 hours per individual per two months. The observations of 10 individuals of *L. borneensis* showed that they were more inactive in the morning, with a tendency to be more active and feeding in the afternoon. During inactivity, lizards remained motionless in the bamboo; when active, they were moving in water and foraging.

Key words: behavior, ex-situ habitat, focal animal sampling, food preference, Lanthanotidae

INTRODUCTION

Lanthanotus borneensis Steindachner, 1878 (earless monitor) is the sole surviving member of the Family Lanthanotidae and is endemic to Borneo. The lizard is elusive in its natural habitat and so far was only found in the lowlands of Borneo (Langner, 2017; Das & Auliya, 2021). Human activities pose an increasing danger to the natural habitats of earless monitor. These activities include habitat degradation resulting from plantation development (Curran et al., 2004), agriculture, and mining (Yaap et al., 2012). Additionally, poaching and illegal trade pose significant threats, with the black-market trade operating on both national and international scales (Nijman & Stoner, 2014). Currently, the species is listed in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and given the status of Endangered (EN) in the IUCN Red List of Threatened Species.

Laboratory-based studies on *L. borneensis* have been conducted, including analysis of morphological description (Arida, 2015), anatomy (Rieppel, 1983; Maisano et al., 2002), taxonomy and phylogeny (Lee, 2005), and evolution (Ast, 2001; Conrad et al., 2014). However, studies on activity patterns of *L. borneensis* and other species of reptiles are relatively rare

compared to species belonging to other animal groups, such as birds and mammals (Liu et al., 2007). Lizards, on the other hand, are often seen as excellent models for the study of behavioral evolution (Langkilde et al., 2003).

Previous studies describing activities of *L. borneensis* reported behavior of submerging in water without surfacing for 36 minutes, raising nostril to the water surface to take air (Harrison, 1961), mating and egg-laying (Shirawa & Bachini, 2015), putative agonistic behavior and feigning death (*thanatosis*) (Langner, 2017), as well as feeding in captivity (Al Ryzal, 2017; Arroyyan et al., 2021). *L. borneensis* is thought fossorial, semi-aquatic, and nocturnal, given its morphological structure (Harrison, 1961) and time of encounter in the wild (Yaap et al., 2012; Langner, 2017). This study aimed to determine the daily activities of *L. borneensis* and confirm the mentioned traits.

MATERIALS AND METHODS

Animals and Management of Experiments

The observation was conducted from May to June 2019 at the Reptile House of Museum Zoologicum Bogoriense (MZB), a live animal research facility of the former Indonesian Institute of Sciences (LIPI) – now merged into BRIN. Lizards came from confiscation events at Soekkarno-Hatta International Airport, Jakarta in 2014 and 2018. These animals were given care at the reptile house in fish tanks and fed with diverse prey choices to determine their preference; however, lizards tend to prefer earthworms and shrimp pieces (Al Ryzal, 2017). Thus, earthworms (*Lumbricus* sp.) – P1 and shrimp pieces (*Litopenaeus* sp.) – P2 were fed to lizards during observation periods.

The Focal animal sampling method (Altmann, 1974) was applied to collect data on daily activity of the Earless monitor with the help of five (5) CCTV (Closed Circuit Television) cameras. Activity data were not categorized in sex and age due to the difficulty of accurate determination. Prior to observation period, lizards were acclimatized for two weeks and fed with earthworms and shrimp pieces. Recorded observations were made twice a week (Wednesdays and Saturdays) for all ten (10) individual lizards (ID number I to X), i.e five individuals each day. Observations for diurnality were made at 09:00 – 11:00; whereas for nocturnality at 15:15 – 17:15, when the fish tanks and cameras completely covered with tarpaulin to generate darkness/ evening ambience.

Body Size Measurements

The body size of all ten (10) *L. borneensis* individuals was measured as Snout-Vent Length (SVL) to the nearest 0.1 cm and Body mass (BM) to the nearest 0.01 gram. Body mass was taken at one-monthly intervals, namely before the start of observations, during the observation period, and at the end of all observations in this study.

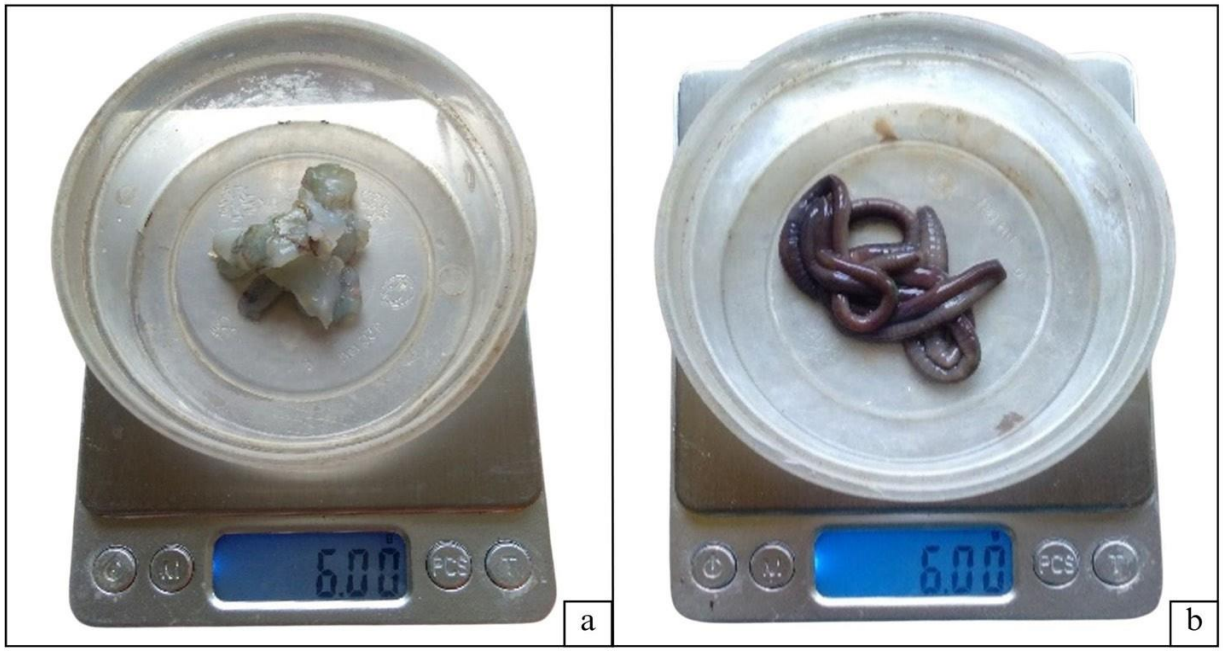

Figure 1. Types of feed given during the study, **a**. shrimp pieces (*Litopenaeus* sp.), **b**. earthworms (*Lumbricus* sp.)

Food Item Preference

Food items were placed in each of the fish tanks just before the diurnal recording began. Shrimp pieces were fed for the first four weeks and earthworms were fed for the following four weeks. The shrimp pieces were prepared by removing its shell and cutting only the flesh into smaller parts (Fig. 1.a). The earthworms were kept frozen for storage before being fed to the lizards for observations (Fig. 1.b). Each individual lizard was given 6.00 g of either food item. To determine preference, food item was given to both recorded and unrecorded individuals (Fig. 2).

Daily Activity

The observed behaviors during the experiment were categorized as still/inactive, active, and feeding, as the lizards dominantly showed these three **(**Table 1.**).** Ten individuals of *L. borneensis* were observed in turn. For one observation with CCTV, five *L. borneensis* were placed in observation tanks, one individual in each tank (Fig. 2.A), while the other five individuals (unobserved individuals) were each put into a single chamber (Fig. 2.B). Activity observations were made on Wednesdays (individuals I–V) and Saturdays (individuals VI–X). For one month and one type of food, each individual was observed four times. Over two months, each individual was observed eight times with a duration of 120 minutes per individual per observation, totaling 8 x 120 minutes per individual (16 hours per individual).

Environmental Parameters

Air temperature and humidity were environmental parameters measured using a Thermohygrometer. Water acidity was measured using pH Universal Indicator paper. The obtained air temperature and humidity were calculated as the average of values before and after recording; the value of the water acidity level was taken just before the recording began.

Table 1. Ethogram of *Lanthanotus borneensis* (modified from Greenberg, 1977; Torr & Shine, 1994; Langkilde *et al*., 2003)

No	Activity	Description
	Inactive (I)	*L. borneensis* is motionless.
1.	inside a bamboo - I.1	remaining in bamboo hollow
2.	under a wood/bamboo -I.2	remaining under wood or bamboo
3.	inside a burrow - I.3	remaining in a mud burrow
4.	underground (whole body) - I.4	remaining completely underground
5.	underground (snout visible) - I.5	remaining underground but tip of snout visible on soil surface
6.	underwater (whole body) - I.6	remaining completely underwater
7.	underwater (snout visible) - I.7	remaining underwater but tip of snout visible on water surface
8.	on soil substrate - I.8	remaining on the soil surface
9.	floating - I.9	remaining motionless on water surface
	Active (A)	*L. borneensis* is performing any movement.
1.	anterior body movement - A.1	performing movements of anterior body parts, e.g head, forelimbs
2.	posterior body movement - A.2	performing movements of posterior body parts, e.g tail, hind limbs
3.	walking - A.3	moving on soil surface
4.	swimming - A.4	moving on water surface
5.	diving - A.5	moving in water and at bottom of a tank
6.	digging - A.6	moving forelimbs and snout to enter the soil substrate
	Feeding (F)	Movements of *L. borneensis* from foraging to ingestion of food.
1.	foraging - F.1	moving for food or to food items with or without moving the head to the right or left
2.	grabbing food items - F.2	biting off food items with its mouth
3.	bringing food items into water - F.3	carrying food items in its mouth into water
4.	swallowing - F.4	ingesting food items

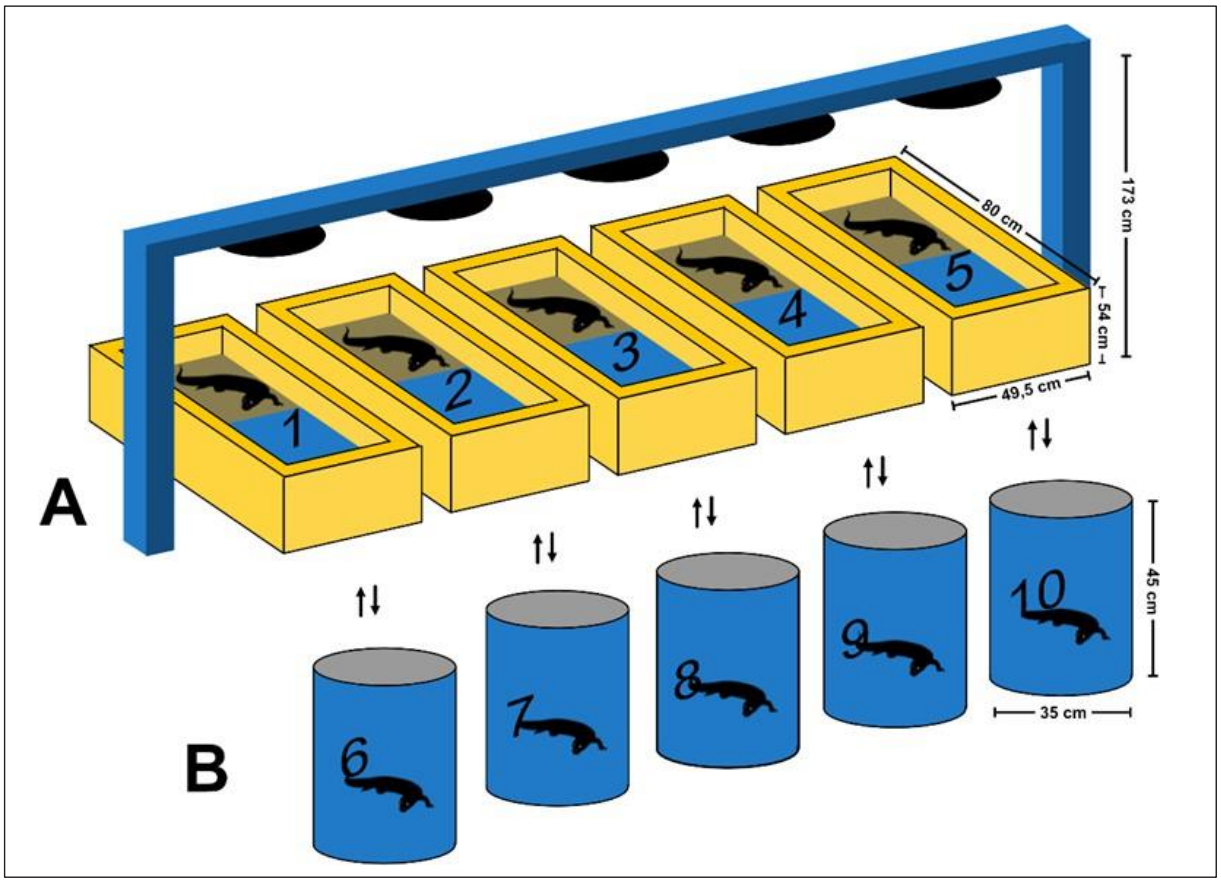

Figure 2. Design of observation tanks (a. Observation tanks with a CCTV above each of them to record activities and behavior of five *L. borneensis*, b. Chambers for keeping the other five *L. borneensis* without recording their activities.

RESULTS

Body Measurements

Body mass of all individual *L. borneensis* seemed to fluctuate during the course of observation but was almost always reduced post-P2, except for individual I. One individual was as light as 32.9 g (individual IV) during the acclimatization period, whereas another was as heavy as 107.8 g (individual III) during the second trial when fed with worms (Fig. 3). The average BM of individuals during acclimatization period (P0) was 54.5 ± 11 g; during the first trial (P1) was 63.9 ± 20 g, and during the second trial (P2) was 64.8 ± 20.8 g. After all trials were done (P3), the average BM decreased to 54.7 ± 25.8 g.

Snout-Vent Length (SVL) of all individual *L. borneensis* in this study was in the range of 16.5 – 20.1 cm. Individuals IX and X are relatively shorter and individual III was the longest among all samples. The average SVL during the acclimatization period was 17.8 ± 1.1 cm and during the second trial (P2) or after all trials done (P3) was 18.0 ± 1.4 cm. Table 2. shows SVL for each individual lizard at the beginning and at the end of this study.

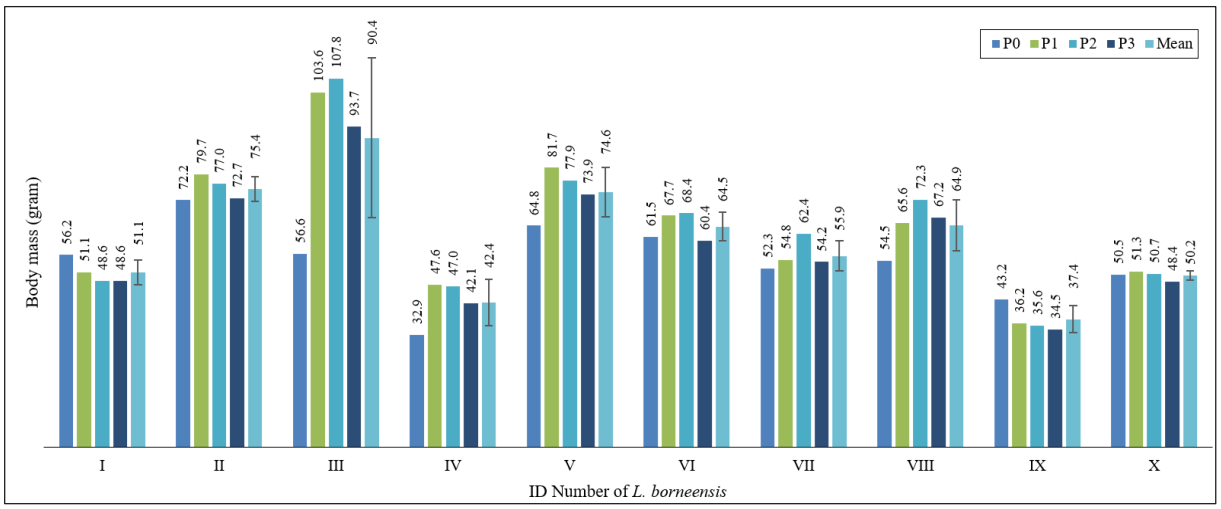

Figure 3. Body mass (BM) of individuals *L. borneensis* in left-to-right sequence at P0 (acclimatization), P1(shrimp meat), P2 (worms), and P3 (post-experiment).

Table 2. Body length of lizards in this study measured as Snout-Vent Length (SVL)

ID Number	Snout-Vent Length	
	acclimatization (P0)	post-experiment (P3)
I	18.0	18.0
II	18.7	19.0
III	20.1	20.1
IV	17.0	17.0
V	17.0	17.2
VI	17.0	17.3
VII	18.3	18.6
VIII	19.0	19.5
IX	16.5	16.5
X	16.5	16.8
average	17.81 ± 1.21	18.00 ± 1.24

Preference for Food Items

Preference for a particular food item was determined by the frequency the item was taken by an individual lizard. For each item, there were four chances for the lizards to feed on. Lizards tend to prefer earthworms (P2) than pieces of shrimp (P1). Almost all individuals took the earthworms at least once in four chances, especially when not recorded (R-). Four and one lizards did not take shrimp pieces during recording and in the chamber (Fig. 5), respectively. Moreover, six individual lizards, i.e., III, IV, V, VI, VII, VIII offered with earthworms, readily took the item at full frequency (four times out of four chances). On the other hand, only two individuals, i.e., II and IV taking shrimp pieces at full frequency, especially when not recorded (Fig. 4).

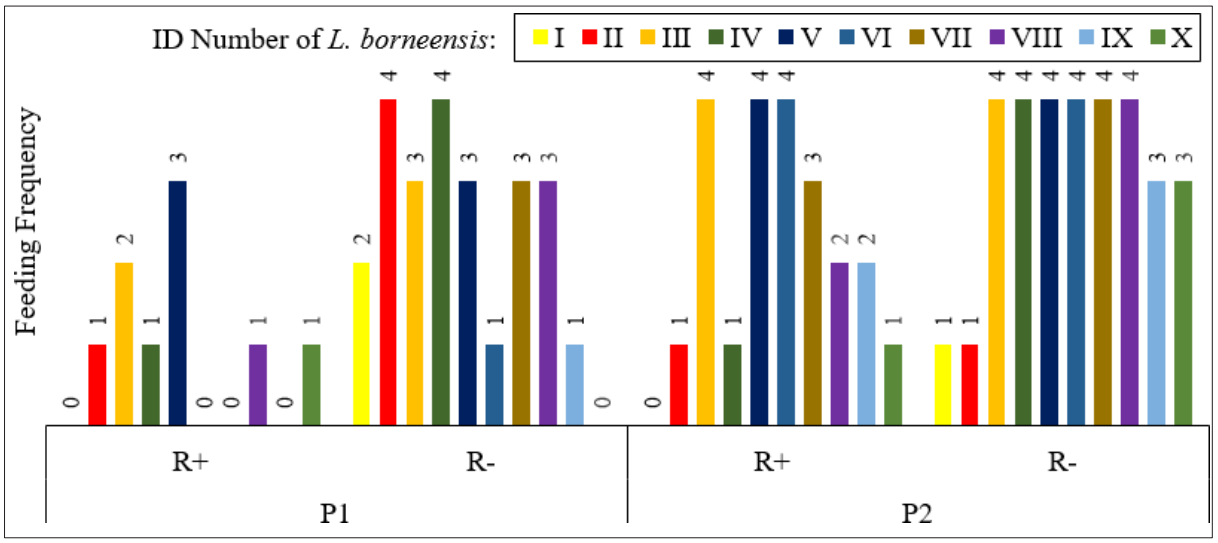

Figure 4. Feeding frequency of *L. borneensis*. R+ (recorded, in observation tanks), and R- (not recorded, in chambers) offered with shrimp pieces (P1) and earthworms (P2), respectively

These lizards (Fig. 5) seemed to feed at night during the long recording break. There were some clues to the lizards' feeding behavior in a certain time slot during the course of the experiment, even when the cameras were off during a break. Reduced weight of leftover food items given to the lizards the previous day was found after overnight recording breaks between 17:15 and 09:00, indicating a feeding event or more during this time slot. Similarly, leftover food item was found reduced in weight after recording breaks between 11:00 and 15:15.

Figure 5. A view of an experimental tank for recording (left); a lizard was fed in a chamber (right) when not recorded.

Overall, all lizards fed on both food items provided in three time slots in the morning, afternoon, and evening. Only one individual, i.e., VIII fed during recording break in the late morning to afternoon. Some individuals fed more frequently than others, for example indivduals III, IV, and V, than individuals I and X. In this case, individuals with higher feeding frequency also fed more frequently during the long overnight camera break, which lasted almost 16 hours (Table 3).

Table 3. Observed (recorded) and assumed (recording break) feeding periods of *L. borneensis*

ID Number	morning/ recorded (09:00 – 11:00)	afternoon/ break (11:00 – 15:15)	evening/ recorded (15:15 - 17:15)	overnight/ break (17:15 – 09:00)	Total
I	0	0	1	2	3
II	2	0	2	5	9
III	4	0	6	5	15
IV	5	0	2	6	13
V	4	0	4	7	15
VI	2	0	2	7	11
VII	3	0	2	5	10
VIII	1	1	3	5	10
IX	1	0	1	6	8
X	0	0	0	5	5
Total	22	1	23	53	

Daily Activity

All individual lizards were primarily inactive and remained motionless almost the entire time during recording sessions in the mornings and afternoons, with an average of at least 93% of the recorded observation period. On average, these lizards were active only for about 7% (8.27 minutes) of the recording time in the evening when fed with earthworms. More so, they were active for less than three minutes in the evening, when fed with pieces of shrimp. The mornings were relatively calm for these lizards, with minimum activity observed on camera (Fig. 6).

During inactivity, the lizards were dominantly remaining inside a bamboo hollow, inside a burrow, and underwater but with snout visible (Figs. 9: I.1, I.3, and I.7, respectively). The average proportion of time to remain inactive in the observation tanks ranged from 27.48% of recording time for remaining inside a bamboo hollow to 1.80 % for remaining completely underwater. The lizards seemed to remain completely underwater or underground for shorter moments, i.e., 3.75% and 1.80 – 5.46%, respectively, compared to when they remained in some kind of shelter or on open parts of the tanks but with their snout visible on the surface of the substrate.

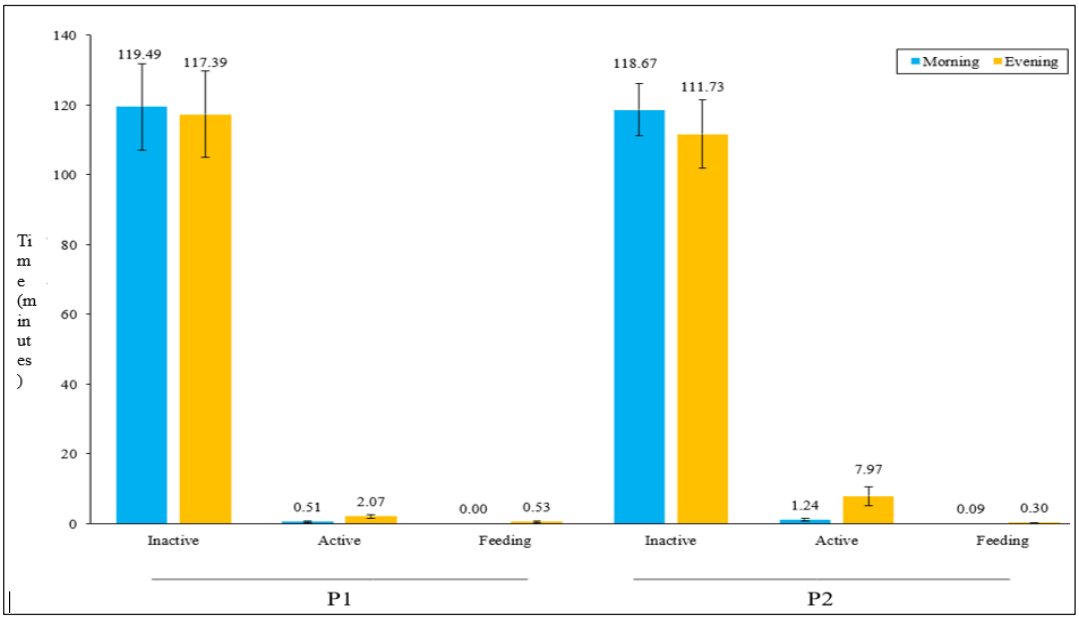

Figure 6. Average times spent for daily activities of *L. borneensis* during 120 minutes of recorded observation

When active, the lizards were mostly observed moving underwater (0.39 – 3.71%). Separately, lizards' feeding behavior is mainly foraging for less than 0.3% of the recorded observation period or about 20 seconds. Moving about and feeding activities, i.e., A.4 and F.1, respectively, tend to occur during the evening session of the observation (Fig. 7). During this session, the observation tanks were completely put under a tarpaulin cover to create darkness between 15:15 to 17:15 hours of local time.

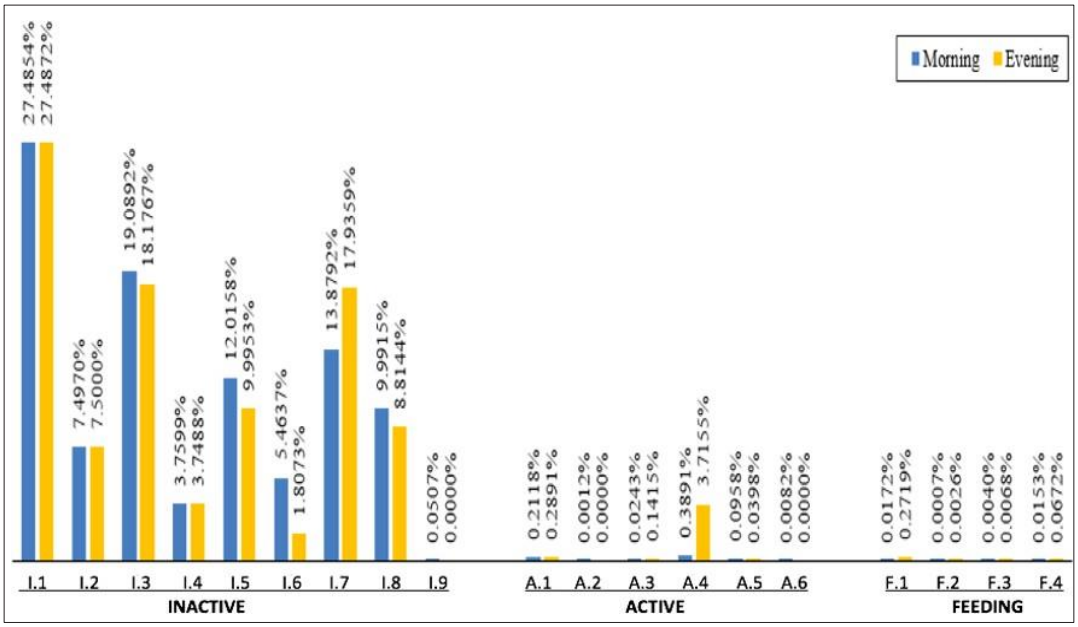

Figure 7. Proportion of time spent inactive, active, and feeding during recorded observations.

A few of the lizards are likely more active than the others for particular food item given, except individual VI. Individuals IX and X, for example, tend to be active when given shrimp pieces than earthworms. On the other hand, individuals V and VIII were more active when fed with earthworms than shrimp pieces. Individual VI was always active for longer time, regardless of given food items (Fig. 8).

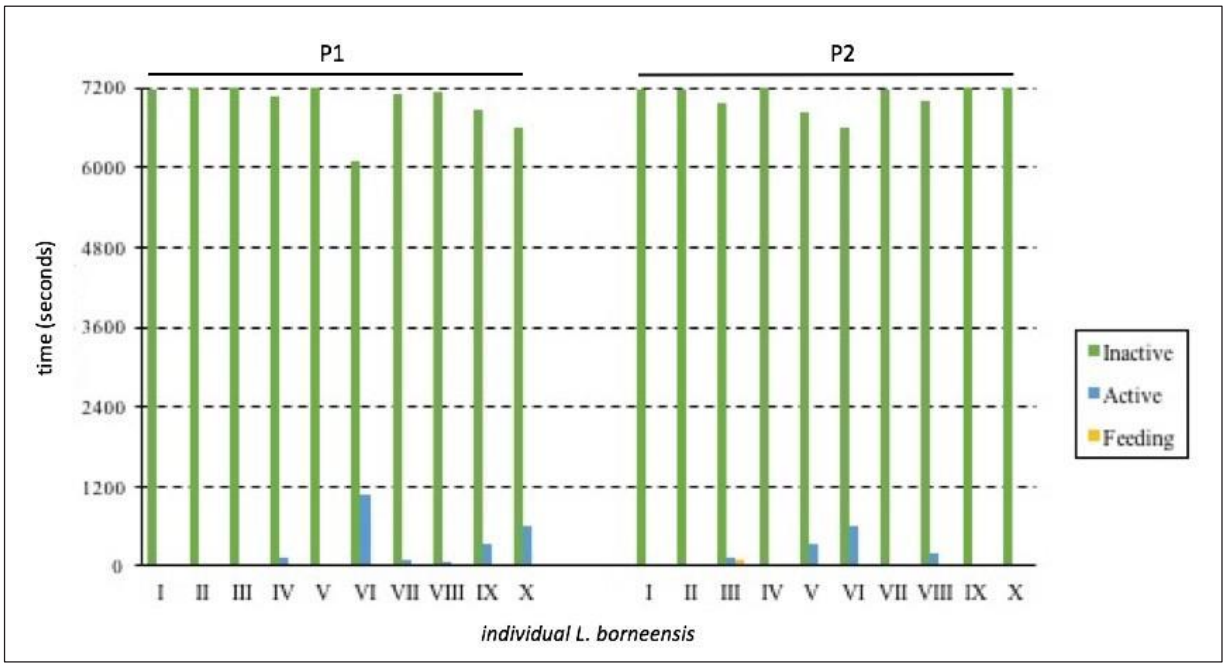

Figure 8. Distribution of time spent by ten *L. borneensis* during recorded observations for three activity categories.

The acidity level (pH) of water in the observation tanks during the experiments was constant at 6. Average air temperature at the Reptile House in the mornings was slightly higher than those in the evenings of May and June 2019. Similarly, the humidity level was higher in the mornings than in the evenings of May 2019; however, it was lower in the mornings than in the evenings in June 2019 (Table 4).

Table 4. Environmental parameters in P1 (May) and P2 (June)

Treatment	Parameters	Times	Mean	SD
P1	Temperature (°C)	Mornings	27.79	1.52
		Evenings	26.64	1.55
P2		Mornings	28.35	0.93
		Evenings	27.69	0.46
P1	Humidity (%)	Mornings	85.63	5.79
		Evenings	83.63	7.36
P2		Mornings	79.88	6.83
		Evenings	82.75	7.19
P1 and P2	pH		6	6

Figure 9. Positions of *L. borneensis* in the observation tanks during inactivity.

DISCUSSION

All individuals of *L. borneensis* in the recording experiments were more inactive than active for most of the time. There were feeding activities observed during the morning and dark (evening) sessions, indicating positive responses of most individuals to both food items given. However, lizards tend to prefer earthworms to shrimp pieces (Fig. 4) and fed more frequently during the overnight recording break. These findings lead to our next hypothesis, that *L. borneensis* forages after dusk in its original habitats (but see Arroyyan et al., 2021, for captive experiments). Thus, such darkness generated during the recording session between 15:15 and 17:15 was likely a cue for the lizards to forage. In fact, lizards showed movements of their head or forelimbs on soil substrate or on water surface and simultaneously moved in the direction the food item provided during this recording session (Fig. 7).

When inactive with their whole body submerged underwater or underground, these lizards remained in this posistion only for a relatively short period, approximately for 4.5 and 6.6 minutes, respectively. In contrast, these lizards remained much longer in a position of inactivity, when there was some kind of cover, such as in a bamboo hollow. These lizards also showed a prolonged inactivity positions on some open parts of the tanks, but with their snout protruding on the surface of soil substrate or water (Figs. 7, 9: I.5, I.7, I.8).

Movements of *L. borneensis* during the experiments were primarily performed in water, while the lizards remained motionless mostly on soil substrate (Fig. 7). This observation is consistent with an observation made in the species' natural habitat on Kalimantan (Langner et al., 2017). Our finding on swimming activities also confirms that this species is semi-aquatic, with a preference for living and probably reproducing underwater (Thewissen & Nummela, 2008; Bauer & Jackman, 2008). During the recording sessions, these lizards were moving in water, mostly in the dark. However, they were also observed to forage on soil substrate, when food item was provided. Other than feeding and foraging, lizards mostly remained inactive on soil substrate. An individual was found digging the soil to create a tunnel before staying in for a prolonged time.

There might be a relationship between body size, feeding frequency, and time spent active in our samples; however, this was not statistically analyzed due to a small sample size (n=10). Instead, scrutiny of body sizes and activity patterns of a few individuals can shed light on this putative relationship. A large individual of 20.0 cm SVL, such as individual I, was found a frequent feeder, gained significant BM but not SVL, and spent almost no time active than for feeding, especially on earthworms (Fig. 8, P1 *vs*. P2). Individual V was of 3.0 cm-shorter SVL than individual III but fed as frequently, more active than individual III, especially for other activities than feeding, and grew a slight BM and SVL at the end of the whole experiment. Individual VI was 17.0 cm of SVL and with similar feeding frequency to individuals III and V, i.e., 11 and 15, respectively. This lizard was the most active among all individuals in this study (Fig. 8.) and grew a slight SVL but was with reduced BM than before the experiment (Figs. 3 and 4).

All three individuals III, V, and VI consistently took earthworms at full frequency during the experiment P2; however, individual VI fed slightly less frequently than the other two (Fig. 4.; Table 3.). It is interesting to note, that such frequent feeding is not always a cue for more active time. Individuals III and V remained inactive for most of the time on camera despite being the most frequent feeders. Yet, individual VI was the most actively moving and seemingly also for other activities than feeding (Fig. 8). This leads to a new hypothesis at this point, whether SVL of 20.0 cm or a size equivalent to older adult stage for this species, could prevent more movements than necessary for an individual. Thus, food intake of individual III was probably compensated as the significant increase in BM (but not SVL) than energy for movements. In contrast, an SVL of 17.0 cm or a size equivalent to younger adult stage in this lizard might permit more movements. Therefore, frequent feeding of individuals V and VI was compensated in growth, i.e., increased SVL and/or time spent active for movements other than feeding.

Our study is limited in its experimental replicates and length of recorded observations. Much about the lizards' behavior during the overnight break was unknown in this study. Current knowledge on their nocturnal behavior was based on limited observations, including experiments to capture the feeding behavior of *L. borneensis* in captivity during a period in the evening, i.e., 17:15 – 19:15 with a finding that most lizards were actively feeding before the sunset at 18:15 (Arroyyan et al., 2021). More recorded observations are needed to fill the gap in our knowledge on the nocturnal activities of this cryptic lizard, for example, whether these lizards were most active during the hours after the sunset. Furthermore, specific descriptions of behavior and activities based on sex and age/body size is now necessary, in order to elucidate more deeply the natural history of this endemic and endangered species.

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