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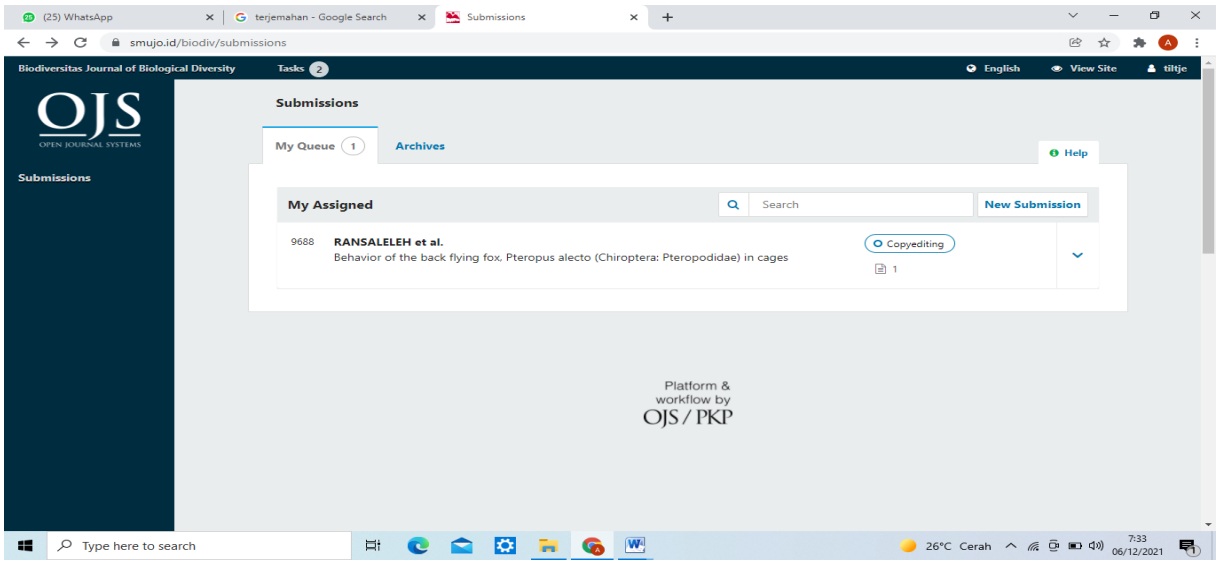
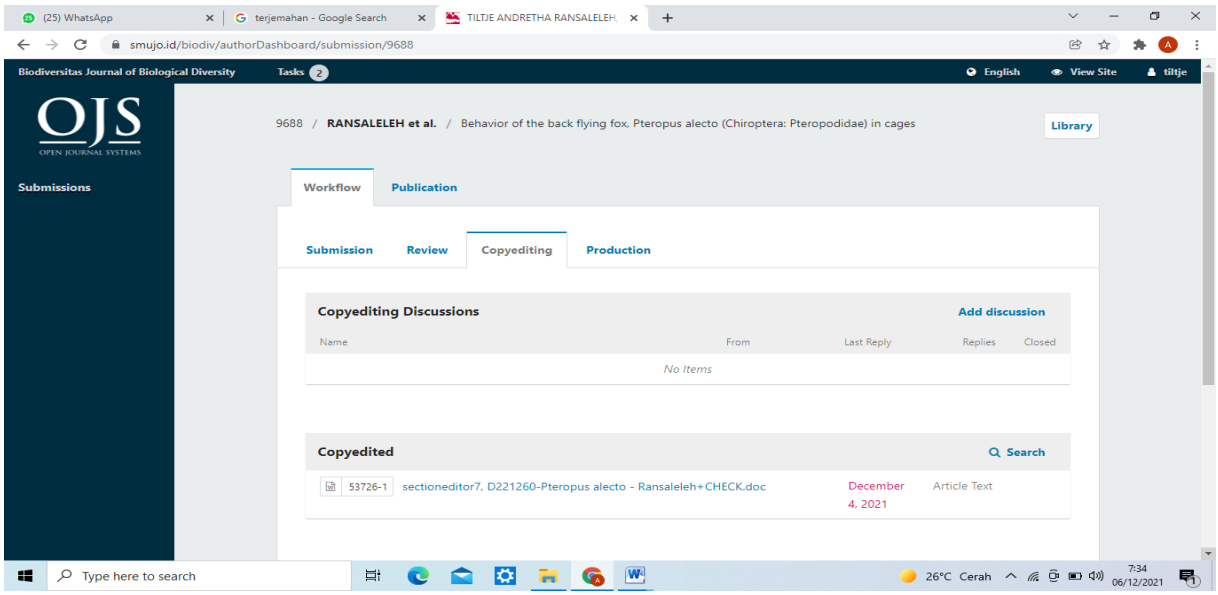
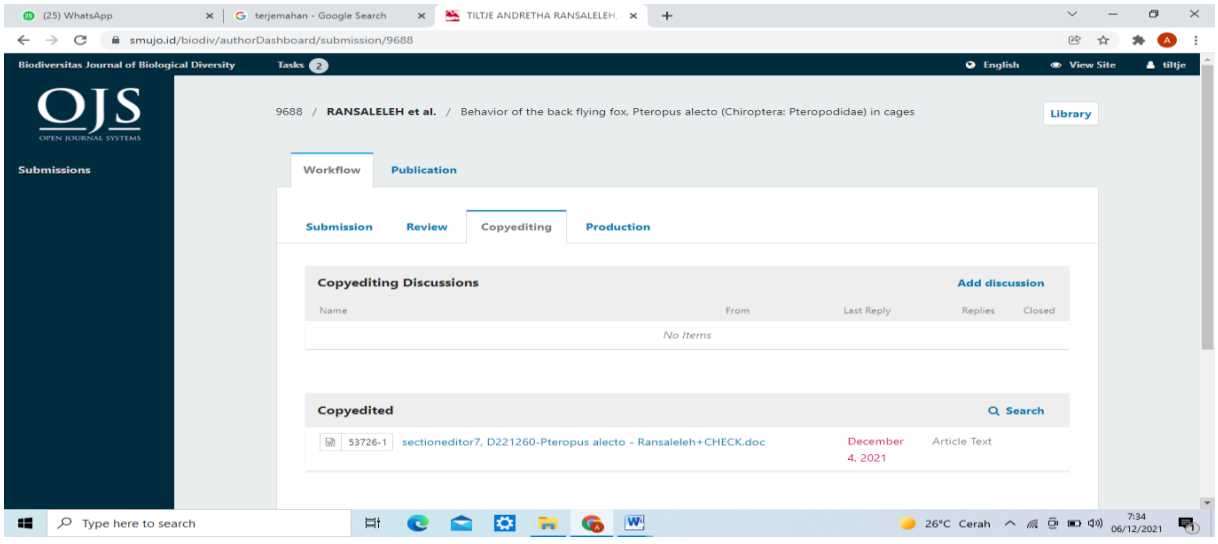
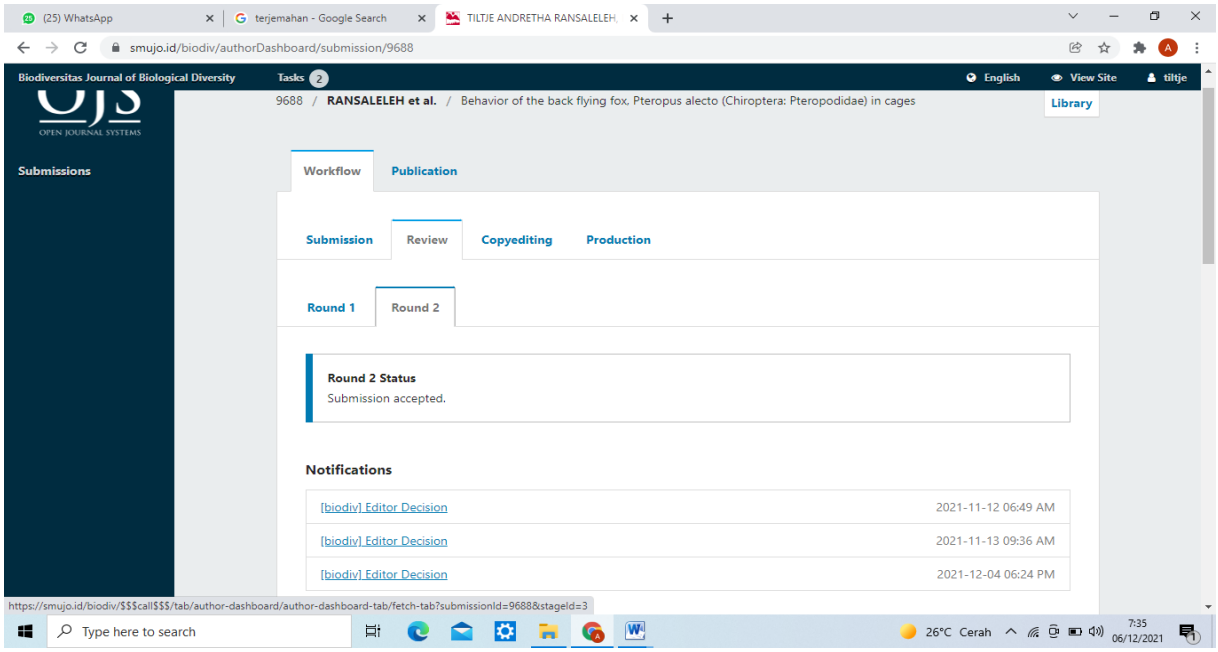
Judul : Behavior of the black flyng fox, *Pteropus alecto* (Chiroptera) in cages





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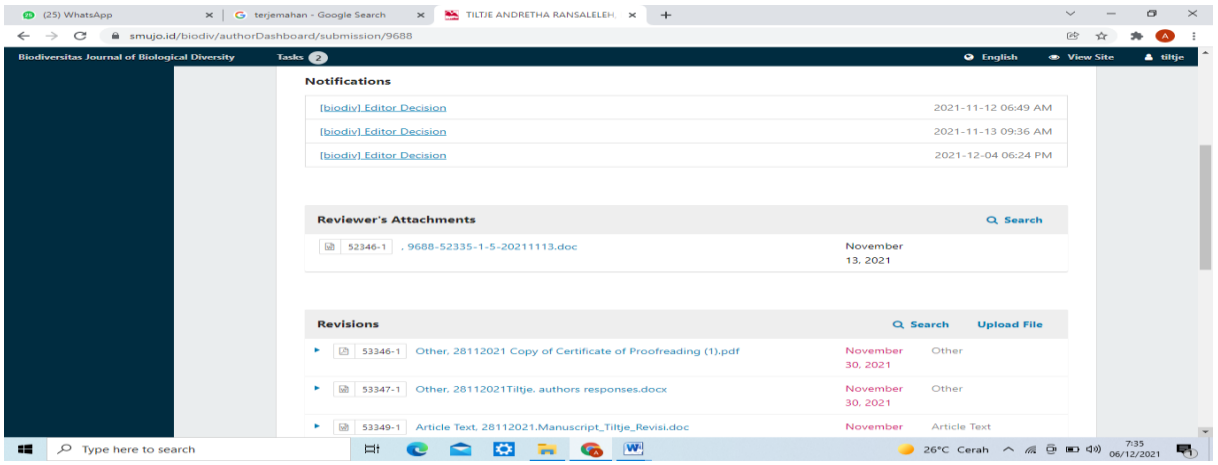
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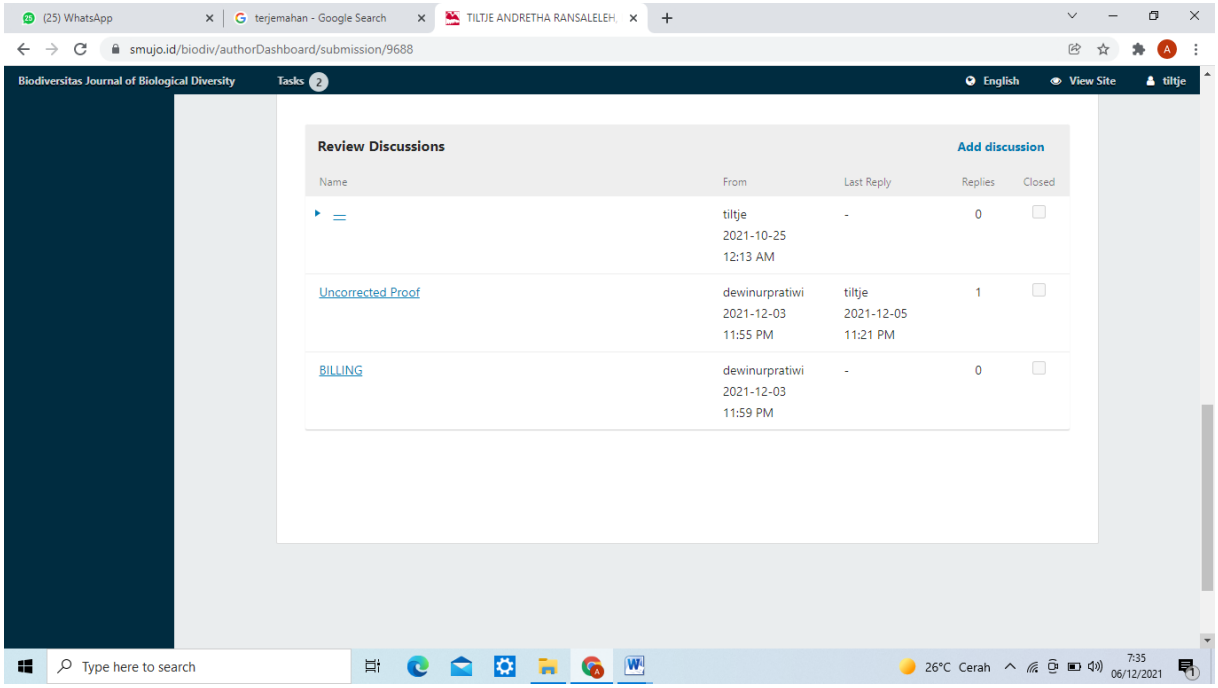
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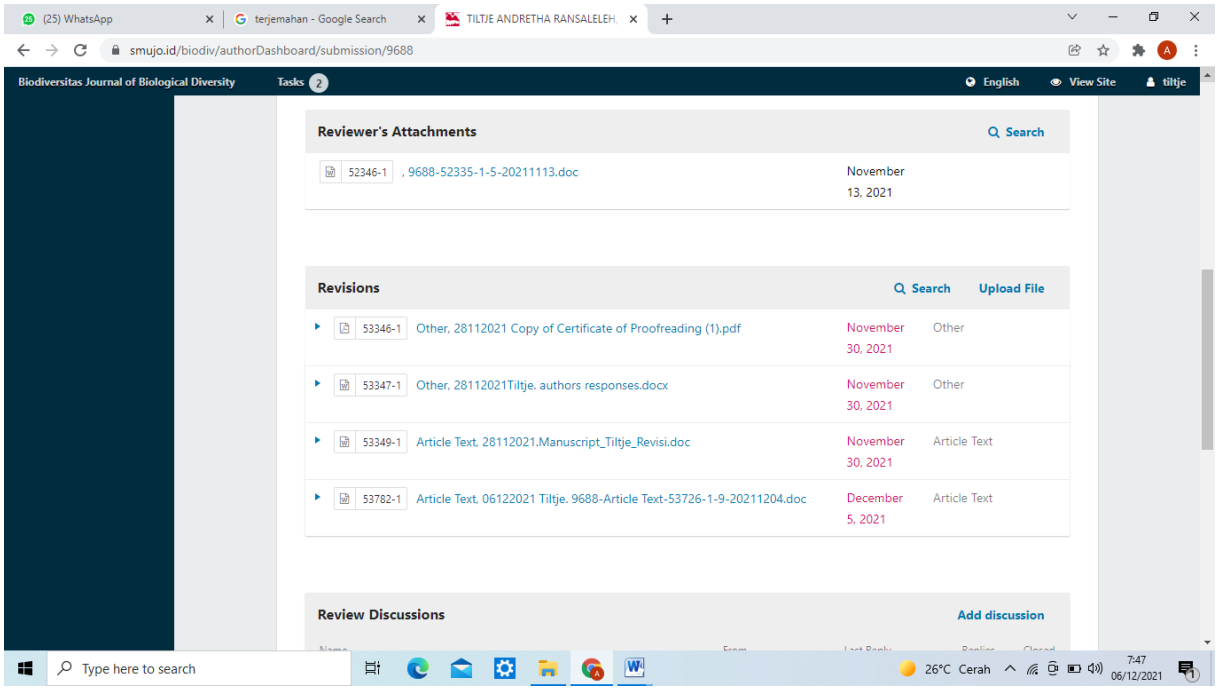
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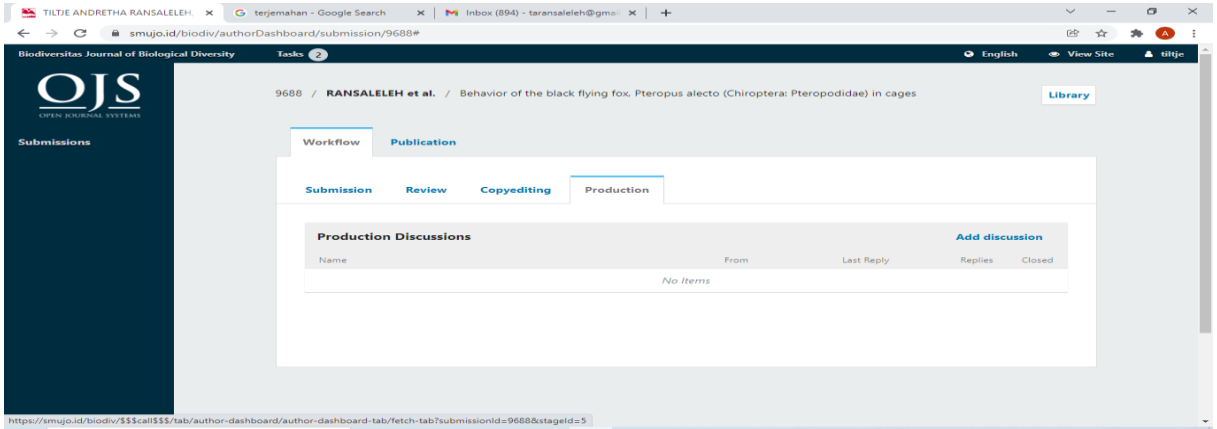
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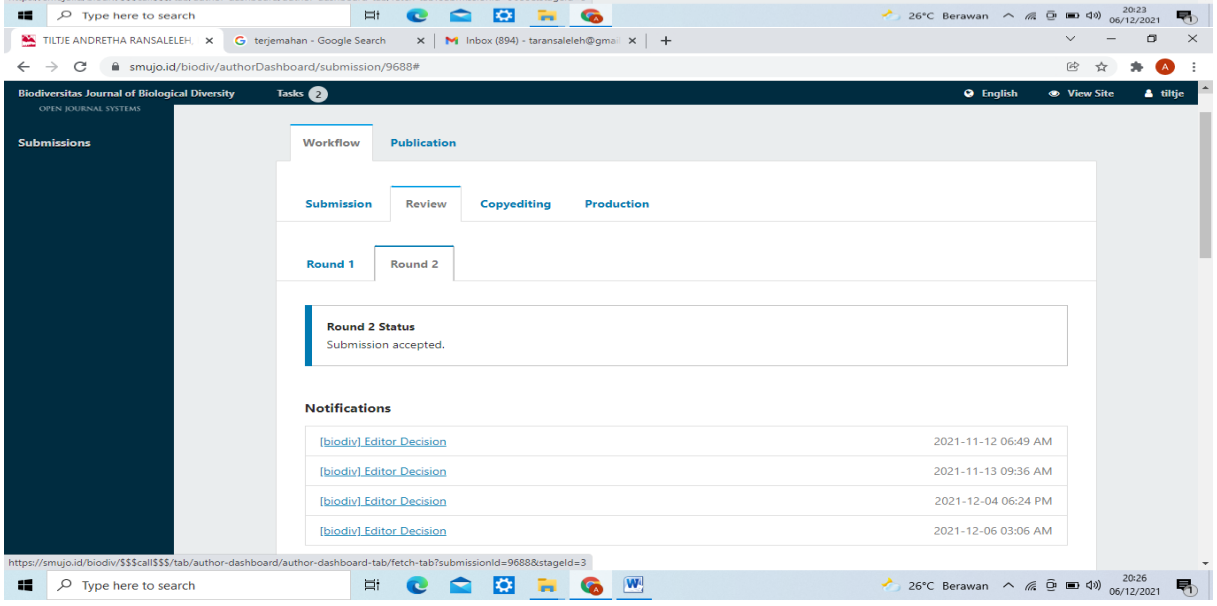
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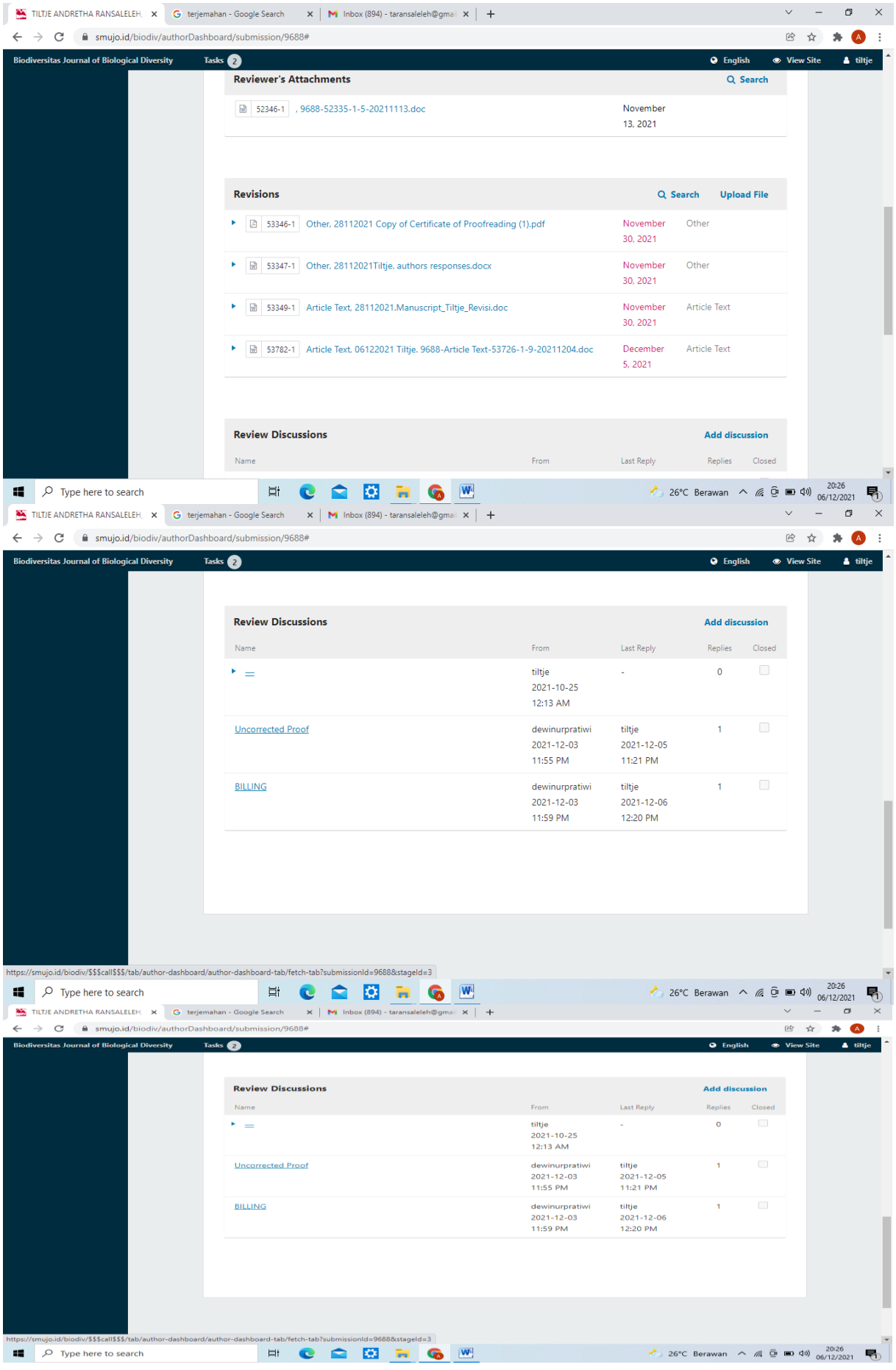
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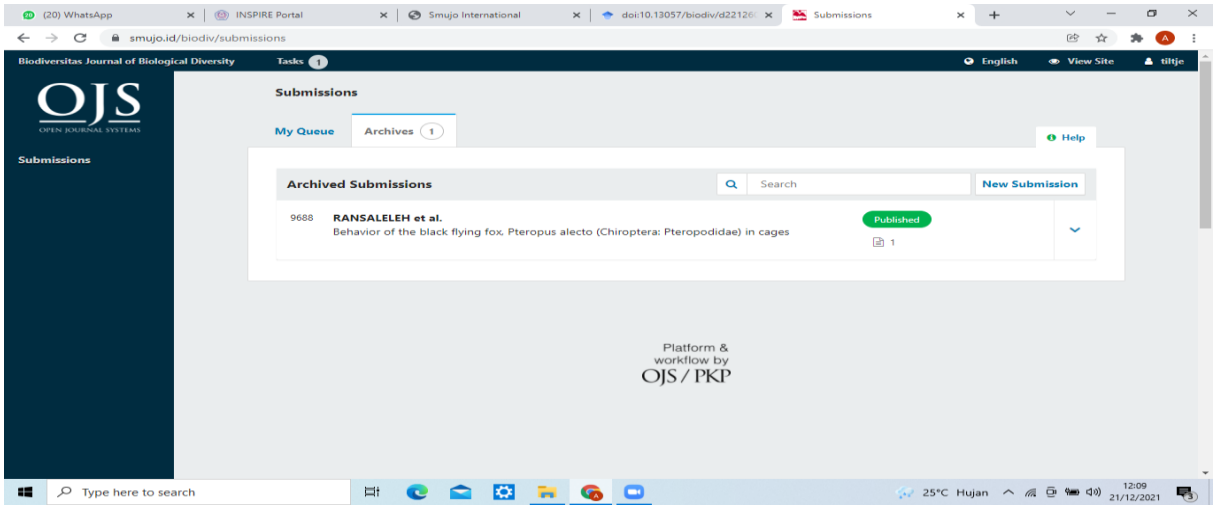
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Day and night behavior of *Pteropus alecto* (Chiroptera: Pteropodidae) in cages

KAWATU

Abstract. The purpose of this study is to examine the behavioral activities of *Pteropus alecto* bats kept in cages through direct observation. The results showed that bats performed the feeding behavior by descending to the bottom of the cage before picking up fruits with their mouths and wings. Furthermore, the time associated with this process ranged from 06.01 to 10.00, and the bats had agonistic behavior performed using claws and wings, which took place from 10.01 to 14.00 in the daytime and 22.01to 02.00 at night. Grooming behavior was carried out using the tongue and wings, from 14.01 to 18.00 during the day and 22.01 to 02.00 during the night. In addition, the bats also performed the sleeping behavior by perching while closing their eyes and wrapping their whole body with wings from 02.01 to 10.00. They also conducted the locomotion and stationary behaviors by perching with eyes open, while flying around the cage with their wings spread apart. This process is usually performed from 10.01 to 14.00 during the day and 22.01 to 02.00 at night. The percentage of day and night behavior activities was agonistic 0.12%, grooming 6.14%, eating 19.36%, sleeping 56.33%, and stationary and locomotive 17.76%.

Keywords: Activity, behavior, day, night, *Pteropus alecto*

INTRODUCTION

Aziz et al. (2017) stated that bats play an ecological role in terms of maintaining forest diversity due to their function as seed dispersers (Seltzer et al. 2013; Deshpande and Kelkar 2015; Lartey et al. 2016) and pollinators of plants ~~(Lim et al. 2018; Sritongchuay et al. 2019)~~ with economic value (Scarlon et al., 2016; Lim et al. 2018; Sritongchuay et al. 2019; Tremlett et al. 2020) such as durian (Aziz et al. 2017; Muhammad et al. 2020; Low et al. 2021). However, they are hunted and consumed in some communities (Scheffers et al. 2012; Ransaleleh et al. 2013; Suwannorang and Schuler 2016) because they are believed to possess medicinal properties (Mildenstein 2016; Aziz et al. 2017; Low et al. 2021; Rocha et al. 2021), as well as increase stamina (Suwannarong et al. 2020).

In North Sulawesi, its meat (flying fox: *Acerodon celebensis* and *Pteropus alecto*) is imported (Sheherazale & Susan, 2015) and traded in traditional markets for consumption (Latinne et al. 2020; Ransaleleh et al. 2020). Based on a survey conducted during the COVID-19 pandemic, frozen flying fox bats are sold in some supermarkets in cities, such as Manado, Tomohon, and Amurang, Indonesia. *Pteropus alecto* is one of the preferred species for consumption (Ruba et al. 2016) due to its large body size of 45.37 to 54.07% (Ransaleleh et al. 2014). Meanwhile, its high demand causes uncontrollable hunting in nature. According to The IUCN Red List of Threatened Species, Least Concern means any species at low risk. However, continuous hunting causes a decline in the population due to the long reproductive cycle, which is once a year, with only one pup per birth.

The rampant hunting and selling of bats depict that the community's understanding of its role in the ecosystem is limited and this will likely lead to the species extinction. Therefore, there is a need to determine its sustainability, including approaches related to the legal status of fruit-eating bats (Maulany et al. 2021), its socialization in human life, and conservation efforts (Frick et al. 2019). Meanwhile, conservation success depends on its management, including behavioral activities such as agonistic, grooming, sleeping, feeding, stationary, and locomotion, which needs to be studied (Markus & Blackshaw 2002; Hofstede & Fenton 2005; Connell et al. 2006). The execution of appropriate behavior during conservation expresses growth and reproduction. The behavioral activities exhibited by *Pteropus alecto* in its habitat were last reported 19 years ago (Markus & Blackshaw 2002; Markus 2002). Therefore, this study is aimed to offer a detailed explanation of

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In cages or in captive?

Comment [BLIND2]: English in general needs to proof read

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Comment [BLIND4]: There should be an explanation on the importance of the study towards bat's conservation. How can studying animals living in captive could better understand the bio-ecological aspects of the animal species in the wild. Or is this going to be useful for future bat captivity? I think this should be emphasized more and highlighted also in the abstract - on the benefit of this particular study.

Comment [BLIND5]: In the beginning of introduction - it is not common to begin with author's names. Better to put the citation at the end of the sentence.

Comment [BLIND6]: In this case, the focused are flying foxes- Pteropodidae, therefore it is might be best to begin explaining the division of bats (mega and micro – chiroptera) and continue with the roles of bats in particular flying foxes.

Additional roles of fruit bats: not only for forest diversity but also forest rejuvenation

the *Pteropus alecto* behavioral activities in cages during the day and at night to preserve bats, thereby leading to its sustainable conservation.

MATERIALS AND METHODS

Study area

This study was carried out in neighborhood V of Wanea Village, Manado City, with coordinates 1º27'39" N and 124º50'33" E (Figure 1) for 4 months, from April to July 2021. A total of 9 *Pteropus alecto* species consisted of 2 adult males, 3 juveniles, 2 females ~~(that had~~ never given birth~~)~~, and 2 lactating ones. Furthermore, a 2.5-meter cage made of tasso and ram wire, with a size of 3 x 1.5 x 1.5 meters (LxWxH), was also utilized.

Figure 1. The study area was in the neighborhood V of Wanea Village, Manado City, with coordinates of 1º27'39" N, 124 º50'33" E.

Procedures

~~The~~ A preliminary observation was carried out to determine the time and type of behavioral activities exhibited in the cage. During the day, these birds were observed from 06.01 to 10.00, 10.01 to 14.00, 14.01 to 18.00, and at night, from 18.01 to 22.00, 22.01 to 02.00, 02.00 to 06.00. This was carried out from March to July 2021. Afterward, the types of behaviors were observed ~~include~~and these included agonistic, grooming, feeding, sleeping, and other activities (locomotion and stationary). These were directly observed using observation sheets, CCTV, and cameras. The recorded and documented data were descriptions of the duration of each observed behavioral activities. ~~This was~~ The data recorded with CCTV cameras~~, which~~ were then re-played, examined, and ~~recorded~~ transferred into~~in~~ the observation sheets. The data~~is~~ ~~information was~~were collected every 2 days during the day and at night, from 06.01 to 06.01 for 24 hours. The settings were as follows, during the day, data collection was carried out by 2 students, while at night, it was performed by 3 people because bats are nocturnal animals. Furthermore, the timing was intended to avoid bias during observations.

Data analysis

The ~~descriptive~~ data on the length of behavioral activities were descriptively tabulated and~~,~~ averaged. ~~, and presented as a percentage narrative form.~~

RESULTS AND DISCUSSION

Feeding behavior of *Pteropus alecto* in cages

Before being fed, all bats perched near the cage door while making repeated sounds. After the food was spread on the floor, each of them crawled quickly to the bottom to grab some with mouth and wings. Afterward, it chewed the food while holding some others with its toes. The other species fed with their legs tied together

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- Flying foxes of Order Megachiroptera
-The roles of flying foxes/fruit bats in particular
-Threats towards flying foxes – hunting & trading for meat consumption
-Captivity as one solution in increasing population of bats and sources for wildlife utilization
-Captive breeding in bats has not much been done in Indonesian's context and therefore this study will fill the existing gaps in particular the roles of behavioural study of bats in overcoming the threats

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At the same time, clear cutting on how behavioral study on captive bats could be used in the context of wild population and or in conservation needs to be stated.

Comment [BLIND9]: Where these individuals were obtained?From the wild or been captivated for some period.
Is this an experimental study where all conditions set up or the captivity was already built?

A little bit history of this will provide a background on existing behavior of the bats living in the captive. This will affect on the habits build by the bat if the captive period is longer.
-Do they captivate in the same period?or different?
-Is there any animal ethic permit for this research?

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Comment [BLIND11]: Parameter's measured should be mentioned. What do you want to examine?
For examples: ...

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Comment [BLIND14]: Only type of activities? How about the time devoted for each activity?
How do you observe?because there are 9 individuals in the cage? Is it scanning methods or

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Comment [BLIND17]: Maybe prior to feeding behaviour, it is better to provide explaination on what kind of activities involve during the observation in the captive set? ...

with wires, and their bodies leaned on the cage floor's bottom near the food. It was observed that some bats did not take food from the floor, rather from those that were perched, such as bats with cubs. Based on the behavioral descriptions, first, the mothers crawled to the bottom to get food while holding their cubs and returned to perch and chew it while they licked the liquid that came out of its mouth. Second, they were released to perch on their own, while the mothers went to the bottom of the cage to get food and returned to where they were perched with their mouths close to that of their cubs. It was observed that they chewed their food severally, then expelled the waste in the form of dietary fiber, and it was noticed that they rarely drank. The feeding behavior of bats in cages is shown in Figure 2.

Figure 2. Description of feeding behavior of *Pteropus alecto* bats in cages

The feeding behavior of *Pteropus ~~Alecto~~ alecto* species in cages was similar to those in their actual habitats. However, the location, fruit type, feeding method, form of food served, and availability were different. Besides, these nocturnal animals directly feed on fruit trees, while farmers provide food for the cultivated ones. Markus and Blackshaw (2002) reported that the feeding behavior of bats in their habitat includes chewing, licking, throwing food, and drinking water. The process of chewing produces juice extract, and the ability of the cubs to lick their mother's mouth is an act of introducing adult food (Dumont & O'neal 2004). The results of this study illustrates that bat conservation in cages does not change the feeding behavior in their habitats. The difference lies in the time and place because they search for food and fruits out of their perches.

The feeding duration of *Pteropus alecto* species was recorded from afternoon till evening, although this activity usually occurred from 18.01 to 22.00, it consumed a lot of time, relatively 11161.4±479.4 seconds. There was no reference to the feeding time and duration, both in their habitat and those under cultivation. However, based on observations, this attribute tends to change when they are not fed at night. In addition, when they are given unlimited food (full at night), they are bound not to eat during the day, irrespective of its availability in the cage. They return to take the leftover food in the late afternoon. This illustrates that the feeding time of cultivated bats is changed to daytime. In contrast to those in their habitat, food is not available on perches, therefore they fly far in search of its sources, and this affects the timing and patterns of their feeding behavior. Schloesing et al. (2020) reported that *Pteropus lylei* species depend on experience, availability and quality of food sources, and familiarity with the habitat. Moreover, Choden et al. (2019) reported that these species fly over relatively 6.88 to 105 km at night to forage. Welbergen (2008) reported that *Pteropus alecto* species usually leave their perches in search of food starting from 17.30 to 18.00. Similarly, *Pteropus poliocephalus* belongs to the family of *Pteropus alecto*, with its foraging time carried out in the evenings because it depends on the weather and the presence of predators (Welbergen 2006).

Agonistic behavior of *Pteropus alecto* in cages

The agonistic behavior of *Pteropus alecto* species was exhibited whenever they were given food (fruits), about to mate, or awake. During the feeding procedure, the dominant ones chased and attacked the others with their claws, resulting in a fight. The chased bats continue to dodge while aiming and picking up the fruits with the help of their wings and perches far from the attacking one while eating. This behavior occurred repeatedly and stopped after they had all been fed. Meanwhile, during the mating process, it was initially observed that the male bat approaches one of the females while circling the perch and attacking its counterparts with their claws. The attacked one tend to counterattack, using its foot and claws, and this occurred severally. The female also hits back at the target, while screaming and a fight ensues, it then tries to evade by moving from one place to another and wrapping the whole body with its wings. The subsequent observed agonistic behavior relates to the

Comment [BLIND18]: How different? In time for example between wild and captive set? As there is no data shown in the results on time, therefore, it is best to present your data as suggested above.

Comment [BLIND19]: This can also be presented in a description table similar as above.

Agonistic behaviour

No.	Behaviour	Description of behaviour	Time (second)	Figure
1.	Food provision			
2.	Mating process			

How about frequency of each behaviour?I think this can also be measured

Comment [BLIND20]: Agonistic behaviour in feeding especially in a cage occurred due to competition in getting food.

Is there any influences of the cage size towards the agonistic behaviour?

It is actually interesting to see if we make an experiment on the methods of feeding such as provide the food in the same time with larger amount so competition will be lesser and see whether this reduced agonistic behaviour

male bat approaching the female from behind and then hooks its 2 wings on the back while holding that of its target and biting the neck. The female makes a sound and tries to escape from its grip, resulting in a fight. However, once released from the grip, they protect themselves by covering the entire body with their wings. Another observed agonistic behavior was the male approached the target by licking its mouth, head, body, and vagina. The female occasionally makes sounds that cause the male to pause for a moment and then continues with licking the target's vagina while circling the female bat's perched position, still grabbed from behind, which leads to copulation. This final observed agonistic activity is a fistfight that only occurs briefly. Furthermore, when bats are awake, sometimes one of them moves and scratches those next to it, which reacts by making a sound and clawing back at the attacker. The description of the agonistic behavior of *Pteropus alecto* species in cages is shown in Figure 3.

Figure 3. Description of the agonistic behavior of *Pteropus alecto* in cages

There are no scientific reports related to the agonistic behavior of *Pteropus Alecto* species during feeding in their habitat. However, their mating season is similar to the cultivated ones. Markus and Blackshaw (2002) reported that this behavior in their habitat is to maintain roost areas during the mating season. The male bats usually attack others to defend their partners. Welbergen (2011) reported that chasing and fighting using their wings and teeth is one of the territorial behaviors of *Pteropus poliocephalus* species in their habitat.

The agonistic behavior of *Pteropus alecto* species associated with the males trying to mate with the females was observed during the day, especially at night. Meanwhile, during the day, it often occurred from 10.01 to 14-00 for 15.7±9.1 seconds, while at night, it is usually from 22.01 to 02.00, and lasted for 28.2 ±18.2 seconds. Based on observations, the males actively attacked the females from March to early April, while a decline was observed from May to July. The agonistic activity recorded in this study is different from that observed in the habitat due to the struggle to perch, rather than the females' ability to mate, in contrast to that in the cage. No scientific reports have been recorded on the agonistic activity of *Pteropus alecto* species in their habitats both during the day and at night. Markus (2002) reported that initially, these birds flew in the afternoon, they marked tree branches by rubbing their necks and chests during the day. The agonistic activity occurs once they return to perch on the tree in the morning. Meanwhile, resident bats make sounds, chase, and fight non-resident ones perched on tree branches that have been marked, and they, in turn, fly away within a duration of 16.5 ± 6.3 seconds. Furthermore, it was reported that their agonistic behavior during the mating season was relatively poor in their habitat because the distribution of the sex ratio was quite even or the number of adult females was greater than the males. This study reported that the agonistic activity of cultivated bats usually occurs during the day and at night. Therefore, in terms of breeding, it is necessary to pay attention to the duration of feeding the cubs and the ratio of males to females (number of males in one group). This is because, during this season, male bats and breastfeeding mothers are usually active.

Grooming behavior of *Pteropus alecto* in cages

In accordance with the grooming behavior, it was observed that all individuals, including the mothers and their cubs, nurtured themselves, using their tongues, feet, toes, and claws. These were also used to scratch the face, head, teeth, back, neck, and ears. Sometimes the toes were slowly inserted into the ear canal. However, when in a perched position, the tongue is repeatedly and rapidly used to lick the front of the body, starting from the abdomen, chest, genitals, and wings. The stroking of the genitals by the males causes a penile erection

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without ejaculation. The description of *Pteropus alecto* species grooming behavior in cages is shown in Figure 4.

During the observation process, grooming centered on the muzzle, face, and genitals was carried out in pairs. The males performed genital grooming on the females. Meanwhile, the mothers nurtured the cubs routinely, including during breastfeeding, when they were hugged. In addition, the mothers lick their heads, necks, and backs repeatedly. However, the front and back of their bodies, especially the muzzle are licked when they hang close to their mothers. The grooming behavior of *Pteropus alecto* observed in this study was similar to the process observed in its habitat. Markus and Blackshaw (2002) reported this species generally engages in the wing, ear, infant, and genital grooming. Markus (2002) reported that penile grooming was specially observed during the mating process in its habitat. Grooming behavior is a treatment or effort to rid oneself of food remnants and oil from the skin glands (Markus and Blackshaw 2002).

Figure 4. Description of the grooming behavior of *Pteropus alecto* in cages

In respect to those in cages, this process was conducted from morning to evening, although, during the day, it often occurs at 14.01 to 18.00 for 1216.7±179.5 seconds, while at night, it takes place from 22.01 to 02.00 for 1930.9±387.8 seconds. Grooming activities are frequently carried out during the day, when they are awake, while at night, it is performed after they have been fed before locomotion and stationary activities. The bats in the cages often engage in this process in the afternoon. Nocturnal grooming activities are reportedly performed at night because bats fly in the wild looking for food sources far from their perches. However, those in cages are fed. Markus and Blackshaw (2002) reported that *Pteropus alecto* species perched on Indooroopilly and Norman Greeks Islands go out to forage in the late afternoons and return to their perches in the mornings. Furthermore, it was stated that this activity was conducted starting in the morning and repeated throughout the day. Connell et al. (2006) reported that grooming behavior in *Pteropus poliocephalus* species mainly occurred in the mornings.

Sleeping behavior of *Pteropus alecto* in a cage

The sleeping behavior of *Pteropus alecto* was monitored throughout the study and described thrice. First, they perched on one leg, with its wings wrapped around the body and the head tucked underneath. Second, they perched on 2 legs, with wings wrapped around the body, head pointing downwards, and eyes closed. The most common sleeping behavior is perching on one leg with the head tucked under the wings. The initial behavior was generally exhibited during the cold weather, especially at night and in the mornings, as well as when it rains along with temperatures ranging from 24ºC to 28ºC with humidity of 98 to 80%. The second and third were conducted during the hot season with temperatures ranging from 29ºC to 32ºC and 76 to 59% humidity. Based on observations, the *Pteropus al~~a~~ecto*'s perching and sleeping positions never changed according to the initial, back to back, juvenile bats being close to their mothers, and males being alone, occasionally. These species are usually awake when there are disturbances around the cage, such as people passing. This is proven by the movement of their heads and eyes while automatically shaking their ears, as shown in Figure 5. Based on this study, it was reported that the sleeping behavior in the cage is similar to that on trees. Markus and Blackshaw (2002), reported that this species either perches on both legs or one, with its wings wrapped throughout the body, and the head tucked underneath. Furthermore, several sleeping behavioral activities are regulated by weather and disturbances, and when there is a disturbance, they react by directing their gaze. During the hot weather, the bats open their wings, while in the cold season, it is folded, and in addition, heavy rain stops all their activities. Additionally, the distribution of *Pteropus alecto* perch in its habitat is consistent and does not change according to the existing group.

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Figure 5. Description of the sleeping behavior of *Pteropus alecto* in a cage

The sleeping time of those in the cage starts from 10.01 pm to 18.00. However, these nocturnal animals slept at night from 10.01 to 02.00 for 1270.6±235.6 seconds and from 02.00 to 06.00 for 11513.7±345.2 seconds. During this period, the bats were wake most of the time, performing certain activities such as feeding, grooming, agonistic, perching, and walking back and forth in the cage. Sleep during the day was mostly from 06.01 to 10.00 for 13967.9±560.9 seconds, and from 10.01 to 14.00 for 12689.4±250.0 seconds. In the afternoons from 14.01 to 18.00, their sleeping time decreases to reduce, to 9225.6±359.1 seconds because they start to carry out other activities such as perching while grooming, being agonistic, and feeding. Most of the sleeping behavior was performed from 06.01 to 10.00 because the weather temperature ranges from 24ºC to 29ºC. However, towards noon, the time reduced because the temperature increased from approximately 29ºC to 33ºC. At this time, bats perched while opening and flapping their wings. There is no information on the duration of sleep in the habitat at night because bats usually fly at that time in search of food. In contrast to those in cages, their food was available, therefore the time for foraging was used for sleeping and other activities. There is also no information about their sleep duration in the natural habitat when perched during the day. However, Markus and Blackshaw (2002) reported that the diurnal pattern of *Pteropus alecto* is dominated by nesting, sleeping, grooming, and slight social activities, irrespective of the fact that the bats are awake for a long time during the day, although they are mostly inactive. Connell et al. (2006) reported that *Pteropus poliocephalus* species generally slept in their habitat during the day.

Locomotion and stationary behavior of *Pteropus alecto* in the cage

The observed stationary behavior was, first, (streach), the bat perched, with its wings, spread wide to the left, right, and forward, and then folded backward. Second, they (wing fan) perched, with part of its wings drooping while being flapped slowly, in accordance with the movement of the head, ears, and eyes looking around the cage. Third (static flight), the bat perched while the wings were flapped rapidly for a few seconds, then folded back. The first stationary behavior is usually performed during the day and at night, while the second is usually observed during the day when the weather is hot, and the third is at night. In general, static flight is mostly practiced by cub and juvenile bats. Based on observations, the infant bats were taught to fly by their mother in a place far from the others. The cubs were hooked to the mothers' legs on a ram wire, a moment later, they flapped their wings once and touched that of the infants, which caused them to kick -flap theirs. This activity was accomplished 2 to 3 times. Afterward, they hugged their mothers again, and this activity was repeated until they were able to fly. The stationary behavior of the *Pteropus alecto* species in their habitat was also observed during cultivation, although in different places. Furthermore, the observed locomotive behavior includes the following. First, they perched on 2 legs, the head lifted straight, the wings opened, and then briefly flew around the cage. Second, bats used their feet and claws to move back and forth on the porch, crawl to the bottom, up and down through the cage rams in rapid motion. The description of the locomotion and stationary behavior of this species in cages are shown in Figure 6.

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Figure 6. Description of locomotion and stationary behavior of *Pteropus alecto* in cages

The locomotion and stationary behavior generally do not involve physical contact with other bats in the cage. There are no differences between the cultivated ones and those in its habitat. Markus and Blackshaw (2002) reported that bats flapping their wings (wing fans) and opening their mouths (pant) are actions engaged in to cool their bodies during the hot weather. In addition, spreading their wings wide (stretch) is completed before they relax. The static flight was carried out to strengthen the wings and chest muscles in preparation for movement. Furthermore, in its habitat, *Pteropus alecto* performs locomotion using both legs to hold branches, drooping wings (open on the left and right), back and forth, up and downs, as well as briefly flying between trees. Locomotion (moving) and stationary (remaining at a place) behavior is an activity that involves moving from one place to another without making any physical contact with other bats, by flapping, flying, and perching while covering all or part of their bodies with its wings while shaking their heads, and opening their eyes (Markus and Blackshaw, 2002).

Locomotion and stationary activities of bats in cages were carried out during the day and at night. However, it was often performed at night from 10.01 to 02.00 for 9661.5±389.3 seconds and from 02.01 to 06.00 for 7902.7±250.9 seconds (Table 1). This activity is carried out because bats are nocturnal animals and are mostly active at night. This time is used for foraging and returning to the perch in the early hours of the morning after getting food. In the cage, food is already available, therefore they engage in other activities. Locomotion and stationary activities of bats in cages at night are different from those performed during the day. At night, they move around quickly and perform motions in an active manner. At the same time, during the day, they just perch in place, awake, and move when there is internal interference from others or external factors such as exposure to sunlight. People visiting the location around the cage. These activities are different from those carried out in nature. This is because, at night, they do not stay in the perch, except for cubs that are not yet able to fly. Markus and Blackshaw (2002) reported that at night, they are left by their mothers, and they move by dragging and climbing branches, and sometimes they congregate in small groups, wrestling at close range and with their chests sticking together occasionally. Pulling wings without anyone dodging is interpreted as a play activity. Locomotion and stationary activities of *Pteropus vampirus* bats in nature have been reported by Hengyan et al. (2017), relating to the fact that they are awake and engage in various practices during the day.

Duration and percentage of day and night behavioral activity of *Pteropus alecto* in a cage

The percentage of day and night behavioral activity performed by *Pteropus alecto* in the cage is shown in Table 1.

Table 1. Duration and percentage of day and night behavioral activity performed by *Pteropus alecto* in cages

Behavior	Day		Night		Total Activity	
	Duration (second)	(%)	Duration (second)	(%)	Duration (second)	(%)
Feeding	2756,18	3,19	13970,21	16,17	16726,39	19,36
Agonistic	52,39	0,06	56,16	0,06	108,56	0,12
Grooming	2459,60	2,84	3088,19	3,57	5547,58	6,41
Sleeping	35882,35	41,53	12784,33	14,80	48666,68	56,33
Stationary and locomotion	2049,31	2,37	13300,91	15,39	15350,22	17,76
Total	43199,83	49,99	43199,82	49,99	86399,64	98,98

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The activities were dominated by sleeping, feeding, stationary and locomotion, grooming, and agonistic behaviors at 56.33%, 19.36%, 17.76%, 6.41%, and 0.12%, respectively. This means that 56.33% of bats did not engage in these practices, only 43.67% did. The dominant behavior during the day was sleeping, which was performed by 41.53% of them, while at night 16.17% engaged in feeding. The least percentage of behavioral activities during the day and at night was agonistic. Grooming, stationary, and locomotion were often carried out at night. There was no comparative literature on the percentage of day and night behavioral activities performed by cultivated Pteropus *Alecto* species and those in nature. However, the percentage of daytime behavioral activities was observed in the *Cynopterus sphinx* and *Pteropus vampyrus* species. Syamsi (2013) reported that 66.17% of *Cynopterus sphinx* slept during the day, followed by 21.09% that engaged in stationary and locomotion activities and 11.98% that participated in grooming. Hengyan et al. (2017) reported that the daytime activity of *Pteropus vampyrus* species in their habitat was 53.1 ± 13.9%, grooming 5.7±2.3%, aggression 2.4±7%, locomotion 2.3±1.6. The percentage of agonistic illustrated that the bats have adapted to the environment and food provided in the cage because fights that caused injuries and stress rarely occurred. Therefore, the percentage of behavioral activities performed by the species in cages provides information and an initial description of the sustainable ex-situ breeding strategy.

Comment [BLIND38]: A conclusion on how the behavior of the species in the captive set is required. There should be a link between the findings and how this could contribute towards the conservation of the bats are also needed – to answer the urgency of this study as been mentioned in the introduction.

ACKNOWLEDGEMENTS

The authors are grateful to the Chancellor of Sam Ratulangi University through the Chair of the Institute for Research and Community Service for funding this study with the 2021 Unsrat Superior Basic Research (RDUU) scheme with contract number No. 235/UN12-13/LT/2021 and Assignment Letter No. 715/UN12.13/LT/2021.

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Day and night behavior of *Pteropus alecto* (Chiroptera: Pteropodidae) in cages

Abstract. The purpose of this study is to examine the behavioral activities of *Pteropus alecto* bats kept in cages through direct observation. The results showed that bats performed the feeding behavior by descending to the bottom of the cage before picking up fruits with their mouths and wings. Furthermore, the time associated with this process ranged from 06.01 to 10.00, and the bats had agonistic behavior performed using claws and wings, which took place from 10.01 to 14.00 in the daytime and 22.01to 02.00 at night. Grooming behavior was carried out using the tongue and wings, from 14.01 to 18.00 during the day and 22.01 to 02.00 during the night. In addition, the bats also performed the sleeping behavior by perching while closing their eyes and wrapping their whole body with wings from 02.01 to 10.00. They also conducted the locomotion and stationary behaviors by perching with eyes open, while flying around the cage with their wings spread apart. This process is usually performed from 10.01 to 14.00 during the day and 22.01 to 02.00 at night. The percentage of day and night behavior activities was agonistic 0.12%, grooming 6.14%, eating 19.36%, sleeping 56.33%, and stationary and locomotive 17.76%.

Keywords: Activity, behavior, day, night, *Pteropus alecto*

INTRODUCTION

Aziz et al. (2017) stated that bats play an ecological role in terms of maintaining forest diversity due to their function as seed dispersers (Seltzer et al. 2013; Deshpande and Kelkar 2015; Lartey et al. 2016) and pollinators of plants (Lim et al. 2018; Sritongchuay et al. 2019) with economic value (Scarlon et al., 2016; Tremlett et al. 2020) such as durian (Aziz et al. 2017; Muhammad et al. 2020; Low et al. 2021). However, they are hunted and consumed in some communities (Scheffers et al. 2012; Ransaleleh et al. 2013; Suwannorang and Schuler 2016) because they are believed to possess medicinal properties (Mildenstein 2016; Aziz et al. 2017; Low et al. 2021; Rocha et al. 2021), as well as increase stamina (Suwannarong et al. 2020).

In North Sulawesi, its meat (flying fox: *Acerodon celebensis* and *Pteropus alecto*) is imported (Sheherazale & Susan, 2015) and traded in traditional markets for consumption (Latinne et al. 2020; Ransaleleh et al. 2020). Based on a survey conducted during the COVID-19 pandemic, frozen flying fox bats are sold in some supermarkets in cities, such as Manado, Tomohon, and Amurang, of North Sulawesi Indonesia. *Pteropus alecto* is one of the preferred species for consumption (Ruba et al. 2016) due to its large body size of 45.37 to 54.07% (Ransaleleh et al. 2014). Meanwhile, its high demand causes uncontrollable hunting in nature. According to The IUCN Red List of Threatened Species, Least Concern means any species at low risk. However, continuous hunting causes a decline in the population due to the long reproductive cycle, which is once a year, with only one pup per birth.

The rampant hunting and selling of bats depict that the community's understanding of its role in the ecosystem is limited and this will likely lead to the species extinction. Therefore, there is a need to determine its sustainability, including approaches related to the legal status of fruit-eating bats (Maulany et al. 2021), its socialization in human life, and conservation efforts (Frick et al. 2019). Meanwhile, conservation success depends on its management, including behavioral activities such as agonistic, grooming, sleeping, feeding, stationary, and locomotion, which needs to be studied (Markus & Blackshaw 2002; Hofstede & Fenton 2005; Connell et al. 2006). The execution of appropriate behavior during conservation expresses growth and reproduction. The behavioral activities exhibited by *Pteropus alecto* in its habitat were last reported 19 years ago (Markus & Blackshaw 2002; Markus 2002). Therefore, this study is aimed to offer a detailed explanation of the *Pteropus alecto* behavioral activities in cages during the day and at night to preserve bats, thereby leading to its sustainable conservation.

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MATERIALS AND METHODS

Study area

This study was carried out in neighborhood V of Wanea Village, Manado City, with coordinates 1º27'39" N and 124º50'33" E (Figure 1) for 4 months, from April to July 2021. A total of 9 *Pteropus alecto* species consisted of 2 adult males, 3 juveniles, 2 females that had never given birth, and 2 lactating ones. Furthermore, a 2.5-meter cage made of tasso and ram wire, with a size of 3 x 1.5 x 1.5 meters (LxWxH), was also utilized.

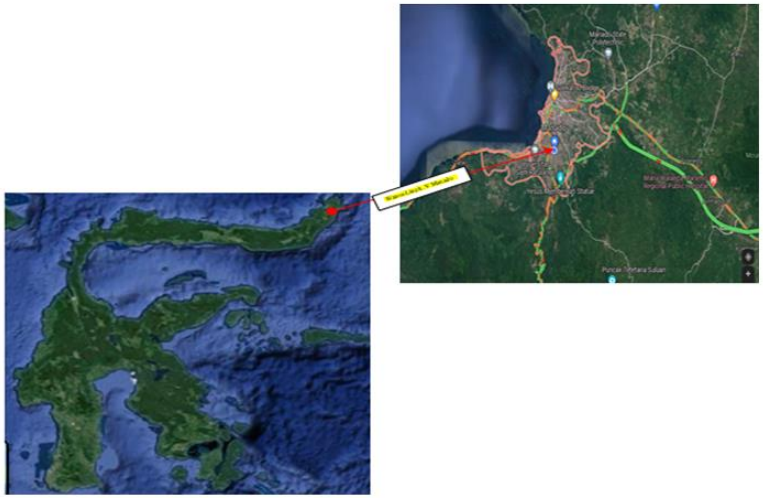

Figure 1. The study area was in the neighborhood V of Wanea Village, Manado City, with coordinates of 1º27'39" N, 124 º50'33" E**.**

Procedures

The preliminary observation was carried out to determine the time and type of behavioral activities exhibited in the cage. During the day, these birds were observed from 06.01 to 10.00, 10.01 to 14.00, 14.01 to 18.00, and at night, from 18.01 to 22.00, 22.01 to 02.00, 02.00 to 06.00. This was carried out from March to July 2021. Afterward, the types of behaviors observed include agonistic, grooming, feeding, sleeping, and other activities (locomotion and stationary). These were directly observed using observation sheets, CCTV, and cameras. The recorded and documented data were descriptions of the duration of each observed behavioral activities. This was recorded with CCTV cameras, which were re-played, examined, and recorded in the observation sheets. This information was collected every 2 days during the day and at night, from 06.01 to 06.01 for 24 hours. The settings were as follows, during the day, data collection was carried out by 2 students, while at night, it was performed by 3 people because bats are nocturnal animals. Furthermore, the timing was intended to avoid bias during observations.

Comment [FP5]: Birds or bats?

Comment [FP6]: Any literatures are referred for this method?

Data analysis

The descriptive data on the length of behavioral activities were tabulated, averaged, and presented as a percentage narrative form.

RESULTS AND DISCUSSION

Feeding behavior of *Pteropus alecto* in cages

Before being fed, all bats perched near the cage door while making repeated sounds. After the food was spread on the floor, each of them crawled quickly to the bottom to grab some with mouth and wings. Afterward, it chewed the food while holding some others with its toes. The other species fed with their legs tied together with wires, and their bodies leaned on the cage floor's bottom near the food. It was observed that some bats did not take food from the floor, rather from those that were perched, such as bats with cubs. Based on the behavioral descriptions, first, the mothers crawled to the bottom to get food while holding their cubs and returned to perch and chew it while they licked the liquid that came out of its mouth. Second, they were released to perch on their own, while the mothers went to the bottom of the cage to get food and returned to where they

were perched with their mouths close to that of their cubs. It was observed that they chewed their food severally, then expelled the waste in the form of dietary fiber, and it was noticed that they rarely drank. The feeding behavior of bats in cages is shown in Figure 2.

Figure 2. Description of feeding behavior of *Pteropus alecto* bats in cages

The feeding behavior of *Pteropus Alecto* species in cages was similar to those in their actual habitats. However, the location, fruit type, feeding method, form of food served, and availability were different. Besides, these nocturnal animals directly feed on fruit trees, while farmers provide food for the cultivated ones. Markus and Blackshaw (2002) reported that the feeding behavior of bats in their habitat includes chewing, licking, throwing food, and drinking water. The process of chewing produces juice extract, and the ability of the cubs to lick their mother's mouth is an act of introducing adult food (Dumont & O'neal 2004). The results of this study illustrates that bat conservation in cages does not change the feeding behavior in their habitats. The difference lies in the time and place because they search for food and fruits out of their perches.

The feeding duration of *Pteropus alecto* species was recorded from afternoon till evening, although this activity usually occurred from 18.01 to 22.00, it consumed a lot of time, relatively 11161.4±479.4 seconds. There was no reference to the feeding time and duration, both in their habitat and those under cultivation. However, based on observations, this attribute tends to change when they are not fed at night. In addition, when they are given unlimited food (full at night), they are bound not to eat during the day, irrespective of its availability in the cage. They return to take the leftover food in the late afternoon. This illustrates that the feeding time of cultivated bats is changed to daytime. In contrast to those in their habitat, food is not available on perches, therefore they fly far in search of its sources, and this affects the timing and patterns of their feeding behavior. Schloesing et al. (2020) reported that *Pteropus lylei* species depend on experience, availability and quality of food sources, and familiarity with the habitat. Moreover, Choden et al. (2019) reported that these species fly over relatively 6.88 to 105 km at night to forage. Welbergen (2008) reported that *Pteropus alecto* species usually leave their perches in search of food starting from 17.30 to 18.00. Similarly, *Pteropus poliecephalus* belongs to the family of *Pteropus alecto*, with its foraging time carried out in the evenings because it depends on the weather and the presence of predators (Welbergen 2006).

Agonistic behavior of *Pteropus alecto* in cages

The agonistic behavior of *Pteropus alecto* species was exhibited whenever they were given food (fruits), about to mate, or awake. During the feeding procedure, the dominant ones chased and attacked the others with their claws, resulting in a fight. The chased bats continue to dodge while aiming and picking up the fruits with the help of their wings and perches far from the attacking one while eating. This behavior occurred repeatedly and stopped after they had all been fed. Meanwhile, during the mating process, it was initially observed that the male bat approaches one of the females while circling the perch and attacking its counterparts with their claws. The attacked one tend to counterattack, using its foot and claws, and this occurred severally. The female also hits back at the target, while screaming and a fight ensues, it then tries to evade by moving from one place to another and wrapping the whole body with its wings. The subsequent observed agonistic behavior relates to the male bat approaching the female from behind and then hooks its 2 wings on the back while holding that of its target and biting the neck. The female makes a sound and tries to escape from its grip, resulting in a fight. However, once released from the grip, they protect themselves by covering the entire body with their wings. Another observed agonistic behavior was the male approached the target by licking its mouth, head, body, and vagina. The female occasionally makes sounds that cause the male to pause for a moment and then continues

Comment [FP7]: Picture are numbered a, b, c and give more explanations in each number of picture. Apply for the rest of pictures that more than one

Comment [FP8]: Natural?

Comment [FP9]: Maybe author should explain the difference between type of fruit, feeding method and form of food served, compared to the animals habits in their natural habitat. For example, why author choose particular types of fruit, or the food are served by chopping the fruit, or the whole fruit, in terms of availability maybe in cage food are always available – ad libitum etc.

Comment [FP10]: How about the feeding frequency? Because in natural habitats, time for feeding is different from this study. Is this also influence the feeding behavior?

with licking the target's vagina while circling the female bat's perched position, still grabbed from behind, which leads to copulation. This final observed agonistic activity is a fistfight that only occurs briefly. Furthermore, when bats are awake, sometimes one of them moves and scratches those next to it, which reacts by making a sound and clawing back at the attacker. The description of the agonistic behavior of *Pteropus alecto* species in cages is shown in Figure 3.

Figure 3. Description of the agonistic behavior of *Pteropus alecto* in cages

There are no scientific reports related to the agonistic behavior of *Pteropus Alecto* species during feeding in their habitat. However, their mating season is similar to the cultivated ones. Markus and Blackshaw (2002) reported that this behavior in their habitat is to maintain roost areas during the mating season. The male bats usually attack others to defend their partners. Welbergen (2011) reported that chasing and fighting using their wings and teeth is one of the territorial behaviors of *Pteropus poliocephalus* species in their habitat.

Comment [FP11]: It is better to provide the mating season. It occurs along the year, or on particular moths? So we can compare with the period of this study between March and July

The agonistic behavior of *Pteropus alecto* species associated with the males trying to mate with the females was observed during the day, especially at night. Meanwhile, during the day, it often occurred from 10.01 to 14-00 for 15.7±9.1 seconds, while at night, it is usually from 22.01 to 02.00, and lasted for 28.2 ±18.2 seconds. Based on observations, the males actively attacked the females from March to early April, while a decline was observed from May to July. The agonistic activity recorded in this study is different from that observed in the habitat due to the struggle to perch, rather than the females' ability to mate, in contrast to that in the cage. No scientific reports have been recorded on the agonistic activity of *Pteropus alecto* species in their habitats both during the day and at night. Markus (2002) reported that initially, these birds flew in the afternoon, they marked tree branches by rubbing their necks and chests during the day. The agonistic activity occurs once they return to perch on the tree in the morning. Meanwhile, resident bats make sounds, chase, and fight non-resident ones perched on tree branches that have been marked, and they, in turn, fly away within a duration of 16.5 ± 6.3 seconds. Furthermore, it was reported that their agonistic behavior during the mating season was relatively poor in their habitat because the distribution of the sex ratio was quite even or the number of adult females was greater than the males. This study reported that the agonistic activity of cultivated bats usually occurs during the day and at night. Therefore, in terms of breeding, it is necessary to pay attention to the duration of feeding the cubs and the ratio of males to females (number of males in one group). This is because, during this season, male bats and breastfeeding mothers are usually active.

Grooming behavior of *Pteropus alecto* in cages

In accordance with the grooming behavior, it was observed that all individuals, including the mothers and their cubs, nurtured themselves, using their tongues, feet, toes, and claws. These were also used to scratch the face, head, teeth, back, neck, and ears. Sometimes the toes were slowly inserted into the ear canal. However, when in a perched position, the tongue is repeatedly and rapidly used to lick the front of the body, starting from the abdomen, chest, genitals, and wings. The stroking of the genitals by the males causes a penile erection without ejaculation. The description of *Pteropus alecto* species grooming behavior in cages is shown in Figure 4.

During the observation process, grooming centered on the muzzle, face, and genitals was carried out in pairs. The males performed genital grooming on the females. Meanwhile, the mothers nurtured the cubs routinely, including during breastfeeding, when they were hugged. In addition, the mothers lick their heads, necks, and backs repeatedly. However, the front and back of their bodies, especially the muzzle are licked when they hang

close to their mothers. The grooming behavior of *Pteropus alecto* observed in this study was similar to the process observed in its habitat. Markus and Blackshaw (2002) reported this species generally engages in the wing, ear, infant, and genital grooming. Markus (2002) reported that penile grooming was specially observed during the mating process in its habitat. Grooming behavior is a treatment or effort to rid oneself of food remnants and oil from the skin glands (Markus and Blackshaw 2002).

Figure 4. Description of the grooming behavior of *Pteropus alecto* in cages

In respect to those in cages, this process was conducted from morning to evening, although, during the day, it often occurs at 14.01 to 18.00 for 1216.7±179.5 seconds, while at night, it takes place from 22.01 to 02.00 for 1930.9±387.8 seconds. Grooming activities are frequently carried out during the day, when they are awake, while at night, it is performed after they have been fed before locomotion and stationary activities. The bats in the cages often engage in this process in the afternoon. Nocturnal grooming activities are reportedly performed at night because bats fly in the wild looking for food sources far from their perches. However, those in cages are fed. Markus and Blackshaw (2002) reported that *Pteropus alecto* species perched on Indooroopilly and Norman Greeks Islands go out to forage in the late afternoons and return to their perches in the mornings. Furthermore, it was stated that this activity was conducted starting in the morning and repeated throughout the day. Connell et al. (2006) reported that grooming behavior in *Pteropus poliocephalus* species mainly occurred in the mornings.

Sleeping behavior of *Pteropus alecto* in a cage

The sleeping behavior of *Pteropus alecto* was monitored throughout the study and described thrice. First, they perched on one leg, with its wings wrapped around the body and the head tucked underneath. Second, they perched on 2 legs, with wings wrapped around the body, head pointing downwards, and eyes closed. The most common sleeping behavior is perching on one leg with the head tucked under the wings. The initial behavior was generally exhibited during the cold weather, especially at night and in the mornings, as well as when it rains along with temperatures ranging from 24ºC to 28ºC with humidity of 98 to 80%. The second and third were conducted during the hot season with temperatures ranging from 29ºC to 32ºC and 76 to 59% humidity. Based on observations, the *Pteropus alacto*'s perching and sleeping positions never changed according to the initial, back to back, juvenile bats being close to their mothers, and males being alone, occasionally. These species are usually awake when there are disturbances around the cage, such as people passing. This is proven by the movement of their heads and eyes while automatically shaking their ears, as shown in Figure 5. Based on this study, it was reported that the sleeping behavior in the cage is similar to that on trees. Markus and Blackshaw (2002), reported that this species either perches on both legs or one, with its wings wrapped throughout the body, and the head tucked underneath. Furthermore, several sleeping behavioral activities are regulated by weather and disturbances, and when there is a disturbance, they react by directing their gaze. During the hot weather, the bats open their wings, while in the cold season, it is folded, and in addition, heavy rain stops all their activities. Additionally, the distribution of *Pteropus alecto* perch in its habitat is consistent and does not change according to the existing group.

Figure 5. Description of the sleeping behavior of *Pteropus alecto* in a cage

The sleeping time of those in the cage starts from 10.01 pm to 18.00. However, these nocturnal animals slept at night from 10.01 to 02.00 for 1270.6±235.6 seconds and from 02.00 to 06.00 for 11513.7±345.2 seconds. During this period, the bats were wake most of the time, performing certain activities such as feeding, grooming, agonistic, perching, and walking back and forth in the cage. Sleep during the day was mostly from 06.01 to 10.00 for 13967.9±560.9 seconds, and from 10.01 to 14.00 for 12689.4±250.0 seconds. In the afternoons from 14.01 to 18.00, their sleeping time decreases to reduce, to 9225.6±359.1 seconds because they start to carry out other activities such as perching while grooming, being agonistic, and feeding. Most of the sleeping behavior was performed from 06.01 to 10.00 because the weather temperature ranges from 24ºC to 29ºC. However, towards noon, the time reduced because the temperature increased from approximately 29ºC to 33ºC. At this time, bats perched while opening and flapping their wings. There is no information on the duration of sleep in the habitat at night because bats usually fly at that time in search of food. In contrast to those in cages, their food was available, therefore the time for foraging was used for sleeping and other activities. There is also no information about their sleep duration in the natural habitat when perched during the day. However, Markus and Blackshaw (2002) reported that the diurnal pattern of *Pteropus alecto* is dominated by nesting, sleeping, grooming, and slight social activities, irrespective of the fact that the bats are awake for a long time during the day, although they are mostly inactive. Connell et al. (2006) reported that *Pteropus poliocephalus* species generally slept in their habitat during the day.

Locomotion and stationary behavior of *Pteropus alecto* in the cage

The observed stationary behavior was, first, (streach), the bat perched, with its wings, spread wide to the left, right, and forward, and then folded backward. Second, they (wing fan) perched, with part of its wings drooping while being flapped slowly, in accordance with the movement of the head, ears, and eyes looking around the cage. Third (static flight), the bat perched while the wings were flapped rapidly for a few seconds, then folded back. The first stationary behavior is usually performed during the day and at night, while the second is usually observed during the day when the weather is hot, and the third is at night. In general, static flight is mostly practiced by cub and juvenile bats. Based on observations, the infant bats were taught to fly by their mother in a place far from the others. The cubs were hooked to the mothers' legs on a ram wire, a moment later, they flapped their wings once and touched that of the infants, which caused them to kick -flap theirs. This activity was accomplished 2 to 3 times. Afterward, they hugged their mothers again, and this activity was repeated until they were able to fly. The stationary behavior of the *Pteropus alecto* species in their habitat was also observed during cultivation, although in different places. Furthermore, the observed locomotive behavior includes the following. First, they perched on 2 legs, the head lifted straight, the wings opened, and then briefly flew around the cage. Second, bats used their feet and claws to move back and forth on the porch, crawl to the bottom, up and down through the cage rams in rapid motion. The description of the locomotion and stationary behavior of this species in cages are shown in Figure 6.

Figure 6. Description of locomotion and stationary behavior of *Pteropus alecto* in cages

The locomotion and stationary behavior generally do not involve physical contact with other bats in the cage. There are no differences between the cultivated ones and those in its habitat. Markus and Blackshaw (2002) reported that bats flapping their wings (wing fans) and opening their mouths (pant) are actions engaged in to cool their bodies during the hot weather. In addition, spreading their wings wide (stretch) is completed before they relax. The static flight was carried out to strengthen the wings and chest muscles in preparation for movement. Furthermore, in its habitat, *Pteropus alecto* performs locomotion using both legs to hold branches, drooping wings (open on the left and right), back and forth, up and downs, as well as briefly flying between trees. Locomotion (moving) and stationary (remaining at a place) behavior is an activity that involves moving from one place to another without making any physical contact with other bats, by flapping, flying, and perching while covering all or part of their bodies with its wings while shaking their heads, and opening their eyes (Markus and Blackshaw, 2002).

Locomotion and stationary activities of bats in cages were carried out during the day and at night. However, it was often performed at night from 10.01 to 02.00 for 9661.5±389.3 seconds and from 02.01 to 06.00 for 7902.7±250.9 seconds (Table 1). This activity is carried out because bats are nocturnal animals and are mostly active at night. This time is used for foraging and returning to the perch in the early hours of the morning after getting food. In the cage, food is already available, therefore they engage in other activities. Locomotion and stationary activities of bats in cages at night are different from those performed during the day. At night, they move around quickly and perform motions in an active manner. At the same time, during the day, they just perch in place, awake, and move when there is internal interference from others or external factors such as exposure to sunlight. People visiting the location around the cage. These activities are different from those carried out in nature. This is because, at night, they do not stay in the perch, except for cubs that are not yet able to fly. Markus and Blackshaw (2002) reported that at night, they are left by their mothers, and they move by dragging and climbing branches, and sometimes they congregate in small groups, wrestling at close range and with their chests sticking together occasionally. Pulling wings without anyone dodging is interpreted as a play activity. Locomotion and stationary activities of *Pteropus vampirus* bats in nature have been reported by Hengyan et al. (2017), relating to the fact that they are awake and engage in various practices during the day.

Duration and percentage of day and night behavioral activity of *Pteropus alecto* in a cage

The percentage of day and night behavioral activity performed by *Pteropus alecto* in the cage is shown in Table 1.

Table 1. Duration and percentage of day and night behavioral activity performed by *Pteropus alecto* in cages

Behavior	Day		Night		Total Activity	
	Duration (second)	(%)	Duration (second)	(%)	Duration (second)	(%)
Feeding	2756,18	3,19	13970,21	16,17	16726,39	19,36
Agonistic	52,39	0,06	56,16	0,06	108,56	0,12
Grooming	2459,60	2,84	3088,19	3,57	5547,58	6,41
Sleeping	35882,35	41,53	12784,33	14,80	48666,68	56,33
Stationary and locomotion	2049,31	2,37	13300,91	15,39	15350,22	17,76
Total	43199,83	49,99	43199,82	49,99	86399,64	98,98

The activities were dominated by sleeping, feeding, stationary and locomotion, grooming, and agonistic behaviors at 56.33%, 19.36%, 17.76%, 6.41%, and 0.12%, respectively. This means that 56.33% of bats did not engage in these practices, only 43.67% did. The dominant behavior during the day was sleeping, which was performed by 41.53% of them, while at night 16.17% engaged in feeding. The least percentage of behavioral activities during the day and at night was agonistic. Grooming, stationary, and locomotion were often carried out at night. There was no comparative literature on the percentage of day and night behavioral activities performed by cultivated Pteropus *Alecto* species and those in nature. However, the percentage of daytime behavioral activities was observed in the *Cynopterus sphinx* and *Pteropus vampyrus* species. Syamsi (2013) reported that 66.17% of *Cynopterus sphinx* slept during the day, followed by 21.09% that engaged in stationary and locomotion activities and 11.98% that participated in grooming. Hengyan et al. (2017) reported that the daytime activity of *Pteropus vampyrus* species in their habitat was 53.1 ± 13.9%, grooming 5.7±2.3%, aggression 2.4±7%, locomotion 2.3±1.6. The percentage of agonistic illustrated that the bats have adapted to the environment and food provided in the cage because fights that caused injuries and stress rarely occurred. Therefore, the percentage of behavioral activities performed by the species in cages provides information and an initial description of the sustainable ex-situ breeding strategy.

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Comment [FP12]: Please consult the GFA to ensure that authors have applied the guidance in reference writing

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Behavior of the Back ~~Fying~~Flying Fox, *Pteropus alecto* (Chiroptera: Pteropodidae) in cages

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Abstract. Hunting and illegal trading ~~are~~have become ~~serious~~a common thread ~~to~~for the Black Flying Fox in Sulawesi~~. On the other hand,~~ but information on its biology and behavior as a baseline for conservation and management program is still lacking. ~~The aim of~~Therefore, this study ~~is~~aims to examine the behavioral activities of Black Flying Fox, *Pteropus alecto* -kept in ~~a~~ cages through direct observation. The results showed that ~~bats performed the~~ feeding ~~behavior~~was carried out by descending to the bottom of the cage before picking up fruits with ~~their mouths~~the mouth and wings. Furthermore, the time associated with this process ranged from 06.01 to 10.00, ~~and~~while agonistic behavior performed using claws and wings~~, which~~ took place from 10.01 to 14.00 in the daytime and 22.~~01to~~01 to 02.00 at night. Grooming ~~behavior~~ was ~~done by~~carried out using ~~their~~the tongue and wings, from 14.01 to 18.00 during the day and 22.01 to 02.00 during the night. ~~In addition~~Subsequently, the bats ~~also performed a sleeping behavior~~slept by perching ~~while closing their~~ with the eyes closed and ~~wrapping their~~the whole body wrapped with the wings from 02.01 to 10.00~~. Locomotion~~, while locomotion and stationary behaviors were performed by perching with eyes open~~, while~~ and flying around the cage with ~~their~~the wings spread apart from 10.01 to 14.00 during the day and 22.01 to 02.00 at night. The percentage of day and night behavior activities consist of agonistic 0.12%, grooming 6.14%, eating 19.36%, sleeping 56.33%, and stationary and locomotive 17.76%. ~~This study increases a better~~ The results improve the understanding ~~on the~~ of *P. alecto's daily activities* ~~of P. alecto~~ in the cage which ~~it is~~are difficult to ~~be observed~~observe in the wild~~.~~ and ~~provides an~~provide insight for conservation and wildlife management. Furthermore, information from this study is useful for future bat captivity ~~program in the next future~~programs.

~~Key words~~Keywords**:** activity, behavior, day, night, Flying fox, *Pteropus alecto*.

Running title: The behavior of the bat in the cage

INTRODUCTION

Bats play an ecological role in ~~terms of~~ maintaining forest diversity due to ~~their~~the function as seed dispersers (Seltzer *et al*. 2013; Deshpande and Kelkar 2015; Lartey *et al.* 2016) and pollinators of plants ~~which has hight~~with high economic value ~~(~~such as durian (Scarlon *et al.,* 2016; Lim *et al.* 2018; Sritongchuay *et al.* 2019; Tremlett *et al.* 2020~~) such as durian (~~; Aziz *et al.* 2017; Muhammad *et al.* 2020; Low *et al.* 2021). However, they are hunted and consumed in some communities (Scheffers *et al.* 2012; Ransaleleh *et al.* 2013; Suwannorang and Schuler 2016) ~~because they are believed~~due to ~~possess~~the medicinal properties (Mildenstein 2016; Aziz *et al.* 2017; Low et al. 2021; Rocha *et al.* 2021), ~~as well as~~and the ability to increase stamina (Suwannarong *et al.* 2020).

In North Sulawesi, ~~bat~~bats meat ~~(~~particularly flying ~~fox:~~foxes such as *Acerodon celebensis* and *Pteropus alecto*~~) is~~ are imported and traded in traditional markets for consumption (Sheherazale & Susan, 2015; Latinne *et al.* 2020; Ransaleleh *et al.* 2020). Based on a survey conducted during the COVID-19 pandemic, frozen flying fox are sold in some supermarkets in cities, such as Manado, Tomohon, and Amurang, of North Sulawesi, Indonesia. Meanwhile, *P. alecto* is one of the preferred species for consumption (Ruba *et al.* 2016) due to its large body size with the percentage of carcass ranging from 45.37 to 54.07% of the total body weight (Ransaleleh *et al.* 2014~~). Meanwhile,~~), but its high demand causes uncontrollable hunting ~~in nature~~. According to ~~The~~the IUCN Red List category and criteria, *P. alecto* is ~~listed~~categorized as Least Concern ~~means any~~, indicating that it is a species at low risk. However, the continuous hunting ~~on~~of this species which has a long reproductive cycle, once a year, with only one pup per birth~~. Causes~~ might lead to a serious population decline.

The rampant hunting and selling of bats depict that the community's ~~understanding~~understandi\ng of its role in the ecosystem is limited and this ~~will likely~~might lead to ~~the species~~ extinction. Therefore, there is a need to determine its sustainability, ~~including~~through approaches related to the legal status of fruit-eating bats (Maulany *et al.* 2021), ~~its~~ socialization in human life, and conservation efforts (Frick *et al.* 2019). ~~Despite of biology of bats, in particular its~~The behavioral activities such as agonistic, grooming, sleeping, feeding, stationary, and locomotion ~~are~~provide essential

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information for its conservation and management (Markus & Blackshaw 2002; Hofstede & Fenton 2005; Connell *et al.* 2006). ~~There~~However, there is a lack of information and study on the behavior of flying fox bats in Indonesia. The behavioral activities exhibited by *P. alecto* in its habitat were ~~last~~ reported 19 years ago (Markus & Blackshaw 2002; Markus 2002), ~~which~~and were observed during the day. ~~Complete~~This is because a complete observation of flying fox behavior covering day and night activities in ~~their~~the habitat is difficult ~~to be done. Hence~~, consequently, observation in captivity ~~could be~~is one of the suggested methods ~~to~~. Therefore, this study ~~their behavior. This study is aimed~~aims to observe the behavioral activities of *P. alecto* in cages during the day and at night. ~~Other than to support~~Aside from supporting an effective wildlife management program, this study also provides information ~~or as a pilot study~~ to develop ~~bat~~bats captivity which ~~never~~has not been ~~done~~carried out previously. Captivity and domestication ~~could be~~ are proposed as one of the solutions to increase ~~bat~~bats population, a source for wildlife utilization, and overcome the threats such as ~~bat~~ hunting in ~~their~~the natural habitat.

MATERIALS AND METHODS

Study area

This study was carried out in neighborhood V of Wanea Village, Manado City, with coordinates 1º27'39" N and 124º50'33" E (Figure 1) for four months, from April to July 2021. A total of ~~nine individuals of~~ 9 *P.alecto* species ~~consisted~~consisting of two adult males, three juveniles, two females that had never given birth, and two lactating ~~individual.~~individuals were used. All ~~individual~~subjects were kept in the 2.5-meter cage made of tasso and ram wire, with a size of 3 x 1.5 x 1.5 meters (LxWxH). ~~,~~Meanwhile, the adult ~~individuals~~subjects were rescued from the wildlife market and ~~put~~placed in the ~~captivity~~cage since 2011. In 2020, they were moved from the old cage ~~which was~~ made from wood to a new one, while the ~~current cage. Sub-adult~~sub-adults and juveniles were born in this new cage in 2020.

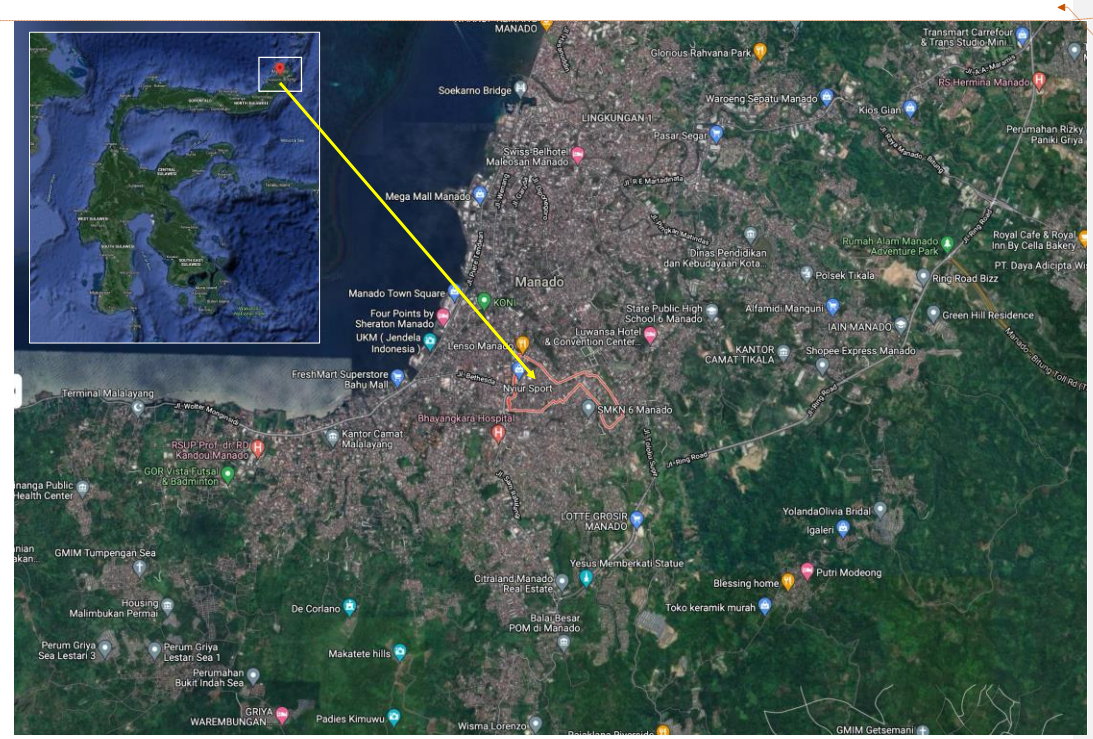

Figure 1: The study area was in the neighborhood V of Wanea Village, Manado City, with coordinates of 1º27'39" N, 124 º50'33" E.

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Procedures

The preliminary observation was ~~carried out~~conducted to determine the time and type of behavioral activities exhibited in the cage. During the day, ~~individuals of flying fox~~the subjects were observed from 06.01 to 10.00, 10.01 to 14.00, 14.01 to 18.00, and at night, from 18.01 to 22.00, 22.01 to 02.00, 02.00 to 06.00. This was carried out from March to July 2021~~.~~ ~~The~~ and the types ~~of~~ behaviors ~~which were~~ observed include agonistic, grooming, feeding, sleeping, and other activities ~~(~~such as locomotion and stationary~~). These~~ which were directly observed using observation sheets, CCTV, and cameras. The recorded and documented data were the duration descriptions of ~~the duration of~~ each observed behavioral ~~activities. Recorded~~ activity. Furthermore, the recorded activities from the CCTV cameras~~,~~ were ~~then~~ re-played, examined, and recorded in the observation sheets. ~~Because of~~Given that there is no previous similar study, ~~we set the~~ data and information collection were set consistently for every two days during the day and at night, from 06.01 to 06.01 for 24 hours throughout this study ~~consistently (method was modified from~~ (Markus and Blackshaw, 2002). Furthermore, environmental conditions including the air temperature and humidity were also recorded periodically, during the day (06.00- 10.00, 10.00-14.00, 14.00-18.00) and at night (18.00-22.00, 22.00-02.00, 02.00-06.00). During the day, data collection was carried out by two persons, while at night, it was performed by three persons to avoid bias observation since bats as nocturnal animals~~, is~~ are more active during the night.

Data analysis

The descriptive data on ~~the flying fox~~*P. alecto* behavior including the length of activities were then tabulated, averaged, and presented as a percentage narrative form.

RESULTS AND DISCUSSION

Feeding behavior of *P. alecto*~~-~~ in cages.

Before ~~being fed~~feeding, all bats perched near the cage door while making repeated sounds~~. After~~, then after the food was spread on the floor, each ~~of them~~ crawled down quickly to grab some with the mouth and wings. Afterward, they chewed the food ~~while holding~~and also held some ~~others~~ with ~~its~~the toes. ~~The other individual~~Other individuals fed with ~~their~~the legs tied together with wires, and ~~their~~the bodies ~~leaned~~leaning on the cage floor near the food. It was observed that some bats did not take food from the floor, rather from those that were perched, such as bats with cubs. Based on the observed behavioral descriptions, first, the mothers crawled to the bottom to get food while holding ~~their~~the cubs ~~and~~, returned to perch, as well as chewed and ~~chew it while they~~ licked the liquid that came out of its mouth. Second, ~~they~~the cubs were released to perch ~~on their own~~separately, while the mothers went to the bottom of the cage to get food and returned to ~~where they were perched with their mouths~~ close to ~~that of their cubs. It was observed that they chewed their~~the cubs. The food was chewed severally, then ~~expelled~~ the waste in the form of dietary fiber was expelled, and it was noticed that ~~they~~the subjects rarely drank. The feeding behavior of bats in cages is shown in Figure 2.

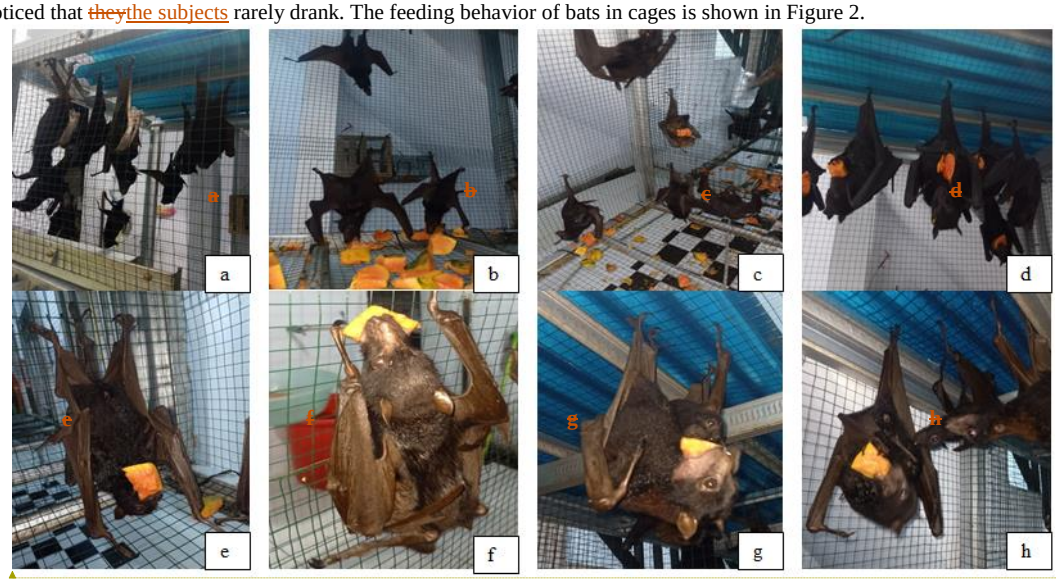

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Figure 2. Description of feeding behavior of ~~-~~*P. alecto* in the cage. (a) perch close to the cage door before feeding time, (b) take the food with ~~their~~the mouth, (c) eating with physical distancing between one individual to the others, (d) eating while hanging in the cage roof, (e) eating close to the cage floor, (f) bite the fruit and move back to the perch site, (g) feeding the infant, (h) grab (steal) the food from the other ~~individual~~individuals.

The feeding behavior of *P. alecto* species in cages was similar to ~~those~~others in ~~their~~the natural habitats~~. However,~~, but the location, fruit type, feeding method, form of food served, and availability were different. Papaya (*Carica papaya*) was chosen as the main type of food ~~during this study~~ based on the previous observations. ~~Based on our~~The preliminary ~~observation, *P. alecto*~~examination showed that the subjects tend to choose chopped papaya compared to ~~the~~ other provided ~~fruit~~fruits such as guava, water apple, and banana which were hung in the cage roof. Chopped papaya was scattered around the cage to give more ~~option~~options for the ~~bat~~bats and avoid fighting~~ among them~~. Markus and Blackshaw (2002) reported that the feeding behavior of bats in ~~their~~the habitat includes chewing, licking, throwing food, and drinking water. ~~The~~Meanwhile, the process of chewing produces juice extract, and the ability of the cubs to lick ~~their~~the mother's mouth is an act of introducing adult food (Dumont & O'neal 2004). ~~Results of this study illustrates~~The results illustrate that ~~bat~~ the bats in cages ~~showed~~show similar feeding behavior with ~~the bat~~others in ~~their~~the natural habitats as mentioned by Markus and Blackshaw (2002~~). However.~~), but It differs ~~on the~~ in relation to food availability and ~~how to get it. Food~~sources. In this study, the feed was always prepared in the ~~captivity~~cage, while wild bats need to forage to ~~get their own~~obtain food.

Bats ~~actives~~are nocturnal animals, hence, they are active during the night and spend most of the day time for rest and sleeping. ~~Ad~~Consequently, ad libitum feeding was chosen in this study with most of the fruit ~~was~~being prepared at 18.00. The feeding duration ~~of *P. alecto*~~ was recorded from afternoon till evening, although this activity usually ~~occurred~~occurs from 18.01 to 22.00, and it ~~consumed~~took a ~~lot of~~long time, relatively 11161.4±479.4 seconds. ~~There was~~ Although there are no ~~report or study~~reports on ~~their~~the feeding time and duration, both in ~~their~~the natural habitat and ~~those under captivity. However, based on~~in the cage. the observations~~,~~ carried out showed that this attribute tends to change when they are not fed at night. ~~In addition~~Furthermore, when ~~they are given unlimited~~the subjects were not fed with sufficient food (full at night), they are bound not to eat during the day, irrespective of its availability in the cage~~. They~~ but rather return to take the leftover food in the late afternoon. This illustrates that the feeding time of the captive bats ~~is~~has changed to daytime. In contrast ~~to those in their habitat, ~~, food is not available on perches~~,~~ for subjects in the natural habitat, therefore, they fly far in search of ~~its~~other sources, and this affects the timing and patterns of ~~their~~the feeding behavior. Schloesing ***et al.*** (2020) reported that other flying fox species, *P. lylei* depend on experience, availability and quality of food sources, ~~and~~as well as familiarity with the habitat. Moreover, Choden ***et al.*** (2019) ~~reported~~stated that these species fly over relatively 6.88 to 105 km at night to forage~~.~~, while Welbergen (2008) reported that *P. alecto* species usually leave ~~their~~the perches in search of food starting from 17.30 to 18.00. Similarly, *P. poliocephalus* foraging time ~~carried out~~is often in the evenings because it depends on the weather and the presence of predators (Welbergen, 2006).

Agonistic behavior of *P. alecto* in cages

The agonistic behavior of ~~*Pteropus*~~*P. alecto* species was exhibited ~~whenever they were given~~when receiving food (fruits), about to mate, or awake. During the feeding procedure, the dominant ones chased and attacked the others with ~~their~~ claws, ~~resulting~~thereby culminating in a fight. The chased bats continue to dodge while aiming and picking up the

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fruits ~~with~~using the ~~help of their~~ wings and perches far from the attacking one while eating. This behavior occurred repeatedly and stopped after they had all been fed. Meanwhile, during the mating process, ~~it was~~the male bats initially ~~observed that the male bat approaches~~approache one of the females while circling the perch and attacking its counterparts with ~~their~~the claws. The attacked one ~~tend~~tends to counterattack, using its foot and claws, and this occurred severally. The female also hits back at the target, while screaming and a fight ensues, it then tries to evade by moving from one place to another and wrapping the whole body with its wings. The subsequent observed agonistic behavior relates to the male ~~bat~~bats approaching the female from behind and then ~~hooks~~hooking its 2 wings on the back while holding that of its target and biting the neck. The female makes a sound and tries to escape from its grip, ~~resulting in~~leading to a fight. However, once released from the grip, they protect themselves by covering the entire body with ~~their~~the wings. Another observed ~~agonistic~~ behavior was the male ~~approached~~approaching the target by licking its mouth, head, body, and vagina. The female occasionally ~~makes~~produces sounds that cause the male to pause for a moment and then continues with licking the target's vagina while circling the ~~female bat's~~ perched position~~, still grabbed~~ and grabbing from behind, which leads to copulation. ~~This~~The final observed ~~agonistic~~ activity is a fistfight that only occurs briefly. Furthermore, when bats are awake, ~~sometimes~~ one ~~of them~~often moves and scratches ~~those~~others next to it, which reacts by making a sound and clawing back at the attacker. The description of the agonistic behavior of *P. alecto* in cages is shown in Figure 3.

Figure 3. Description of the agonistic behavior of *P. alecto* ~~-~~in the cage. (a) chasing other ~~individual~~individuals (b) fighting over the food, (c) attacking with the ~~wing to other individual~~wings which move down to take the fruit, (d) fighting ~~in~~on the floor, (e) male moving closer to female, (f) male attack female with the wing thumb, (g) male and female attack each other, (h) male embrace and bite the female's neck

There are no scientific reports related to the agonistic behavior of *P alecto* species during feeding in ~~their~~the habitat. However, ~~their~~the mating season which ~~were predicted~~was suggested to be from February to April (~~–~~Markus and Blackshaw~~,~~ 2002), is similar to the ~~bat~~bats in ~~the~~ captivity. ~~-~~Markus and Blackshaw (~~-~~2002) reported that this behavior in ~~their~~the habitat is to maintain roost areas during the mating season. The male bats usually attack others to defend ~~their~~the partners~~. This~~, this behavior was also recorded in other species of flying fox, *P. poliochalus* which ~~chasing~~chases and ~~fighting~~fights each other using ~~their~~ wings and teeth to defend ~~their~~individual territory (Welbergen, 2011).

The agonistic behavior of *P. alecto* associated with the males trying to mate with the females was observed during the day and at night. During the day, it often occurred from 10.01 to 14-00 for 15.7±9.1 seconds, while at night, it is usually from 22.01 to 02.00, and lasted for 28.2 ±18.2 seconds. Based on the observations, the males actively attacked the females from March to early April, while it rarely happen from May to July~~.~~ ~~The~~However, the agonistic activity recorded in this study is different from that observed in the habitat due to the struggle to perch~~, rather than the females' ability~~ compared to ~~mate, in contrast to that in~~ the cage~~.~~ ~~No scientific~~There are no previous reports ~~have been recorded~~ on the agonistic activity of *P. alecto* in ~~their~~the natural habitats both during the day and night. Markus (2002) reported that initially, these ~~bat flew~~bats fly in the afternoon, ~~they marked~~mark tree branches by rubbing ~~their~~the necks and chests during the day~~,~~ and the agonistic activity occurs once they return to perch on the tree in the morning. Moreover, ~~Markus (2002) also~~ it was observed that resident bats which ~~is~~are the individuals that ~~have their~~ own ~~roost~~ and ~~stay on it~~ permanently stay on the roost make sounds, chase, and fight non-resident ones~~,~~ ~~perched~~which perch on~~,~~ the marked tree branches~~ that have been marked~~, and they, in turn~~,~~ fly away within a duration of 16.5 ± 6.3 seconds. Furthermore, ~~it was reported that their~~the

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agonistic behavior during the mating season was relatively poor in ~~their~~the natural habitat ~~because~~due to the uneven sex ratio distribution ~~of the sex ratio was quite even or~~that is, the number of adult females was greater than the males. ~~This study reported~~The results also showed that the agonistic activity of captive bats usually occurs during the day and at night. Therefore, in terms of breeding, ~~it~~there is ~~necessary~~a need to pay serious attention to the duration of feeding the cubs and the ratio of males to females ~~(~~namely the number of males in one group~~)~~. This is because, during this season, male bats and breastfeeding mothers are usually active.

Grooming behavior of *P. ~~a~~lecto~~.~~* in cages

~~In accordance with the grooming~~Grooming behavior~~, it was observed that~~ is a treatment or effort to rid oneself of food remnants and oil from the skin glands (Markus and Blackshaw, 2002). Based on the observation, all individuals, including the mothers and ~~their~~the cubs, nurtured themselves, using ~~their~~the tongues, feet, toes, and claws. These were also used to scratch the face, head, teeth, back, neck, and ears. Sometimes the toes were slowly inserted into the ear canal~~. However,~~, but when in a perched position, the tongue is repeatedly and rapidly used to lick the front of the body, starting from the abdomen, chest, genitals, and wings. The stroking of the genitals by the males causes a penile erection without ejaculation. The grooming behavior of *P. alecto* in cages is shown in Figure 4.

During the observation process, grooming centered on the muzzle, face, and genitals was carried out in pairs. The males performed genital grooming on the females~~. Meanwhile,~~, while the mothers nurtured the cubs routinely, including during breastfeeding~~, when they were hugged. In addition~~ by hugging. Also, the mothers lick ~~their~~the heads, necks, and backs repeatedly~~. However,~~, but the front and back of ~~their~~the bodies, especially the muzzle are licked when ~~they hang~~hanging close to ~~their~~the mothers. The grooming behavior of *P. alecto* observed in this study was similar to the process observed in its natural habitat. Markus and Blackshaw (2002) reported that this species generally engages in ~~the~~ wing, ear, infant, and genital grooming. Furthermore, Markus (2002) ~~reported~~stated that penile grooming was ~~specially~~particularly observed during the mating process in ~~its~~the natural habitat~~. Grooming behavior is a treatment or effort to rid oneself of food remnants and oil from the skin glands (Markus and Blackshaw 2002).~~

Figure 4. Description of the grooming behavior of *P. alecto* in the cage. (a) wing ~~autogrooming~~auto grooming, (b) mouth and ear ~~autogrooming~~auto grooming, (c) male ~~autogrooming~~auto grooming caused the erection of its penis, (d) muzzle allogrooming, (e) vaginal allogrooming, (f) mouth allogrooming, (g) female grooming to its infant wing, (h) female grooming to its infant mouth

~~In respect to those in cages, this~~The grooming process was conducted from morning to evening~~, although~~, during the day, it often occurs at 14.01 to 18.00 for 1216.7±179.5 seconds, while at night, it takes place from 22.01 to 02.00 for 1930.9±387.8 seconds. Grooming activities ~~are~~were frequently carried out during the day, when ~~they are~~the subjects were awake, while at night, it ~~is~~was performed after they have been fed before locomotion and stationary activities. ~~The bats in the cages often engage in this process in the afternoon. Nocturnal~~Meanwhile, nocturnal grooming activities in ~~their~~the natural habitat are reported rarely because bats emerge from ~~their~~the roost and fly to forage~~. However, those~~, while others in cages are fed. Markus and Blackshaw (2002) reported that *P. alecto* ~~perched on~~found in Indooroopilly and Norman Greeks Islands go out to forage in the late afternoons and return to ~~their~~the perches in the mornings. Furthermore, it was stated that this activity ~~was conducted starting~~starts in the morning and is repeated throughout the day. This is consistent

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with Connell *et al.* (2006) which reported that grooming behavior in *P. poliocephalus* species mainly occurred in the mornings.

Sleeping behavior of *P. alecto* in cages

The sleeping behavior of *P. alecto* was monitored throughout the study in two ways. First, first, they perched on one leg, with its wings wrapped around the body and the head tucked underneath. Second, they perched on two legs, with wings wrapped around the body, head pointing downwards, and eyes closed. TheHowever, the most common sleeping behavior is perching on one leg with the head tucked under the wings. The first behavior was generally exhibited during the cold weather, especially at night and in the mornings, as well as when it rains alongduring rainfall with temperatures ranging from 24ºC to 28ºC with humidity of 98 to 80%. The second – was conducted during the hot season with temperatures ranging from 29ºC to 32ºC and 76 to 59% humidity. Based on ourthe observations, the *P. alecto*'s perching and sleeping positions never changed according to the initial, back to back,did not change as the juvenile bats beingwere close to theirthe mothers, andwhile the males being alone,were occasionally alone. This species usually awakewakes up when there are disturbances around the cage, such as people passing. This is proven by the movement of theirthe heads and eyes while automatically shaking theirthe ears, as shown in Figure 5. Based on this study, it was reported thatthe results, the sleeping behavior in the cage is similar to that on trees. Markus and Blackshaw (2002), reported that this species eitherusually perches on both legs or one, with its wings wrapped throughout the body, and the head tucked underneath. Furthermore, severalthe sleeping behavioral activities arewere regulated by the weather and disturbances, and when there is a disturbance, they react by directing theirthe gaze. During the hot weather, the bats open theirthe wings, while in the cold season, it is folded, and in addition,but when there is heavy rain stopsrainfall, all their activities are stopped. Additionally, the distribution of *P. alecto* perch in its natural habitat is consistent and does not change according to the existing group.

Figure 5. Description of the sleeping behavior of *P. alecto* in the cage. (a) sleeping in a group, hanging with one leg and covercovering the head with theirthe wing, (b) sleeping in a subgroupsub-group, hanging with one leg and covercovering the head with theirthe wing, (c) sleeping alone, (d) sleeping in back to back position, (e) sleeping in a group, hanging with one leg and face the ground, (f) sleeping in a subgroupsub-group, hanging with two leg and face the ground, (g) sub-adult individual sleep close to theirthe mother, (h) sleep in their ownindividual position

The sleeping time of thosefor the subjects in the cage starts from 10.01 to 18.00. However, these nocturnal animals but they slept at night from 10.01 to 02.00 for 1270.6±235.6 seconds and from 02.00 to 06.00 for 11513.7±345.2 seconds. During this period, the bats were wakeawake most of the time, performing certain activities such as feeding, grooming, agonistic, perching, and walking back and forth in the cage. Sleep during the day was mostly from 06.01 to 10.00 for 13967.9±560.9 seconds, and from 10.01 to 14.00 for 12689.4±250.0 seconds. In the afternoons from 14.01 to 18.00, theirthe sleeping time decreases to reduce, to 9225.6±359.1 seconds because they start to carry out otherdue to certain activities such as perching while, grooming, being agonistic, and feeding. MostFurthermore, most of the sleeping behavior was performed from 06.01 to 10.00 because the weather temperature rangesranged from 24ºC to 29ºC. However, towards noon, the time reduced because the temperature increased from approximately 29ºC to 33ºC. At this time, bats perched

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while opening and flapping ~~their~~the wings. There is no information on the duration of sleep in the natural habitat at night because bats usually fly at that time in search of food. ~~In contrast~~Compared to ~~those~~others in the cages, ~~their~~the food ~~was~~is usually available, therefore the time for foraging was used for sleeping and other activities. ~~There is also no information about their sleep duration in the natural habitat when perched during the day.~~ However, Markus and Blackshaw (2002) reported that the diurnal pattern of *P. alecto* is dominated by nesting, sleeping, grooming, and slight social activities, ~~irrespective of the fact that the bats are~~despite being awake for a long time during the day~~,~~ although ~~they are~~ mostly inactive. Also, Connell *et al.* (2006) reported that *P. poliocephalus* generally ~~slept~~sleeps in ~~their~~the habitat during the day.

Locomotion and stationary behavior of *P. alecto* in cages

The observed stationary behavior ~~was~~is as follows, first, ~~(*streach*),~~ the ~~bat perched,~~bats *stretch* by perching with its wings, ~~spread~~spreading wide to the left, right, and forward, and then ~~folded~~folding backward. Second, ~~(~~the *wing fan* ~~they) they perched,~~is used by perching with part of its wings drooping while ~~being flapped~~flapping slowly~~, in accordance with~~ according to the movement of the head, ears, and eyes looking around the cage. ~~Third, (~~The third is *static flight*~~), bat perched~~ performed by perching while the wings were flapped rapidly for a few seconds, and then folded back. The first stationary behavior is usually performed during the day and at night, while the second is usually observed during the day when the weather is hot, and the third is at night. In general, the static flight is mostly practiced by cub and juvenile bats~~.~~ ~~Based on observations, the infant bats~~ that were ~~taught~~still learning how to fly ~~by their mother in a place far~~ from the ~~others~~mother. The cubs were hooked to the mothers' legs on a ram wire, a moment later, they flapped ~~their~~the wings once and touched that of the infants, ~~which caused them to kick flap theirs. This~~this activity was accomplished 2 to 3 times. ~~Afterward, they~~Furthermore, the infants hugged ~~their~~the mothers again, and this activity was repeated until they were able to fly. The stationary behavior of the *P. alecto* ~~in their~~the natural habitat was also observed~~, although~~ but in different places. ~~Furthermore, the~~The observed locomotive behavior includes the following~~. First~~, first, they perched on the two legs, the head lifted straight, the wings opened, and then briefly flew around the cage. Second, the bats used ~~their~~both feet and claws to move back and forth on the porch, and crawl to the bottom, up and down through the cage rams in rapid motion. The description of the locomotion and stationary behavior of this species in cages are shown in Figure 6.

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Figure 6. Description of locomotion and stationary behavior of *P. alecto* in cages (a) perch with eyes looking ahead, (b) flight preparation, (c) wings drooping while being fluttered, (d) wings spread wide, (e) infant learn to fly, (f) mother opens wings behind ~~her~~the infant, (g) juvenile opens wings while others are awake, (h) perch while awake

The locomotion and stationary behavior generally do not involve physical contact with other bats in the cage~~. There~~, also, there are no differences between the ~~captive ones~~captives and ~~those~~others in ~~its~~the natural habitat. Markus and Blackshaw (2002) reported that ~~bats~~the flapping ~~their~~of wings and opening ~~their~~of mouths *(pant)* are actions engaged ~~in~~ to cool ~~their bodies~~the body during ~~the~~ hot weather~~. In addition,~~, while the spreading ~~their~~of wings wide (stretch) is ~~completed before they~~performed to relax. ~~The~~Furthermore, the static flight was carried out to strengthen the wings and chest muscles in preparation for movement. ~~Furthermore, in its~~ In the natural habitat, *P. alecto* performs locomotion using both legs to hold branches, drooping wings ~~(~~which open on the left ~~and~~ right~~)~~, back and forth, up ~~and downs~~ down, as well as briefly flying between the trees. Locomotion (moving) and stationary (remaining at a place) behavior is an activity that involves moving from one place to another without making any physical contact with other bats, by flapping, flying, and perching while covering all or part of ~~their bodies~~the body with its wings while shaking ~~their~~the heads, and opening ~~their~~the eyes (Markus and Blackshaw, 2002).

Locomotion and stationary activities of bats in cages were carried out during the day and at night. However, it was often performed at night from 10.01 to 02.00 for 9661.5±389.3 seconds and from 02.01 to 06.00 for 7902.7±250.9 seconds (Table 1). This ~~activity is carried out~~is because bats are nocturnal animals and are mostly active at night~~. This~~ as this time is used for foraging and returning to the perch in the early hours of the morning after getting food. In the cage, food is already available, therefore, they engage in other activities. ~~Locomotion~~However, the locomotion and stationary activities of bats in cages at night ~~are~~were different from ~~those~~others performed during the day. At night, ~~they~~the bats move around quickly and actively perform motions ~~in an active manner. At the same time,~~ while during the day, they ~~just~~simply perch in a place, stay awake, and move when there is internal interference from others or external factors such as exposure to sunlight~~. People~~ or people visiting the location around the cage. These activities are different ~~from those carried out in nature. This is~~compared to others in the natural habitat, because, at night, they do not stay in the perch, except for cubs that are ~~not~~ yet ~~able~~unable to fly. Markus and Blackshaw (2002) reported that at night, ~~they~~the cubs are left by ~~their~~the mothers, and they move by dragging ~~and~~or climbing branches~~,~~ and sometimes ~~they~~ congregate ~~in~~to form small groups, wrestling at close range ~~and~~ with ~~their~~the chests sticking together occasionally. Pulling wings without anyone dodging is interpreted as a play activity. ~~Locomotion~~Meanwhile, the locomotion and stationary activities of *P. vampyrus* bats in nature have been reported by Hengyan *et al.* (2017), ~~relating to the fact~~which stated that they are mostly awake and engage in various practices during the day.

Duration and percentage of day and night behavioral activity of *P. alecto* in cages

Table 1: Duration and percentage of day and night behavioral activity performed by *P. alecto* in cages.

Behavior	Day		Night		Total Activity	
	Duration (second)	(%)	Duration (second)	(%)	Duration (second)	(%)
Feeding	2756,18	3,19	13970,21	16,17	16726,39	19,36

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Agonistic		52,3	0,06	56,16	0,06	108,56	0,12
Grooming	9		2,84	3088,19	3,57	5547,58	6,41
Sleeping		2459,60	41,53	12784,33	14,80	48666,68	56,33
Stationary and locomotion		35882,35	2,37	13300,91	15,39	15350,22	17,76
Total		2049,31	49,99	43199,82	49,99	86399,64	98,98
		43199,83					

The activities of *P. alecto* were dominated by sleeping, feeding, stationary and locomotion, grooming, ~~and~~as well as agonistic behaviors at 56.33%, 19.36%, 17.76%, 6.41%, and 0.12%, respectively (Table 1). This ~~means~~indicates that 56.33% of bats did not engage in these practices, ~~only~~while 43.67% did. The dominant behavior during the day was sleeping, which was performed by 41.53~~% of them,~~%, while at night 16.17% engaged in feeding. ~~The~~ In contrast, the least ~~percentage of~~ behavioral activities during the day and at night ~~was~~were agonistic~~. Grooming~~, while grooming, stationary, and locomotion were often carried out at night. There ~~was~~is no comparative literature on the percentage of day and night behavioral activities performed by captive~~,~~ *P. alecto* species and ~~those~~others in ~~nature~~the natural habitat. The percentage of daytime behavioral activities was observed in the *Cynopterus sphinx* and *Pteropus vampyrus* species. Syamsi (2013) reported that 66.17% of *Cynopterus sphinx* slept during the day, followed by 21.09% that engaged in stationary and locomotion activities ~~and~~as well as 11.98% that participated in grooming. Furthermore, Hengyan *et al.* (2017) reported that the daytime activity of *P. vampyrus* species in ~~their~~the habitat was 53.1 ± 13.9~~%,~~% grooming, 5.7±2.3~~%, aggression~~% agonistic, 2.4±7~~%,~~% locomotion, and 2.3±1.6 stationary. The percentage of agonistic ~~illustrated~~behavior illustrates that the bats have adapted to the environment and food provided in the cage ~~because~~, consequently, fights that ~~caused~~cause injuries and stress rarely ~~occurred~~occur. Therefore, the percentage of behavioral activities performed by the species in cages provides information and an initial description of the sustainable ex-situ breeding strategy. ~~Bat~~ Based on the results, cage breeding ~~in the captivity could be~~is suggested as one of the solutions to provide source for ~~bat utilisation~~bats utilization and reduce ~~the threat~~threats such as ~~bat~~ hunting in ~~their~~the natural habitat. Moreover, ~~we hope~~it is expected that the ~~success story and~~ important behavior information ~~of~~obtained from flying fox in the cage ~~can be~~is implemented for other species of bat.

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Behavior of the Back Flying Fox, *Pteropus alecto* (Chiroptera: Pteropodidae) in cages

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Abstract. Hunting and illegal trading have become a common thread for the Black Flying Fox in Sulawesi but information on its biology and behavior as a baseline for conservation and management program is still lacking. Therefore, this study aims to examine the behavioral activities of Black Flying Fox, *Pteropus alecto* kept in cages through direct observation. The results showed that feeding was carried out by descending to the bottom of the cage before picking up fruits with the mouth and wings. Furthermore, the time associated with this process ranged from 06.01 to 10.00, while agonistic behavior performed using claws and wings took place from 10.01 to 14.00 in the daytime and 22.01 to 02.00 at night. Grooming was carried out using the tongue and wings, from 14.01 to 18.00 during the day and 22.01 to 02.00 during the night. Subsequently, the bats slept by perching with the eyes closed and the whole body wrapped with the wings from 02.01 to 10.00, while locomotion and stationary behaviors were performed by perching with eyes open and flying around the cage with the wings spread apart from 10.01 to 14.00 during the day and 22.01 to 02.00 at night. The percentage of day and night behavior activities consist of agonistic 0.12%, grooming 6.14%, eating 19.36%, sleeping 56.33%, and stationary and locomotive 17.76%. The results improve the understanding of *P. alecto's daily activities* in the cage which are difficult to observe in the wild and provide insight for conservation and wildlife management. Furthermore, information from this study is useful for future bat captivity programs.

Keywords: activity, behavior, day, night, Flying fox, *Pteropus alecto*.

Running title: The behavior of the bat in the cage

INTRODUCTION

Bats play an ecological role in maintaining forest diversity due to the function as seed dispersers (Seltzer *et al*. 2013; Deshpande and Kelkar 2015; Lartey *et al.* 2016) and pollinators of plants with high economic value such as durian (Scarlon *et al.*, 2016; Lim *et al.* 2018; Sritongchuay *et al.* 2019; Tremlett *et al.* 2020; Aziz *et al.* 2017; Muhammad *et al.* 2020; Low *et al.* 2021). However, they are hunted and consumed in some communities (Scheffers *et al.* 2012; Ransaleleh *et al.* 2013; Suwannorang and Schuler 2016) due to the medicinal properties (Mildenstein 2016; Aziz *et al.* 2017; Low et al. 2021; Rocha *et al.* 2021), and the ability to increase stamina (Suwannarong *et al.* 2020).

In North Sulawesi, bats meat particularly flying foxes such as *Acerodon celebensis* and *Pteropus alecto* are imported and traded in traditional markets for consumption (Sheherazale & Susan, 2015; Latinne *et al.* 2020; Ransaleleh *et al.* 2020). Based on a survey conducted during the COVID-19 pandemic, frozen flying fox are sold in some supermarkets in cities, such as Manado, Tomohon, and Amurang, of North Sulawesi, Indonesia. Meanwhile, *P. alecto* is one of the preferred species for consumption (Ruba *et al.* 2016) due to its large body size with the percentage of carcass ranging from 45.37 to 54.07% of the total body weight (Ransaleleh *et al*. 2014), but its high demand causes uncontrollable hunting. According to the IUCN Red List category and criteria, *P. alecto* is categorized as Least Concern, indicating that it is a species at low risk. However, the continuous hunting of this species which has a long reproductive cycle, once a year, with only one pup per birth might lead to a serious population decline.

The rampant hunting and selling of bats depict that the community's understandi\ng of its role in the ecosystem is limited and this might lead to extinction. Therefore, there is a need to determine its sustainability, through approaches related to the legal status of fruit-eating bats (Maulany *et al.* 2021), socialization in human life, and conservation efforts (Frick *et al.* 2019). The behavioral activities such as agonistic, grooming, sleeping, feeding, stationary, and locomotion provide essential information for its conservation and management (Markus & Blackshaw 2002; Hofstede & Fenton 2005; Connell *et al.* 2006). However, there is a lack of information and study on the behavior of flying fox bats in Indonesia. The behavioral activities exhibited by *P. alecto* in its habitat were reported 19 years ago (Markus & Blackshaw 2002; Markus 2002), and were observed during the day. This is because a complete observation of flying fox behavior covering day and night activities in the habitat is difficult, consequently, observation in captivity is one of the suggested methods. Therefore, this study aims to observe the behavioral activities of *P. alecto* in cages during the day and at night. Aside from supporting an effective wildlife management program, this study also provides information to develop bats captivity which has not

been carried out previously. Captivity and domestication are proposed as one of the solutions to increase bats population, a source for wildlife utilization, and overcome the threats such as hunting in the natural habitat.

MATERIALS AND METHODS

Study area

This study was carried out in neighborhood V of Wanea Village, Manado City, with coordinates 1º27'39" N and 124º50'33" E (Figure 1) for four months, from April to July 2021. A total of 9 *P.alecto* species consisting of two adult males, three juveniles, two females that had never given birth, and two lactating individuals were used. All subjects were kept in the 2.5-meter cage made of tasso and ram wire, with a size of 3 x 1.5 x 1.5 meters (LxWxH). Meanwhile, the adult subjects were rescued from the wildlife market and placed in the cage since 2011. In 2020, they were moved from the old cage made from wood to a new one, while the sub-adults and juveniles were born in this new cage in 2020.

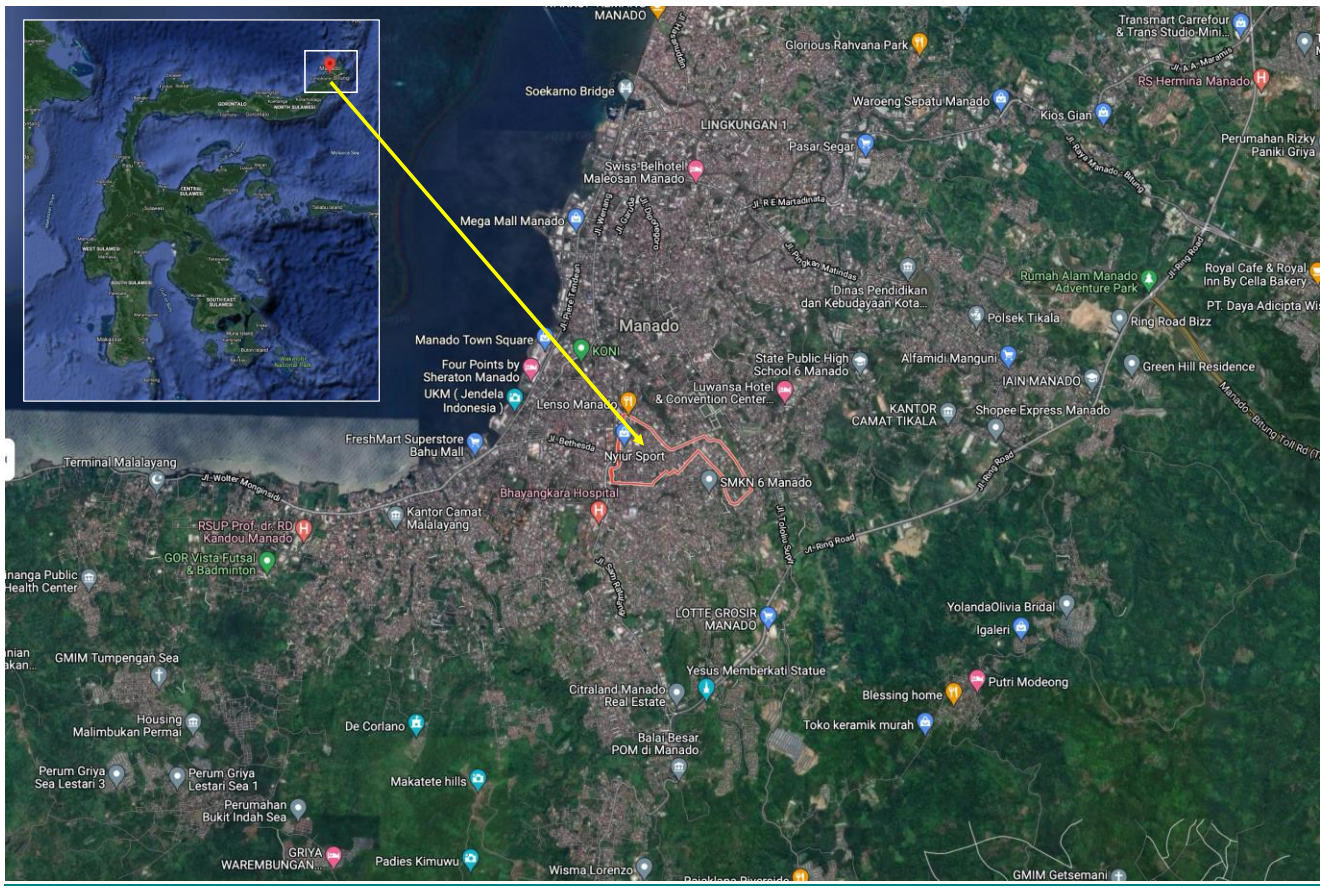

Figure 1: The study area was in the neighborhood V of Wanea Village, Manado City, with coordinates of 1º27'39" N, 124 º50'33" E.

Procedures

The preliminary observation was conducted to determine the time and type of behavioral activities exhibited in the cage. During the day, the subjects were observed from 06.01 to 10.00, 10.01 to 14.00, 14.01 to 18.00, and at night, from 18.01 to 22.00, 22.01 to 02.00, 02.00 to 06.00. This was carried out from March to July 2021 and the types of behaviors observed include agonistic, grooming, feeding, sleeping, and other activities such as locomotion and stationary which were directly observed using observation sheets, CCTV, and cameras. The recorded and documented data were the duration descriptions of each observed behavioral activity. Furthermore, the recorded activities from the CCTV cameras were re-played, examined, and recorded in the observation sheets. Given that there is no previous similar study, data and information collection were set consistently for every two days during the day and at night, from 06.01 to 06.01 for 24 hours throughout this study (Markus and Blackshaw, 2002). Furthermore, environmental conditions including the air temperature and humidity were also recorded periodically, during the day (06.00- 10.00, 10.00-14.00, 14.00-18.00) and at night (18.00-22.00, 22.00-02.00, 02.00-06.00). During the day, data collection was carried out by two persons, while at

night, it was performed by three persons to avoid bias observation since bats as nocturnal animals are more active during the night.

Data analysis

The descriptive data on *P. alecto* behavior including the length of activities were then tabulated, averaged, and presented as a percentage narrative form.

RESULTS AND DISCUSSION

Feeding behavior of *P. alecto* in cages.

Before feeding, all bats perched near the cage door while making repeated sounds, then after the food was spread on the floor, each crawled down quickly to grab some with the mouth and wings. Afterward, they chewed the food and also held some with the toes. Other individuals fed with the legs tied together with wires, and the bodies leaning on the cage floor near the food. It was observed that some bats did not take food from the floor, rather from those that were perched, such as bats with cubs. Based on the observed behavioral descriptions, first, the mothers crawled to the bottom to get food while holding the cubs, returned to perch, as well as chewed and licked the liquid that came out of its mouth. Second, the cubs were released to perch separately, while the mothers went to the bottom of the cage to get food and returned to close to the cubs. The food was chewed severally, then the waste in the form of dietary fiber was expelled, and it was noticed that the subjects rarely drank. The feeding behavior of bats in cages is shown in Figure 2.

Figure 2. Description of feeding behavior of *P. alecto* in the cage. (a) perch close to the cage door before feeding time, (b) take the food with the mouth, (c) eating with physical distancing between one individual to the others, (d) eating while hanging in the cage roof, (e) eating close to the cage floor, (f) bite the fruit and move back to the perch site, (g) feeding the infant, (h) grab (steal) the food from the other individuals.

The feeding behavior of *P. alecto* species in cages was similar to others in the natural habitats, but the location, fruit type, feeding method, form of food served, and availability were different. Papaya (*Carica papaya*) was chosen as the main type of food based on the previous observations. The preliminary examination showed that the subjects tend to choose chopped papaya compared to other provided fruits such as guava, water apple, and banana which were hung in the cage roof. Chopped papaya was scattered around the cage to give more options for the bats and avoid fighting. Markus and Blackshaw (2002) reported that the feeding behavior of bats in the habitat includes chewing, licking, throwing food, and drinking water. Meanwhile, the process of chewing produces juice extract, and the ability of the cubs to lick the mother's mouth is an act of introducing adult food (Dumont & O'neal 2004). The results illustrate that the bats in cages show similar feeding behavior with others in the natural habitats as mentioned by Markus and Blackshaw (2002), but It differs in relation to food availability and sources. In this study, the feed was always prepared in the cage, while wild bats need to forage to obtain food.

Bats are nocturnal animals, hence, they are active during the night and spend most of the day time for rest and sleeping. Consequently, ad libitum feeding was chosen in this study with most of the fruit being prepared at 18.00. The feeding duration was recorded from afternoon till evening, although this activity usually occurs from 18.01 to 22.00, and it took a long time, relatively 11161.4±479.4 seconds. Although there are no reports on the feeding time and duration, both in the natural habitat and in the cage. the observations carried out showed that this attribute tends to change when they are not fed at night. Furthermore, when the subjects were not fed with sufficient food (full at night), they are bound not to eat during the day, irrespective of its availability in the cage but rather return to take the leftover food in the late afternoon. This illustrates that the feeding time of the captive bats has changed to daytime. In contrast, food is not available on perches for subjects in the natural habitat, therefore, they fly far in search of other sources, and this affects the timing and patterns of the feeding behavior. Schloesing *et al.* (2020) reported that other flying fox species, *P. lylei* depend on experience, availability and quality of food sources, as well as familiarity with the habitat. Moreover, Choden *et al.* (2019) stated that these species fly over relatively 6.88 to 105 km at night to forage, while Welbergen (2008) reported that *P. alecto* species usually leave the perches in search of food starting from 17.30 to 18.00. Similarly, *P. poliocephalus* foraging time is often in the evenings because it depends on the weather and the presence of predators (Welbergen, 2006).

Agonistic behavior of *P. alecto* in cages

The agonistic behavior of *P. alecto* species was exhibited when receiving food (fruits), about to mate, or awake. During the feeding procedure, the dominant ones chased and attacked the others with claws, thereby culminating in a fight. The chased bats continue to dodge while aiming and picking up the fruits using the wings and perches far from the attacking one while eating. This behavior occurred repeatedly and stopped after they had all been fed. Meanwhile, during the mating process, the male bats initially approache one of the females while circling the perch and attacking its counterparts with the claws. The attacked one tends to counterattack, using its foot and claws, and this occurred severally. The female also hits back at the target, while screaming and a fight ensues, it then tries to evade by moving from one place to another and wrapping the whole body with its wings. The subsequent observed agonistic behavior relates to the male bats approaching the female from behind and then hooking its 2 wings on the back while holding that of its target and biting the neck. The female makes a sound and tries to escape from its grip, leading to a fight. However, once released from the grip, they protect themselves by covering the entire body with the wings. Another observed behavior was the male approaching the target by licking its mouth, head, body, and vagina. The female occasionally produces sounds that cause the male to pause for a moment and then continues with licking the target's vagina while circling the perched position and grabbing from behind, which leads to copulation. The final observed activity is a fistfight that only occurs briefly. Furthermore, when bats are awake, one often moves and scratches others next to it, which reacts by making a sound and clawing back at the attacker. The description of the agonistic behavior of *P. alecto* in cages is shown in Figure 3.

Figure 3. Description of the agonistic behavior of *P. alecto* in the cage. (a) chasing other individuals (b) fighting over the food, (c) attacking with the wings which move down to take the fruit, (d) fighting on the floor, (e) male moving closer to female, (f) male attack female with the wing thumb, (g) male and female attack each other, (h) male embrace and bite the female's neck

There are no scientific reports related to the agonistic behavior of *P alecto* species during feeding in the habitat. However, the mating season which was suggested to be from February to April (Markus and Blackshaw, 2002), is similar

to the bats in captivity. Markus and Blackshaw (2002) reported that this behavior in the habitat is to maintain roost areas during the mating season. The male bats usually attack others to defend the partners, this behavior was also recorded in other species of flying fox, *P. poliochalus* which chases and fights each other using wings and teeth to defend individual territory (Welbergen, 2011).

The agonistic behavior of *P. alecto* associated with the males trying to mate with the females was observed during the day and at night. During the day, it often occurred from 10.01 to 14-00 for 15.7±9.1 seconds, while at night, it is usually from 22.01 to 02.00, and lasted for 28.2 ±18.2 seconds. Based on the observations, the males actively attacked the females from March to early April, while it rarely happen from May to July. However, the agonistic activity recorded in this study is different from that observed in the habitat due to the struggle to perch compared to the cage. There are no previous reports on the agonistic activity of *P. alecto* in the natural habitats both during the day and night. Markus (2002) reported that initially, these bats fly in the afternoon, mark tree branches by rubbing the necks and chests during the day, and the agonistic activity occurs once they return to perch on the tree in the morning. Moreover, it was observed that resident bats which are the individuals that own and permanently stay on the roost make sounds, chase, and fight non-resident ones which perch on the marked tree branches, and they, in turn fly away within a duration of 16.5 ± 6.3 seconds. Furthermore, the agonistic behavior during the mating season was relatively poor in the natural habitat due to the uneven sex ratio distribution that is, the number of adult females was greater than the males. The results also showed that the agonistic activity of captive bats usually occurs during the day and at night. Therefore, in terms of breeding, there is a need to pay serious attention to the duration of feeding the cubs and the ratio of males to females namely the number of males in one group. This is because, during this season, male bats and breastfeeding mothers are usually active.

Grooming behavior of *P. alecto* in cages

Grooming behavior is a treatment or effort to rid oneself of food remnants and oil from the skin glands (Markus and Blackshaw, 2002). Based on the observation, all individuals, including the mothers and the cubs, nurtured themselves, using the tongues, feet, toes, and claws. These were also used to scratch the face, head, teeth, back, neck, and ears. Sometimes the toes were slowly inserted into the ear canal, but when in a perched position, the tongue is repeatedly and rapidly used to lick the front of the body, starting from the abdomen, chest, genitals, and wings. The stroking of the genitals by the males causes a penile erection without ejaculation. The grooming behavior of *P. alecto* in cages is shown in Figure 4.

During the observation process, grooming centered on the muzzle, face, and genitals was carried out in pairs. The males performed genital grooming on the females, while the mothers nurtured the cubs routinely, including during breastfeeding by hugging. Also, the mothers lick the heads, necks, and backs repeatedly, but the front and back of the bodies, especially the muzzle are licked when hanging close to the mothers. The grooming behavior of *P. alecto* observed in this study was similar to the process observed in its natural habitat. Markus and Blackshaw (2002) reported that this species generally engages in wing, ear, infant, and genital grooming. Furthermore, Markus (2002) stated that penile grooming was particularly observed during the mating process in the natural habitat.

Figure 4. Description of the grooming behavior of *P. alecto* in the cage. (a) wing auto grooming, (b) mouth and ear auto grooming, (c) male auto grooming caused the erection of its penis, (d) muzzle allogrooming, (e) vaginal allogrooming, (f) mouth allogrooming, (g) female grooming to its infant wing, (h) female grooming to its infant mouth

The grooming process was conducted from morning to evening, during the day, it often occurs at 14.01 to 18.00 for 1216.7±179.5 seconds, while at night, it takes place from 22.01 to 02.00 for 1930.9±387.8 seconds. Grooming activities were frequently carried out during the day, when the subjects were awake, while at night, it was performed after they have been fed before locomotion and stationary activities. Meanwhile, nocturnal grooming activities in the natural habitat are reported rarely because bats emerge from the roost and fly to forage, while others in cages are fed. Markus and Blackshaw (2002) reported that *P. alecto* found in Indooroopilly and Norman Greeks Islands go out to forage in the late afternoons and return to the perches in the mornings. Furthermore, it was stated that this activity starts in the morning and is repeated throughout the day. This is consistent with Connell *et al.* (2006) which reported that grooming behavior in *P. poliocephalus* species mainly occurred in the mornings.

Sleeping behavior of *P. alecto* in cages.

The sleeping behavior of *P. alecto* was monitored throughout the study in two ways, first, they perched on one leg, with its wings wrapped around the body and the head tucked underneath. Second, they perched on two legs, with wings wrapped around the body, head pointing downwards, and eyes closed. However, the most common sleeping behavior is perching on one leg with the head tucked under the wings. The first behavior was generally exhibited during the cold weather, especially at night and in the mornings, as well as during rainfall with temperatures ranging from 24ºC to 28ºC with humidity of 98 to 80%. The second was conducted during the hot season with temperatures ranging from 29ºC to 32ºC and 76 to 59% humidity. Based on the observations, the *P. alecto*'s perching and sleeping positions did not change as the juvenile bats were close to the mothers, while the males were occasionally alone. This species usually wakes up when there are disturbances around the cage, such as people passing. This is proven by the movement of the heads and eyes while automatically shaking the ears, as shown in Figure 5. Based on the results, the sleeping behavior in the cage is similar to that on trees. Markus and Blackshaw (2002), reported that this species usually perches on both legs or one, with its wings wrapped throughout the body, and the head tucked underneath. Furthermore, the sleeping behavioral activities were regulated by the weather and when there is a disturbance, they react by directing the gaze. During hot weather, the bats open the wings, while in the cold season, it is folded, but when there is heavy rainfall, all activities are stopped. Additionally, the distribution of *P. alecto* perch in its natural habitat is consistent and does not change according to the existing group.

Figure 5. Description of the sleeping behavior of *P. alecto* in the cage. (a) sleeping in a group, hanging with one leg and covering the head with the wing, (b) sleeping in a sub-group, hanging with one leg and covering the head with the wing, (c) sleeping alone, (d) sleeping in back to back position, (e) sleeping in a group, hanging with one leg and face the ground, (f) sleeping in a sub-group, hanging with two leg and face the ground, (g) sub-adult individual sleep close to the mother, (h) sleep individual position

The sleeping time for the subjects in the cage starts from 10.01 to 18.00 but they slept at night from 10.01 to 02.00 for 1270.6±235.6 seconds and from 02.00 to 06.00 for 11513.7±345.2 seconds. During this period, the bats were awake most of the time, performing certain activities such as feeding, grooming, agonistic, perching, and walking back and forth in the cage. Sleep during the day was mostly from 06.01 to 10.00 for 13967.9±560.9 seconds, and from 10.01 to 14.00 for

12689.4±250.0 seconds. In the afternoons from 14.01 to 18.00, the sleeping time decreases to 9225.6±359.1 seconds due to certain activities such as perching, grooming, agonistic, and feeding. Furthermore, most of the sleeping behavior was performed from 06.01 to 10.00 because the weather temperature ranged from 24ºC to 29ºC. However, towards noon, the time reduced because the temperature increased from approximately 29ºC to 33ºC. At this time, bats perched while opening and flapping the wings. There is no information on the duration of sleep in the natural habitat at night because bats usually fly at that time in search of food. Compared to others in the cages, the food is usually available, therefore the time for foraging was used for sleeping and other activities. However, Markus and Blackshaw (2002) reported that the diurnal pattern of *P. alecto* is dominated by nesting, sleeping, grooming, and slight social activities, despite being awake for a long time during the day although mostly inactive. Also, Connell *et al.* (2006) reported that *P. poliocephalus* generally sleeps in the habitat during the day.

Locomotion and stationary behavior of *P. alecto* in cages

The observed stationary behavior is as follows, first, the bats *stretch* by perching with its wings, spreading wide to the left, right, and forward, and then folding backward. Second, the *wing fan* is used by perching with part of its wings drooping while flapping slowly according to the movement of the head, ears, and eyes looking around the cage. The third is *static flight* performed by perching while the wings were flapped rapidly for a few seconds, and then folded back. The first stationary behavior is usually performed during the day and at night, while the second is usually observed during the day when the weather is hot, and the third is at night. In general, the static flight is mostly practiced by cub and juvenile bats that were still learning how to fly from the mother. The cubs were hooked to the mothers' legs on a ram wire, a moment later, they flapped the wings once and touched that of the infants, this activity was accomplished 2 to 3 times. Furthermore, the infants hugged the mothers again, and this activity was repeated until they were able to fly. The stationary behavior of the *P. alecto* in the natural habitat was also observed but in different places. The observed locomotive behavior includes the following, first, they perched on the two legs, the head lifted straight, the wings opened, and then briefly flew around the cage. Second, the bats used both feet and claws to move back and forth on the porch, and crawl to the bottom, up and down through the cage rams in rapid motion. The description of the locomotion and stationary behavior of this species in cages are shown in Figure 6.

Figure 6. Description of locomotion and stationary behavior of *P. alecto* in cages (a) perch with eyes looking ahead, (b) flight preparation, (c) wings drooping while being fluttered, (d) wings spread wide, (e) infant learn to fly, (f) mother opens wings behind the infant, (g) juvenile opens wings while others are awake, (h) perch while awake

The locomotion and stationary behavior generally do not involve physical contact with other bats in the cage, also, there are no differences between the captives and others in the natural habitat. Markus and Blackshaw (2002) reported that the flapping of wings and opening of mouths *(pant*) are actions engaged to cool the body during hot weather, while the spreading of wings wide (stretch) is performed to relax. Furthermore, the static flight was carried out to strengthen the wings and chest muscles in preparation for movement. In the natural habitat, *P. alecto* performs locomotion using both legs to hold branches, drooping wings which open on the left-right, back and forth, up-down, as well as briefly flying between the trees. Locomotion (moving) and stationary (remaining at a place) behavior is an activity that involves moving from one place to another without making any physical contact with other bats, by flapping, flying, and perching while

covering all or part of the body with its wings while shaking the heads, and opening the eyes (Markus and Blackshaw, 2002).

Locomotion and stationary activities of bats in cages were carried out during the day and at night. However, it was often performed at night from 10.01 to 02.00 for 9661.5±389.3 seconds and from 02.01 to 06.00 for 7902.7±250.9 seconds (Table 1). This is because bats are nocturnal animals and are mostly active at night as this time is used for foraging and returning to the perch in the early hours of the morning after getting food. In the cage, food is already available, therefore, they engage in other activities. However, the locomotion and stationary activities of bats in cages at night were different from others performed during the day. At night, the bats move around quickly and actively perform motions, while during the day, they simply perch in a place, stay awake, and move when there is internal interference from others or external factors such as exposure to sunlight or people visiting the location around the cage. These activities are different compared to others in the natural habitat, because, at night, they do not stay in the perch, except for cubs that are yet unable to fly. Markus and Blackshaw (2002) reported that at night, the cubs are left by the mothers, and they move by dragging or climbing branches and sometimes congregate to form small groups, wrestling at close range with the chests sticking together occasionally. Pulling wings without anyone dodging is interpreted as a play activity. Meanwhile, the locomotion and stationary activities of *P. vampyrus* bats in nature have been reported by Hengyan *et al.* (2017), which stated that they are mostly awake and engage in various practices during the day.

Duration and percentage of day and night behavioral activity of *P. alecto* in cages

Table 1: Duration and percentage of day and night behavioral activity performed by *P. alecto* in cages.

Behavior	Day		Night		Total Activity	
	Duration (second)	(%)	Duration (second)	(%)	Duration (second)	(%)
Feeding	2756,18	3,19	13970,21	16,17	16726,39	19,36
Agonistic	52,39	0,06	56,16	0,06	108,56	0,12
Grooming	2459,60	2,84	3088,19	3,57	5547,58	6,41
Sleeping	35882,35	41,53	12784,33	14,80	48666,68	56,33
Stationary and locomotion	2049,31	2,37	13300,91	15,39	15350,22	17,76
Total	43199,83	49,99	43199,82	49,99	86399,64	98,98

The activities of *P. alecto* were dominated by sleeping, feeding, stationary and locomotion, grooming, as well as agonistic behaviors at 56.33%, 19.36%, 17.76%, 6.41%, and 0.12%, respectively (Table 1). This indicates that 56.33% of bats did not engage in these practices, while 43.67% did. The dominant behavior during the day was sleeping, which was performed by 41.53%, while at night 16.17% engaged in feeding. In contrast, the least behavioral activities during the day and at night were agonistic, while grooming, stationary, and locomotion were often carried out at night. There is no comparative literature on the percentage of day and night behavioral activities performed by captive *P. alecto* species and others in the natural habitat. The percentage of daytime behavioral activities was observed in the *Cynopterus sphinx* and *Pteropus vampyrus* species. Syamsi (2013) reported that 66.17% of *Cynopterus sphinx* slept during the day, followed by 21.09% that engaged in stationary and locomotion activities as well as 11.98% that participated in grooming. Furthermore, Hengyan *et al.* (2017) reported that the daytime activity of *P. vampyrus* species in the habitat was 53.1 ± 13.9% grooming, 5.7±2.3% agonistic, 2.4±7% locomotion, and 2.3±1.6 stationary. The percentage of agonistic behavior illustrates that the bats have adapted to the environment and food provided in the cage, consequently, fights that cause injuries and stress rarely occur. Therefore, the percentage of behavioral activities performed by the species in cages provides information and an initial description of the sustainable ex-situ breeding strategy. Based on the results, cage breeding is suggested as one of the solutions to provide source for bats utilization and reduce threats such as hunting in the natural habitat. Moreover, it is expected that the important behavior information obtained from flying fox in the cage is implemented for other species of bat.

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We just revised our title.

Original title : "**Day and Night Behavior of *Pteropus alecto* (Chiroptera: Pteropodidae) in Cages** "

Corrected title **: "Behavior of the Black Fying Fox, *Pteropus alecto* (Chiroptera: Pteropodidae) in Cages."**

All the comments and response, are in this table below:

Reviewer 01	**Author Responses**
Abstract on line 10-11 Please consult the Guideline for Author – GFA to ensure a format of abstract	The abstract has been corrected according to the guide.
Introduction *Line 34* Not clear, % or gr/kg. Percentage of consumed meat from a total body weight? Or what? *line 48* Delete and later explain in methodology. Observation is conducted in both day and night time	I have corrected the sentence that is. The sentence should be " due to its large body size with the percentage of carcass ranging from of 45.37 to 54.07% of the total body weight. Action has been taken following the suggestion form the reviewer.
Procedures *Line 62* Birds or bats? *Line 68* Any literatures are referred for this method?	Sentence has been revised Change : bird to flying fox Literature has been added (Method was modified from Markus and Blackshaw,2002).
Result and discussion Picture are numbered a, b, c and give more explanations in each number of picture. Apply for the rest of pictures that more than one *Line 90* Natural? Maybe author should explain the difference between type of fruit, feeding method and form of food served, compared to the animals habits in their natural habitat. For example, why author choose particular types of	Action has been taken following the reviewer suggestion. All pictures have been numbered along with explanations Change : " actual to natural" Explanations have been added.

fruit, or the food are served by chopping the fruit, or the whole fruit, in terms of availability maybe in cage food are always available – ad libitum etc. How about the feeding frequency? Because in natural habitats, time for feeding is different from this study. Is this also influence the feeding behavior? It is better to provide the mating season. It occurs along the year, or on particular moths? So we can compare with the period of this study between March and July	
References *Line 293-295* Please consult the GFA to ensure that authors have applied the guidance in reference writing	The reference has been corrected according to the guide
Reviewer 02	**Author Responses**
Line 1-2 Title	Action has been taken. Title has been modified
Line 19-20 (Abstract) Importance of the study for conservation and future captivity program	Action has been taken. Adding the importance of this study in abstract
Line 23-29 Revise the paragraph	Action has been taken. First paragraph of the Introduction section has been revised.
Line 41-48 Rewrite the paragraph: explain the urgency of the study related to the conservation, reducing the bat hunting. Furthermore how the behavioral study of bat captivity could be used in the context of wildlife population and conservation.	Action has been taken. Paragraph has been revised following the suggestion from Reviewer.
Line 54 Where these individuals were obtained? From the wild or been captivated for some period. Is this an experimental study where all conditions set	Action has been taken

up or the captivity was already built? A little bit history of this will provide a background on existing behavior of the bats living in the captive. This will affect on the habits build by the bat if the captive period is longer.	 Information about the studied individuals and captivity have been added.
Line 59 A better map probably better with the north Sulawesi as an insert not only projected as a dot, the map of study area should be bigger than the insert of Sulawesi island	 Action has been taken. Map has been revised.
Line 60 Parameter's measured should be mentioned. What do you want to examine? For examples: 1. Behavioural activities of bats in captive: type of behaviour's observed, length of each activity, frequency of activities	 Measured parameters have been explained in this paragraph.
Line 64 Only type of activities? How about the time devoted for each activity? How do you observe?because there are 9 individuals in the cage? Is it scanning methods or	 Action has been taken. How the observation been done has been explained, including the time (and duration) of observation and the use of CCTV (Camera recording).
Line 69 I think it is not necessary to mention that students were the one who collecting your data	 Action has been taken. Student was changed with person.
Line 75 Maybe prior to feeding behaviour, it is better to provide explaination on what kind of activities involve during the observation in the captive set? if the feeding depending on human food provision, then explain on how many times for daily feeding time, what kind of food provided and what time. Then explain on feeding, what kind of common behaviour during the observation. Why there is no data on time required for each activity? Accompanied by a descriptive table on each behaviour made during feeding so it will be easier for the reader to grasp the results of this study along with the figures. Feeding behaviour No. Behaviour Description Time	 Action has been taken. Activities prior to feeding behavior, how many time of daily feeding, type of food (fruit) have been added. Moreover, we prefer to present our data as a descriptive style (not in table) and continued with the discussion.

Figure of behaviour (second) 1. Beginning of all bats perching 30 Feeding time near the cage	
Line 98 How different? In time for example between wild and captive set? As there is no data shown in the results on time, therefore, it is best to present your data as suggested above.	Action has been taken. The differences of how the bat in captivity and wild bat getting the food have been added.
Line 114 Agonistic behaviour in feeding especially in a cage occurred due to competition in getting food. Is there any influences of the cage size towards the agonistic behaviour? It is actually interesting to see if we make an experiment on the methods of feeding such as provide the food in the same time with larger amount so competition will be lesser and see whether this reduced agonistic behavior	Thank you for the suggestion from reviewer 2. Up till now, these suggestions were not covered in the scope of the current presented study, however it will be considered in our next study of bat in the captivity.
Line 136 Captive?	Action has been taken. Change the "cultivated ones" with " bat in the captivity"
Line 139 Is this also used as an assumption for Pteropus alecto?	Action has been taken. More explanation has been added.
Line 143 History on how long the animals have been in captive, because the longer the captive time, the lesser stress will be created as they have been adapte	History of the studied individuals has been mentioned and explained in the revised Material and Method section
Line 149 What is resident bat and non-resident bat? there should be an explanation in the method perhaps on these two and also history of the captivity	Action has been taken An explanation about the resident – non-resident bats has been added
Line 192 There were no environment conditions measurement written in the method. Please cross check	Action has been taken. Measurement of the environmental conditions has been added to the Material and Method section.

Line 207 Does this mean from 10 pm at night until 6pm in the evening *Line 207-208* Do not understand. Previously mentioned from 10 pm at nite til 6 pm in the evening but in this sentence there are no clear time division. Please use time indicator	Action has been taken. Time division has been changed Action has been taken. Time division has been changed in the first sentence of this paragraph.
Line 245 Captive?	Action has been taken. Sentence has been revised
Line 272 Are there any differences in these behavior at individual's level?	Detail individual behavior has not been included in the Table 1 which present the behavioral activity were performed by all individuals in the cage. However, information about individual activity were mentioned in the discussion descriptively.
Line 287 A conclusion on how the behavior of the species in the captive set is required. There should be a link between the findings and how this could contribute towards the conservation of the bats are also needed – to answer the urgency of this study as been mentioned in the introduction.	Cation has been taken. Revised conclusion has been added to the last paragraph.
Line 293 Please check again and re-write the references According to the jour	Action has been taken. Typos have been checked and revised.