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Effect of environmental temperature and relative humidity towards postural behavior and activity patterns of female *Pongo pygmaeus* at Bukit Merah Orang Utan Island, Perak, Malaysia

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Abstract. *Nozmi N, Dharmalingam S, Yusof NNM, Yusof FZM. 2023. Effect of environmental temperature and relative humidity towards postural behavior and activity patterns of female* Pongo pygmaeus *at Bukit Merah Orang Utan Island, Perak, Malaysia. Biodiversitas 24: 1252-1263.* Variation in environmental conditions is known to have impacts on animal behavior. Previous research showed animals adapt to temperature change by altering their behavior and routine or resorting to relocation in order to survive. This study aims to determine the effect of environmental conditions on Bornean orangutans (*Pongo pygmaeus*) postural behavior and activity patterns in captivity. Focal sampling was carried out at Bukit Merah Orang Utan Island, Perak, Malaysia, for 93 days from March 2021 until June 2021 among four adult female orangutans. Four postural behaviors were observed, which are sitting, lying, clinging and standing, and four activities were selected, which are resting, feeding, playing and moving. We used RS PRO DT-3893 Vane Anemometer to determine the environmental temperature and relative humidity. The data were analyzed via Mann-Whitney U-test. Orangutans had a longer resting period (p: 0.023) and a lying period (p: 0.002) at high temperatures. The behavioral observation also shows similar findings in resting (p: 0.015) and lying duration (p: 0.001) in lower humidity. The results of this study will enhance our understanding of the behavior pattern of female orangutans in ensuring the effectiveness of enrichment activities in the future. This study will also serve as baseline data of behavioral patterns in response to variations of environmental conditions which is affecting the behavior of orangutans in captivity.

Keywords: Activity budget, ambient temperature, environmental humidity, female orangutan, postural modes

Abbreviations: BMOUI: Bukit Merah Orang Utan Island, BMOUIF: Bukti Merah Orang Utan Island Foundation, df: Degree of freedom, IQR: Interquartike range, Mdn: Median (Mdn), n: Total number of observations

INTRODUCTION

Variations in environmental temperature and relative humidity are the common attributes of the Earth that every species must adapt to ensure their species' survivability. The fluctuations have been reported to have several implications on animals and could increase the risk of extinction (Melin et al. 2014; Rakowski et al. 2019; Alston et al. 2020). On top of that, one in every six animal species may be facing extinction due to the changes in temperature and may be affecting the other organisms in the ecosystem (Urban 2015). To overcome this issue, animals have several adaptations to their environmental changes, such as migrating to cooler areas (Mason et al. 2017; Pattinson and Smit 2017) or altering their behavior (Vieira et al. 2019). Each animal species has their own unique way of adapting to temperature variations. For instance, the Western Bornean orangutan (*Pongo pygmaeus* subsp. *wurmbii*) in Sabah would avoid being on mountain tops when the temperature is cold (<18°C), wet and windy (Marshall et al. 2021). The study also deduced that orangutans warm and dry conditions, especially when the temperature is above 23°C (Marshall et al. 2021). In addition, a similar study also concluded that orangutans are mostly found in lowland areas with moderate temperatures compared to highland areas (Santika et al. 2019).

A study on data modeling of orangutans in Sabah demonstrated the role of climate in habitat preference, where they are most likely to build their nest in the forest, which is warmer compared to the area nearby to major roads (Gregory et al. 2012). This is due to the fact that their nesting behavior may be disrupted during colder temperatures as the conditions are inconvenient due to the wetness and windy condition (Marshall et al. 2021). It is also more difficult for them metabolically to regulate their body temperature as they would need more food to keep them warm (Marshall et al. 2021).

In contrast to an orangutan, wild goats (*Capra ibex*) moved into higher ground areas when it was hotter and reduced their foraging activities (Mason et al. 2017). Such

behavior may negatively impact their survival and reproductive activities as they may need to compensate for more time and energy to regulate their thermoregulatory behavior (Carne et al. 2015). In small birds (*Malcorus pectoralis*), the warblers also shifted their locations from the ground into microsites in shady areas and in shrubs as well as spending less time preening and foraging when the temperature exceeded 40°C (Pattinson and Smit 2017). These cases show that it is crucial to understand how the behavior of animals could be influenced by the changes in temperature and relative humidity in order to cope with the environmental fluctuations. The information obtained may also provide better guidance for the authority on how they can improve their management system for orangutan in captivity to increase their welfare which eventually could improve the species survivability.

Primates are among the animals that are affected by the variations in temperature that needs to be highlighted. A study by Graham (2016) notes that about 419 primate species, including apes and monkeys, lemur, lorises and tarsiers, will have to face 10% increment in the temperature (Graham et al. 2016). Currently, there is an abundance of studies that have been done on the impact of heat stress in female animals, mainly on livestock, due to their role in reproduction in producing eggs and meat for human consumption. For example, in cows (*Bos taurus*), heat stress causes low fertility in cattle, thus resulting in an inability to conceive (Wolfenson and Roth 2019). This is due to a shift in reproductive growth which includes oocyte competence, embryonic growth, gonadotropin secretion, ovarian follicular growth steroidogenesis, development of the corpus luteum, and uterine endometrial responses (Wolfenson and Roth 2019). Similarly, in pigs (*Sus domesticus*), heat stress leads to decreasing sow performance, poor growth, and also an increased risk of mortality and morbidity (Ross et al. 2015). In the poultry industry, heat stress has been reported to be linked to reduced growth among broilers and laying hens (*Gallus gallus* subsp. *domesticus*) and their egg production, thus compromising the egg quality and safety (Lara and Rostagno 2013).

In contrast to these cases, in common marmosets (*Callithrix jacchus*), regardless of their sex, it was found that their cortisol level is higher during the dry season compared to in the wet season (Garber et al. 2020). However, among the female common marmosets, female reproduction condition (pregnancy/lactation vs. non-pregnant/non-lactating) was not influenced by changes in their cortisol level (Garber et al. 2020). Despite any changes in temperature, they are still able to deliver high reproductive output even under high temperatures (Garber et al. 2020). Thus, these variations on how heat impacted females in different species inspired this study to be conducted, which aimed to determine the association between the environmental conditions with female orangutan's (*P. pygmaeus*) postural behavior and activity patterns in terms of the temperature differences and relative humidity to maintain their wild behavior. The knowledge gained in this study can be implemented in conservation efforts to maintain biodiversity in the future as environmental changes continue to risk the ecosystems and biodiversity.

MATERIALS AND METHODS

Study area

Bukit Merah Orang Utan Island (BMOUI), Perak, Malaysia, was opened to the public in February 2000 and is governed under the Bukit Merah Orang Utan Foundation (BMOUIF). The aim of BMOUIF is to educate the community, preserve, and treat the orangutan. The island is located at 5°02'N, 100°39'E under the Kerian District, Northern Perak and covers the north-western part of Perak (Figure 1). Previously, the island was known as Pulau Panjang and covered about 14 acres of tropical lowland rainforest trees. The area is suitable for orangutans as the climate and flora resemble the natural habitat of orangutans in Borneo and Sumatra (Indonesia). Visitors can observe orangutans by walking through a tunnel with the animal being protected in safe enclosures. The boat ride from the jetty takes about 10 minutes to arrive at the island. Upon arrival, visitors are welcomed by the floating building consisting of treatment rooms, management offices and a merchandise shop above the water (Figure 2.A) and the entrance of the tunnel (Figure 2.B).

Study animals and husbandry

At the time of the data collection, there were 20 orangutans under the BMOUIF. Orangutan is kept in 19.6 m3 indoor enclosures area individually except for the mothers and their child from 5 p.m. to 9 a.m. They are released to the exhibit area during the day until 5 p.m. Four sexually mature female orangutans were selected in this study which are Baboon (Figure 3A), Careena (Figure 3B), April (Figure 3C) and Kate (Figure 3D) at the time of the data collection. Baboon, April and Careena are adults and Kate is an adolescent. April, Careena and Kate have never been pregnant before. Baboon is originally from Sarawak and was transferred to Bukit Merah in January 2001. She gave birth six times from 2003 until 2015 and delivered Kate in June 2011. Kate is the fifth child of Baboon and was born in June 2011. Careena and April are siblings who share the same mother, Nafsiah. The late Nafsiah arrived at Bukit Merah in January 2002 from Sarawak and died in 2013 (Hayashi et al. 2018).

Diet of the orangutan is tailored to individual needs based on their age and weight. Adult orangutans are fed with 500 mL of vitamin drink and four slices of white bread every morning at 8.30 a.m. Once released to their respective exhibit areas, the subjects are given seasonal local fruits with an average of 500 g per animal consisting of coconut, star fruit, mango, papaya, pineapple, jackfruit, sugarcane, durian, as well as cucumber and carrot. Later in the evening, once the animals have returned to the enclosures, they are fed 600 mL of milk and 500 g of fruits as their last meal of the day (Dharmalingam et al. 2012). Water is given ad libitum in the exhibit area at the platform via water dispensers.

Data collection and procedures

Data collection was carried out for 93 days from March 2021 until June 2021 daily. The temperature and relative humidity were recorded using an anemometer by RS PRO DT-3893 Vane Anemometer. The readings were taken at

the entrance jetty of the island three times and averaged at the beginning of every session. Standardized focal-animal sampling technique was used to observe the postural and activities of each animal for 30 minutes (Morrogh-Bernard et al. 2002). The sampling was carried out individually twice per day, first in the morning and later in the afternoon, with 337 hours of observation. The first observation started at 9.30 a.m. and the second session started at 12 p.m.

In this study, the locomotion behavior and its definition followed Kamaluddin et al. (2022) and Morrogh-Bernard (2009) and were narrowed down to resting, feeding, playing and moving (Table 1 and Figure 4). The description of the positional behavior of the orangutan was recorded following Kamaluddin et al. (2019) and Hunt et al. (1996), and only four were selected, which are sitting, lying, clinging and standing (Table 2 and Figure 5). Note that any behavior with a duration less than 0.7% of the total time distribution is not included in this study which is urinating, defecating, manipulating, grooming, sexual behavior and nesting.

Data analysis

All the data was analyzed using IBM SPSS version 23.0. The descriptive analysis was carried out to determine the frequency, mean, median and standard deviation of the data. Since the sample size was small in this study ($n<10$), the data was more meaningful to be analyzed non-parametrically. Mann-Whitney U-test was used to determine the relationship between environmental temperature and relative humidity towards the postural behavior and activity patterns. Mann-Whitney U-test was also applied to analyze the relationship between the morning and afternoon observation sessions towards the postural behavior and activity patterns. To determine the differences of postural behavior and activity patterns between the individual subjects, the Kruskal-Wallis test was used. Post-hoc pairwise comparisons using Dunn-Bonferroni's correction were applied when significant differences were found. The level of significance in this study is fixed at $p<0.05$.

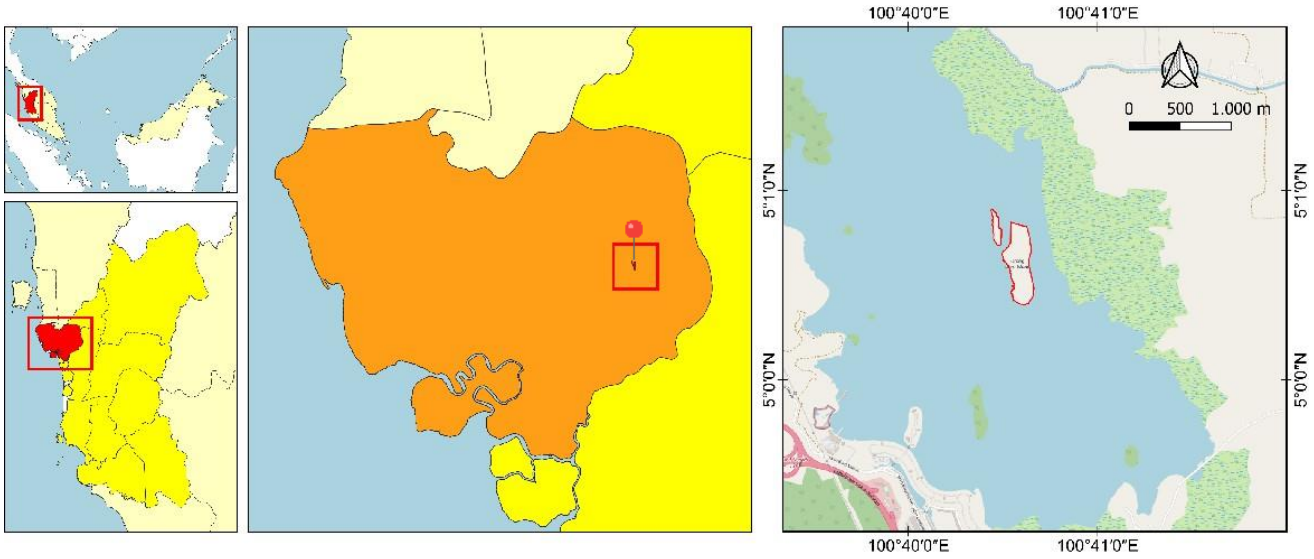

Figure 1. Location of Bukit Merah Orang Utan Island, Perak, Malaysia (5°02′N 100°39′E). Adapted from map of Malaysia by Freepik. Retrieved October 20, 2022 from https://www.freepik.com/premium-vector/3d-isometric-map-malaysia.htm

Figure 2. A. Entrance of Bukit Merah Orang Utan Island, Perak, Malaysia; B. Entrance of the tunnel to the enclosure

Table 1. Ethogram of orangutan's activities by Kamaluddin et al. (2021) and Morrogh-Bernard (2009)

Categories	Definition
Activities	
Resting	Animal is immobile while in a sitting or lying position.
Feeding	Animal is engaged in searching, reaching, obtaining, handling, chewing, swallowing food and drinking, including brief movement around the feeding behavior.
Playing	Animals is in solitary and/or social engagement, including following, making hand contact, fighting, dragging, pushing, and grooming.
Moving	Animal is engaged in traveling on the ground or on trees. Locomotion patterns include brachiating, hanging, clinging, and walking quadrupedally. The animal is considered to be resting during an immobile period for more than one minute in between moving activities.

Table 2. Ethogram of orangutan's postural behavior by Kamaluddin et al. (2019) and Hunt et al. (1996)

Categories	Definition
Posture	
Lying	Lateral lie: Animal is engaged in an inactive phase with elbows supported by the upper part of the body. All lateral body parts touch the ground. Back lie: Animal is engaged in an inactive phase with all body weights resting mostly on the dorsum. This posture was usually displayed by all the orangutans during resting time
Sitting	Animal is positioned in sit in, sit out, sit in/out and angled sit. In this study, only sit-in and sit-out behavior was observed. Sit in: Animal is engaged in this position, usually during resting and feeding. Their body is supported by the ischia, with the body being brought closer to heels and touching the base of the thigh. The knee and hip are closely bent with the hindlimb with body weight supported by the feet. Sit-out: Animal is engaged in this position with both feet out. The ischia support most of the body weight, while the feet are mostly used for balance.
Clinging	Animal is positioned in two types of modes, either bimanual clinging or unimanual forelimb clinging. Bimanual clinging or vertical clinging can be defined as both hands grasping a support with a flexed elbow, with forelimbs adducted and hind limbs flexed at the hip and knee. Unimanual clinging can be defined as only one hand grasping the support with a flexed forelimb.
Standing	Animal is either positioned in the quadrupedal stand or extended bipedal stand. Quadrupedal stand includes four limbs standing horizontally with the elbow and knee wide apart. Extended bipedal stand includes expanding hip and knee and usually mimics human-like standing posture.

Figure 3. Female Bornean orangutans (*P. pygmaeus*) at Bukit Merah Orang Utan Island, Malaysia. A. Baboon (aged 33), B. Careena (aged 14), C. April (aged 12), D. Kate (aged 9)

Figure 4. The activities of orangutan. A. Resting, B. Feeding, C. Playing, D. Moving

Figure 5. The posture of orangutan. A. Lying, B. Sitting, C. Clinging, D. Standing

RESULTS AND DISCUSSIONS

Time distribution of activity patterns and postural behavior of female orangutans

The orangutans spent most of their time resting, followed by playing, feeding and moving. (Figure 6). This result is similar to the study in Bali Safari and Marine Park, where the orangutan in the semi-wild spent most of their time resting, followed by feeding with 63.75% and 23.38%, respectively (Nikmaturrayan et al. 2013). Overall, the most observed posture displayed by the orangutans is lying, followed by sitting, clinging and standing (Figure 7).

Orangutans in semi-wild conditions had higher resting time duration compared to orangutans in the wild, as the food is always readily available and provided by the rangers. They have become used to the routine thus, and somehow it does not motivate them to move around searching for food. In contrast, wild orangutans spent most of their time in the morning feeding and defecating (Sopiansah et al. 2018). These differences in activities are due to the fact that in the wild, they are required to find their own food for survivability, compared to in the captive, where food is readily available and given by their caretaker. In Nanga Tayap Mountain Forest, the feeding activity peaks at 6 a.m., 12 p.m. and 2 p.m. (Sopiansah et al. 2018). In the wild, feeding frequency is more often observed during the day in order for them to obtain enough energy to perform their daily activities.

However, Kamaluddin et al. (2021) reported that the time spent resting (23.2%) and feeding (23.0%) demonstrated an almost similar duration distribution. Comparatively, we can see there is a huge gap between the time resting and the other activities in this study. The huge gap between resting and other activities in this study may be due to the situation at the time of the data collection, where there was a Covid-19 outbreak, and the island was closed to visitors. This result supports a finding by Meade et al. (2021), where it was reported that resting behavior was significantly lower as visitor numbers increased. However, in contrast to Meade's finding, Choo et al. (2011) reported that visitors' effects had a minor influence on orangutans' behavior and might be due to the large enclosure area and human habituation (Choo et al. 2011).

Interestingly, Kruskal-Wallis H test (Table 3) reveals that there is a significant difference in all postural behavior (lying, H(3): 52.669; sitting, H(3): 43.864; clinging, H(3): 161.046; standing, H(3): 144.129 and locomotion patterns (resting, H(3): 47.362; playing, H(3): 43.044; and moving, H(3): 67.109 excluding feeding between all four orangutans (Baboon, April, Careena and Kate) with $p<0.001$.

Resting behavior significantly varies among orangutans, H(3): 47.362, $p<0.001$. Baboon significantly spent a long time resting than Kate and Careena. Baboon, being the eldest of four subjects, is also the heaviest. Aging is found to cause changes in body composition, which it could contribute to the increase of total body fat mass and declining of lean body mass and bone density (Zong et al. 2016). Thus, due to her condition, this finding suggests that perhaps she might have it harder than the younger orangutan to move around without being tired easily, hence why she rested more often compared to younger females. This result is consistent with Hayashi et al. (2018), where it was reported that adult females had longer resting time compared to younger females (Hayashi et al. 2018). Longer resting time had its consequences where it could lead to obesity and is linked to other potential health risks such as diabetes, hypertension and heart failure (Laflamme 2005). Thus, the immediate intervention must be urgently implemented to improve the well-being of the orangutan. Instead of handing them their food directly, enrichment activities can be done to encourage them to search for food, such as putting the food in a basket hanging from higher ground or offering the basket further from their usual location.

Playing behavior also significantly varies among orangutans (Table 3), H(3): 1.539, $p<0.001$. Kate was observed to significantly spent longer time playing than April, Baboon, and Careena. This may be due to the fact that Kate is the youngest among all, therefore, is the most playful. In general, adolescents engage in longer playing behavior than adults (Hayashi et al. 2018).

Influence of environmental temperature and relative humidity towards activity patterns and postural behavior

Air temperature and relative humidity were shown to significantly influence the behavior of female orangutans. Table 4 shows the differences in behavior during lower and higher temperatures, whereas Table 5 shows the differences in behavior during higher and lower humidity. The median environmental temperature is 29.7°C, SD: 1.9, and the median of the relative humidity is 94%, SD: 7.9. A Mann-Whitney U-test reveals that during higher temperatures, resting and lying duration is significantly longer compared to in lower temperatures with a small effect size r: 0.15. Table 5 shows that female orangutan displays resting and lying duration significantly longer in lower humidity with a small effect size r: 0.17 and moderate effect size r: 0.28, respectively.

Time distribution for activity patterns and postural behavior between morning and afternoon sessions

The time of the day also plays a critical role in influencing the behavioral pattern of animals. In this study, orangutans were observed twice daily, one in the morning and the other in the afternoon. Generally, the temperature is higher in the afternoon than in the morning. Lying, sitting, and clinging postural behavior were found to be statistically significant in this study.

In the afternoon, when the temperature is higher, the female orangutans were found to spend their time lounging by lying compared to in the morning with a moderate effect size r: 0.28. In the comparison of their behavior in the afternoon, the observation recorded a longer period of sitting in the morning when the temperature was cooler with a small effect size r: 0.20.

Our findings were aligned with previous research where it was stated that animal movement has a correlation with climate change (Rakowski et al. 2019; Alston et al. 2020). Since movement plays a crucial role in the survivability of

the animals, thus any small changes in movement may affect the animal behavior in other activities as well, such as food searching, feeding, social interaction and their reproductive patterns (Earl et al. 2014). This study emphasizes the influence of environmental temperature and relative humidity on the activity patterns and postural behavior of female orangutans.

Our study suggests that female orangutans tend to be more sedentary when the air is hotter (Table 4). This result is consistent with previous studies with similar findings (Melin et al. 2014; Rakowski et al. 2019; Alston et al. 2020). This is an adaptation strategy for the animal to reduce the risk of hyperthermia by lowering their movement activity to keep them cool (Rakowski et al. 2019). Some other animals adapt to high temperatures by altering their feeding behavior (Pattinson and Smit 2017), identifying thermal refuge (Alston et al. 2020), and changing their posture (Norris and Kunz 2012; Izzati et al. 2021). The effect of this behavior alteration can be observed in Baboon, which is considered as obese as a result of her low locomotion activity. However, the data could be too limited for a conclusion due to the small number of orangutans involved in this study. Further studies involving a larger number of orangutans in captivity should be done in the future by weighing the orangutan after their arrival in captivity and a few months after the arrival to examine their pre- and post-activity patterns and postural behavior.

In addition, female orangutans involved in Bukit Merah has a significantly longer resting period, especially in the afternoon (Table 6), compared to wild orangutans in Indonesia, suggesting that behavioral alteration in semi-wild condition has negatively impacted the behavior of the orangutan. Riedler et al. (2010) reported that reintroduced orangutans in Bukit Tigapuluh, Indonesia spent most of their time (43%) feeding, whereas Morrogh-Bernard et al. (2009) stated that wild orangutans in Ketambe, Indonesia displayed 56% of their time feeding (Morrogh-Bernard et al. 2009; Riedler et al. 2010). These findings are contrasted with our semi-captive individuals, who spent most of their time resting.

This huge gap is probably due to the differences in vegetation diversity and density in the wild and in Bukit Merah. Vegetation density and fruit tree availability are important habitat characteristics for orangutan to support their lives (Marshall et al. 2009). Bukit Merah is an island surrounded by a man-made freshwater lake. Some land areas have been cleared to make pathways for orangutans from the cage area to their exhibit areas. In addition, some land modifications have been made to build platforms for orangutan shelters for their use on hot or rainy days and feeding tubes for fruit transfer during their feeding time (Figure 8A and Figure 8B). These adjustments made by the BMOUI management may have contributed to the longer resting duration of orangutans on the ground, as vegetation density played a major role in facilitating the movements of orangutans (Riedler et al. 2010). These findings are contrasted with our semi-captive individuals, who spent most of their time resting. This huge gap is probably due to the differences in vegetation diversity and density in the wild and in Bukit Merah. Vegetation density and fruit tree availability are important habitat characteristics for orangutan to support their lives (Marshall et al. 2009). Bukit Merah is an island surrounded by a man-made freshwater lake. Some land areas have been cleared to make pathways for orangutans from the cage area to their exhibit areas. In addition, some modifications of the land have been made to build platforms for orangutan's shelter for their use on hot or rainy days and feeding tubes for fruit transfer during their feeding time (Figures 8A and 8B). These adjustments made by the BMOUI management may have contributed to the longer resting duration of orangutans on the ground, as vegetation density played a major role in facilitating movements of orangutans (Riedler et al. 2010).

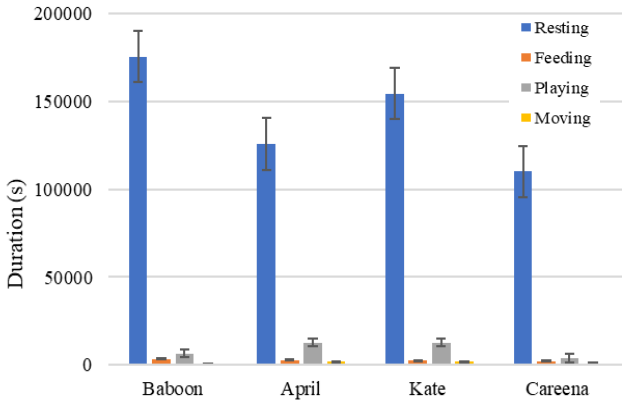

Figure 6. Total time duration (s) of individual female orangutan's activities at Bukit Merah Orang Utan Island, Malaysia

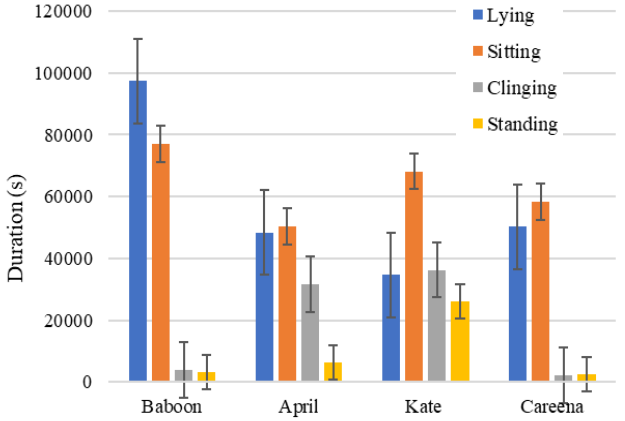

Figure 7. Total time duration (s) of postural behavior of individual female orangutan at Bukit Merah Orang Utan Island, Malaysia

Table 3. Median and interquartile range (IQR) in duration (s) of activity patterns and postural behavior for each individual by using Kruskal-Wallis test

Categories	Median (IQR) (df: 3)				*p*
	Baboon (n: 112)	**April (n: 110)**	**Kate (n: 108)**	**Careena (n: 112)**	
Activities					
Resting	1676.0 (5540)	1188.5 (2369)	1406.5 (1681)	1078.0 (2004)	<0.001**
Feeding	0 (935)	0 (910)	0 (618)	0 (600)	0.673
Playing	0 (1016)	20.5 (960)	22.5 (669)	0 (830)	<0.001**
Moving	0 (42)	10.0 (420)	11.0 (100)	0 (90)	<0.001**
Posture					
Lying	820.5 (1800)	326.0 (1800)	243.0 (1740)	30.0 (1800)	<0.001**
Sitting	609.5 (4480)	392.0 (1783)	566.0 (1691)	298.0 (1922)	<0.001**
Clinging	0 (626)	272.5 (1165)	272.0 (1498)	0 (521)	<0.001**
Standing	0 (1301)	0 (1301)	172.5 (1035)	0 (1622)	<0.001**

Note: **P-value is highly significant at p < 0.01; *P-value is significant at p <0.05

Table 4. Median and interquartile range (IQR) in duration (s) of activity patterns and postural behavior between higher and lower environmental temperature via Mann-Whitney U-test

Categories	Lower temperature (<29.7)	Higher temperature (≥29.7)	*U*	*p*
	Median (IQR) (n: 212)	**Median (IQR) (n: 221)**		
Activities				
Resting	1353.0 (1973)	1460.0 (5540)	26352.5	0.023*
Feeding	0 (618)	0 (935)	23502.0	0.898
Playing	10.0 (830)	12.0 (1016)	25152.0	0.165
Moving	0 (100)	0 (420)	23939.0	0.657
Posture				
Lying	252 (1800)	457 (1800)	27417.0	0.002*
Sitting	492.5 (1922)	488.0 (4480)	23410.0	0.990
Clinging	0 (1173)	0 (1498)	23345.0	0.944
Standing	0 (1061)	0 (1622)	24520.0	0.295

Note: **P-value is highly significant at p < 0.01; *P-value is significant at p <0.05

Table 5. Median and interquartile range (IQR) in duration (s) of activity patterns and postural behavior between higher and lower relative humidity via Mann-Whitney U-test

Categories	Lower humidity (<94.0)	Higher humidity (≥94.0)	*U*	*p*
	Median (IQR) (n: 203)	**Median (IQR) (n: 230)**		
Activities				
Resting	1479 (5540)	1353.0 (1973)	20185.0	0.015*
Feeding	0 (935)	0 (618)	23610.5	0.657
Playing	12 (1016)	10 (703)	20986.5	0.057
Moving	0 (420)	0 (100)	22250.0	0.342
Posture				
Lying	493 (1800)	230.5 (1800)	18227.5	<0.001**
Sitting	465 (4480)	537.5 (1922)	24573.0	0.342
Clinging	0 (1498)	0 (1165)	23483.5	0.897
Standing	0 (1622)	0 (1061)	22009.5	0.200

Note: **P-value is highly significant at p < 0.01; *P-value is significant at p <0.05

Our findings were aligned with previous research where it was stated that animal movement has a correlation with climate change (Rakowski et al. 2019; Alston et al. 2020). Since movement plays a crucial role in the survivability of the animals, thus any small changes in movement may affect the animal behavior in other activities as well, such as food searching, feeding, social interaction and their reproductive patterns (Earl et al. 2014). This study emphasizes the influence of environmental temperature and relative humidity on the activity patterns and postural behavior of female orangutans.

In contrast, both Bukit Tigapuluh and Ketambe have designated areas for national parks which are high-density forests filled with various wildlife and untouchable flora within the areas, with an abundance of fruit trees available (Kuswanda and Barus 2019). The most common plant species are Moraceae, Fagaceae and Lauraceae (Kuswanda and Barus 2019). The same species are also found in Bukit Merah (Dharmalingam et al. 2012), which include fruit with soft flesh like bananas and papaya. However, due to land modification at BMOUI, the tree availability might not be sufficient for the consumption of orangutans. Thus, a planting program for fruit tree species should be initiated to overcome the huge gap of resting and feeding duration of orangutans in captivity to ensure the behavior of orangutans is restored to ensemble their behavior in the wild.

In this study, sitting is significantly longer in the morning (Table 6). In general, orangutans engaged longer in feeding and playing behavior while sitting in the morning compared to in the afternoon. Increasing active behavior in the morning implies that cooler temperatures in the morning with higher relative humidity cause the animal to be more comfortable engaging in active locomotor activities. Lower relative humidity causes the air to be less humid and drier, thus causing the orangutan to be more sedentary in the afternoon. When the air humidity is lower, warm moisture tends to linger on the skin longer, thus causing the body to feel hotter. Thus, to adapt to this uncomfortable situation, orangutans chose to lounge longer in the afternoon when the air was hotter. This modified behavior of orangutans is a survival approach in order to maintain their body temperature (Norris and Kunz 2012; Alston et al. 2020) in order to prevent heat stress. This finding is supported by Izzati et al. (2021), where orangutans became more idle in the early afternoon when the surroundings were hot.

Besides that, orangutans in this study also tend to seek protection from the hot air by locating themselves in shady areas, either by resting under a platform or under the shades of tall trees. This adaptation is also displayed by moose (*Alces alces*), who repositioned themselves to landscapes with more shady areas when the environmental heat increased (Alston et al. 2020). This is because vegetation such as woody trees has proven to be able to lower the temperature of the surrounding areas (Carroll et al. 2016). These behaviors modification calls for better enrichment tools by planting more woody trees in the exhibit areas. Continuous tree planting activities need to be done as orangutans also use the branches and leaves to build the nest throughout the day, besides utilizing the trees to protect them from the harsh heat during the day.

In addition, the nesting behavior of orangutans is also heavily influenced by the tree areas (Auliah et al. 2021). They prefer to build their nest in an area with taller trees with a dense canopy cover to avoid predators and to make the nests safer and more stable (Koops et al. 2012; Cheyne et al. 2013; Davies et al. 2017). At Bukit Merah, nesting behavior is commonly observed on the ground compared to up on the trees. This might be due to the low availability of tall trees with dense canopies on the island (Figure 9A and Figure 9B). At night, the nest provides insulation to the orangutan due to the lower temperature, especially in a savannah area (Fruth 2018). This finding by Fruth may suggest that orangutans might prefer to build their nest up on the trees due to the influence of environmental temperature. However, the effect of abiotic factors such as temperature, humidity and rainfall on preferred nesting height by orangutans is still poorly understood and yet to be explored more in the future (Koops et al. 2012).

Figure 8. A. Exhibit area of the orangutan with a feeding platform in the middle of the water connected by a feeding tube; B. A platform built on a tree bark for hanging and resting purposes

Figure 9.A. Orangutans including Baboon and April resting on the ground at the exhibit areas under the Bertam palm tree (*Eugeissona tristis*); B. Exhibit areas with cleared pathway in between two Bertam palm trees (*E. tristis*)

Tree planting is also important for orangutans as it can help to prevent the risk of pathogen transmission during low relative humidity. Abnormal relative humidity increases the occurrence of infectious disease by damaging the animal'sanimal's respiratory tract, thus increasing the transmission of the pathogens (Xiong et al. 2017). Different pathogens survive at different levels of relative humidity. For instance, the influenza virus thrives at 20-35% relative humidity, whereas most bacteria survive at 55-75% relative humidity (Lowen et al. 2007). The transmission of the flu virus is fully blocked at 80% relative humidity (Lowen et al. 2007). However, in bacteria, the interaction between relative humidity and survivability rate is inversely proportional. Bacteria seem to thrive better than viruses in higher relative humidity due to a more conducive environment for them to survive. The microbial growth of fungi was robust at 80% relative humidity, whereas bacteria grow abundantly at 100% relative humidity (Dannemiller et al. 2017).

In addition to that, a recent finding in Bukit Merah reported that there is the existence of the bacteria Burkholderia cepacia F in the soil (Mohamad et al. 2022). B. cepacia causes severe sepsis to infected individuals and, if not prevented, may cause death to them (Hall et al. 2015). It is also highly transmissible to other individuals; thus, quarantine period is required when the case is confirmed (Shommu et al. 2015). The existence of this bacteria species in Bukit Merah is alarming as the disease could be spread easily among orangutans. To date, there is still no treatment available to treat the infected individuals as the bacteria is resistant to most common antibiotics (Lord et al. 2020). Their ability to survive in a hot environment for a long period has become a major concern to the authority (Mohamad et al. 2022). Nevertheless, there is limited research on the association between relative humidity and survivability of *B. cepacia*. This finding is alarming as it highlights the significance between high environmental temperature with the risk of diseases that may infect the orangutan in captivity. Thus, enrichment programs such as tree planting and building more shady platforms in the exhibit areas for the orangutans to seek protection during hot weather are urgently needed for the benefit of orangutans in captivity.

In conclusion, the results of this study supported our hypothesis that environment temperature and relative humidity influence the postural behavior and activity patterns of female orangutans, where female orangutans are found to be more sedentary during hot and dry days, especially in the afternoon. Younger female was observed to be engaged in active behavior longer compared to an older orangutan. Further studies should consider including larger sample sizes of orangutans in captivity for a better-rounded conclusion. For novelty, similar studies should also be done for orangutans in the wild to compare the behavior of orangutans expressed in different environmental conditions both in captivity and in the wild. A similar study should also be conducted in other primates for a better understanding on the effects of environmental temperature and relative humidity so that the outcome can be used as basic baseline data to improve the enrichment activities for primates in captivity.

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