HAYATI
Journal of Biosciences

Vol. 30 No. 4, July 2023 653-661
DOI:10.4308/hjb.30.4.653-661
ISSN: 1978-3019
EISSN: 2086-4094

Activity Budget and Diet in Sumatran Orangutan (*Pongo abelii*) at Soraya Research Station, Aceh

Mahyana, Kanthi Arum Widayati, Puji Rianti*

Animal Biosciences Study Program, Department of Biology, Faculty of Mathematics and Natural Science, IPB University, Bogor 16680, Indonesia

ARTICLE INFO

Article history:
Received August 30, 2022
Received in revised form January 29, 2023
Accepted February 21, 2023

KEYWORDS:
Sumatran orangutan,
phenology,
FAI,
diet composition,
adaptation

ABSTRACT

Geographical and environmental factors influence the food availability and diet of orangutans. Moreover, tree phenology affects productivity and food availability in orangutan habitats. As a result, orangutans must be able to adapt to their food availability in the wild. This study aims to analyse the daily activity patterns and eating behaviour of the Sumatran orangutan (*Pongo abelii*) and their relationship to food availability through the fruit availability index (FAI) and phenology at Soraya Research Station (SRS), Aceh. From the 648 hours of observation on five orangutans' daily activities, we found that resting is the activity with the highest percentage (48%), followed by feeding (22.5%) and moving (21.8%). The high percentage of resting activity might correlate with its low FAI in SRS (1.01%). The resting activity limits orangutans' energy expenditure. Furthermore, barks, fruits, and other plants (including lianas, ferns, and epiphytes) were the main type of diet of Sumatran orangutans in SRS with a frequency of 40.6%, 28.9%, and 15.6%, respectively. The high bark consumption by the orangutans acts as their fallback diet at SRS and is thought to be a form of adaptation to the low fruit availability. This study showed the orangutan adaptation to low fruit availability in SRS through their daily activity and diet patterns.

1. Introduction

Geographical and environmental factors influence the food availability and diet of orangutans; meanwhile, phenology can measure this influence (Hill and Dunbar 2002). Plant phenology is a repetitive phase or biological life cycle of plants influenced by seasonal factors such as environment and climate (Leith 1974). In tropical forests, plant phenology shows seasonal variations with new leaf, flower, and fruit phases emerging in most communities (van Schaik *et al.* 1993). It is known that plant or tree phenology is closely related to the food availability of orangutans (Marshall *et al.* 2009; van Schaik 1993), which may affect many aspects of orangutan life, physiologically, reproductively, ecologically, behaviourally, and socially (Chapman *et al.* 2012; Harisson and Marshall 2011; Hardus *et al.* 2011; Wich *et al.* 2006).

Food availability affects activity budgets and diet in orangutans (Morrogh-Bernard *et al.* 2009). When fruit availability is high, the percentage of feeding activity in Bornean orangutans reaches 47.2% of the total daily activity, and there is an increase in resting activity when fruit availability begins to decrease (Kanamori *et al.* 2010). When fruit availability is low, orangutans change their diet using fallback foods such as leaves and bark to meet their energy needs (Harisson and Marshall 2011; Knott 1998; Morrogh-Bernard *et al.* 2009; van Schaik *et al.* 1993). This kind of activity has only been reported in Bornean orangutans.

The Sumatran orangutan (*Pongo abelii*) is categorised as critically endangered by the International Union for Conservation of Nature (IUCN) (Singleton *et al.* 2017). Its existence in nature is increasingly threatened due to poaching and high rates of habitat deforestation (Wich *et al.* 2011). Understanding the daily activities and foraging behaviour of orangutans and their relationship to food availability can provide information on how orangutans adapt to environmental changes in their

* Corresponding Author
E-mail Address: pujirianti@apps.ipb.ac.id

habitat (Campbell-Smith *et al.* 2011; Knott 1998). Soraya Research Station (SRS) is located in The Leuser Ecosystem and is a natural habitat for the Sumatran orangutan. The relationship between food availability and its relation to the daily activities and diet of orangutans in this location is unknown. So, this study aims to observe orangutans' daily activities and diet composition in SRS and their correlation with food availability.

2. Materials and Methods

2.1. Time and Place

We observed the activity budget and diet from July 2021 until March 2022 at the Soraya Research Station (SRS), Pasir Belo Village, Sultan Daulat District, Subulussalam City, Aceh Province, Indonesia (N02°55'414"-E97°55'731"). Later, our data were analysed at the Laboratory of Biosystematics and Animal Ecology, Department of Biology, IPB University.

2.2. Field Observation

2.2.1. Phenology and Fruit Availability

We collected the phenological data and fruit availability in SRS by trekking through the existing phenological plots in the area. We also used binoculars to observe high-up phenological items such as fruit, leaves, and flower. We observed 20 plots with 20 × 20 m (0.8 Ha) per plot size monthly comprising approximately 550 trees with a minimum diameter of 10 cm. Moreover, the recorded data for phenological items were the presence of shoots, the number of new leaves, the number of flowers, and the number of fruits per month (Marshall *et al.* 2009; Roth *et al.* 2020). We categorised two types of fruits based on their maturity stage: ripe and unripe.

2.2.2. Annual Phenology and Fruit Availability Index (FAI)

Besides our observation data from July 2021 to March 2022, we used a six-year phenological recording (2017 to 2022) and annual fruit availability data from 2018 to 2022 to calculate the fruit availability index (FAI). FAI was calculated by the number of fruiting tree species in the diet of orangutans divided by the total number of trees with food items (including cambium, leaves, fruit, and flowers) consumed in the plot, multiplied by 100 (Vogel *et al.* 2009). The Leuser Conservation Forum (FKL) team collected this data during their monthly monitoring routine at the SRS and consented to us using its data in this study.

2.2.3. Activity Budgets and Diets

When we had a chance to encounter orangutans in the field, we observed their daily activities and diet items by following them all day until they built their sleeping nests. The observation was conducted with an approximate sight range of 5-10 m to the object. We followed the orangutans every day for a maximum of ten days to avoid too much exposure to humans.

We used the instantaneous method with an interval of two minutes (Altmann 1974) to observe the feeding activities. We recorded all food types, such as fruits, seeds, flowers, young leaves, old leaves, bark, pith, other plants, invertebrates and vertebrates, and other objects (Russons *et al.* 2009). Besides that, we also recorded the daily activities of orangutans. Foraging activity, nest building, self-play, social, travelling, and resting were the daily activity we observed. We collected the daily activities data using the focal animal sampling method under the standard collection of orangutan data in the field (Morrogh-Bernard *et al.* 2002).

2.2.4. Environmental Factors

We measured daily environmental factors such as rainfall and temperature. We also used the environmental data collected during the 2017-2022 period by the FKL team.

3. Results

3.1. Phenology and Fruit Availability

Our findings on phenology in SRS during our observation period (October 2021-March 2022) showed that young leaf is the highest of all (an average of 94.7%), followed by unripe and ripe fruit at 2.5% and 2.0%, respectively (Figure 1A). Flowers show the lowest percentage at 0.8% of the total phases.

3.2. Annual Phenology and Fruit Availability Index (FAI)

As a result of the annual phenology and FAI analysis from 2017 to the latest data in 2022, we found a slightly different level of phenology stages percentage. Young leaves consistently show the highest percentage 93.6% of the total phase for the last six years, followed by unripe fruits, ripe fruits,

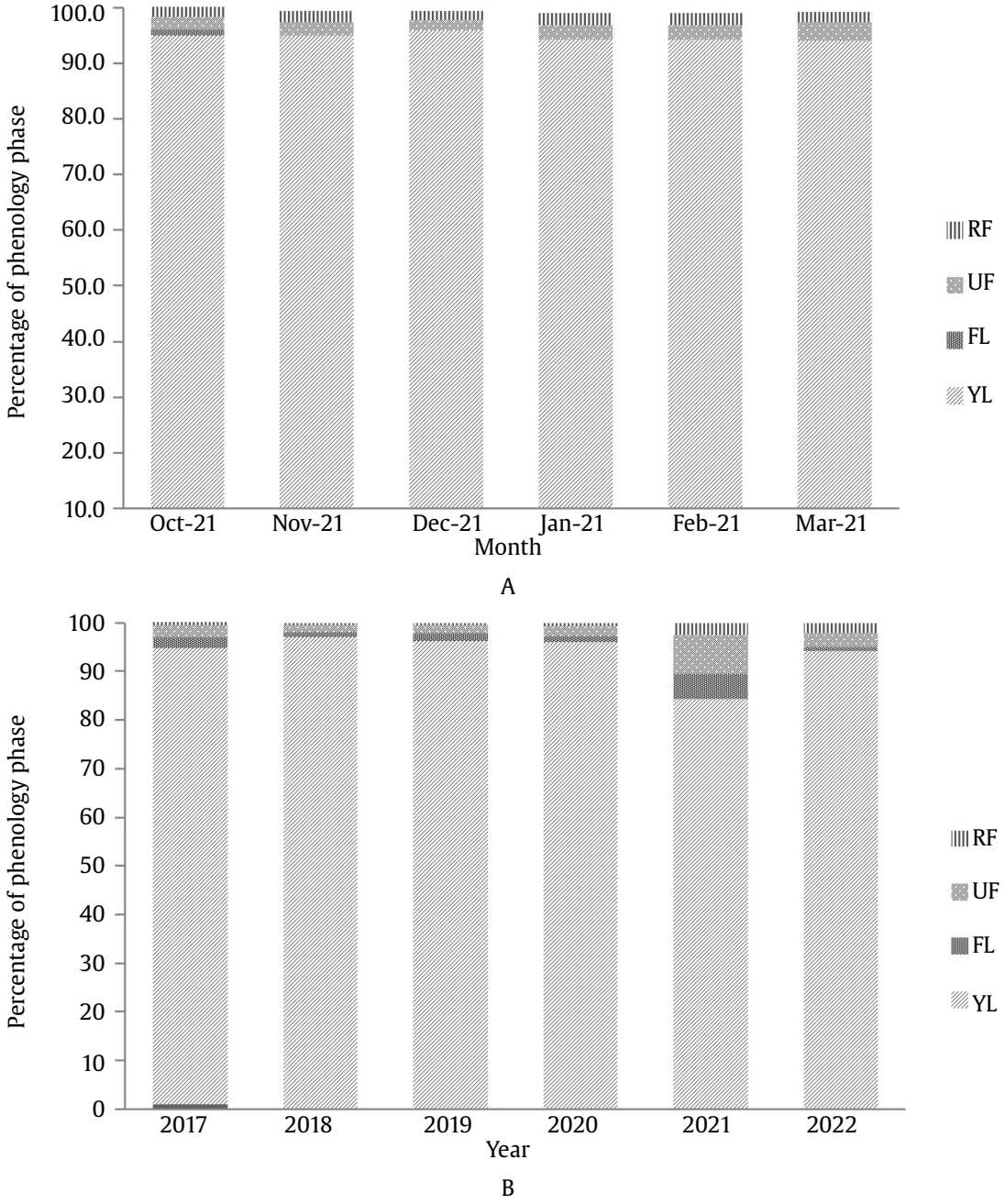

Figure1. Tree phenological pattern at Soraya Research Stations. (A) During this study period (October 2021-March 2022), and (B) during the last 6 years (2017-2022). (RF = ripe fruit, UF = unripe fruit, FL = flower, and YL = young leaf)

and flowers 3.0%, 2.1%, and 2.0%, respectively) (Figure 1B). Our findings indicate that SRS is a habitat with low fruit productivity.

Furthermore, the SRS fruit availability index (FAI, Figure 2) shows that fruit availability does not differ significantly between months and years, except in 2021. In 2021 we found the highest FAI reaching 15.42%, with the peak of fruit season recorded in June, July, and August. From October 2021 to March 2022, FAI at SRS was relatively low compared to the previous months, with an average of only 1.01%.

3.3. Activity Budgets and Diet

We observed and identified five orangutans and followed them between December 2021 and March 2022 for 648 hours (Table 1). We classified them into three age classes: an adult female (Paula), a juvenile male (Pasto), and three adult males (Sandria, Dodo, and Mike). Sandria is an unflanged male, while Dodo and Mike are the flanged males. Adults show the highest percentage for resting (48%), foraging (22.5%), and moving (21.8%), respectively (Figure 3).

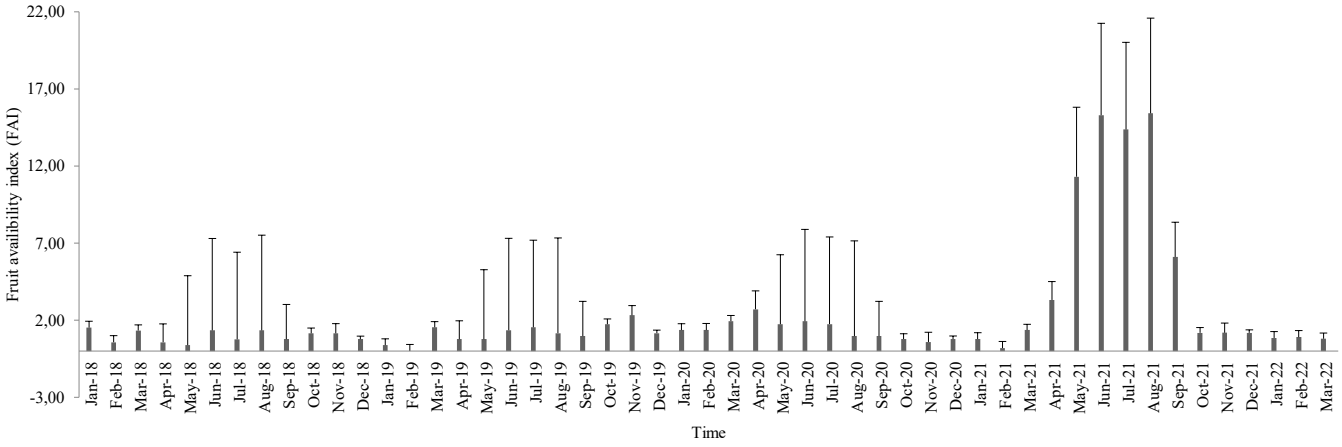

Figure 2. Average fruit availability index (FAI) at the Soraya Research Station from January 2018 to March 2022

Table 1. Characteristics of focal individuals and time of observation (December 2021-March 2022)

Characteristics	Number of individual	Name	Time of observation	Total observation time (hours)	Number of days
Adult female	1	Paula	December-February	278	22
Juvenile male	1	Pasto	December-February	278	22
Adult male (flanged)	2	Dodo	January	48	4
		Mike	February	25	2
Adult male (unflanged)	1	Sandria	March	19	1
	Total			648	51

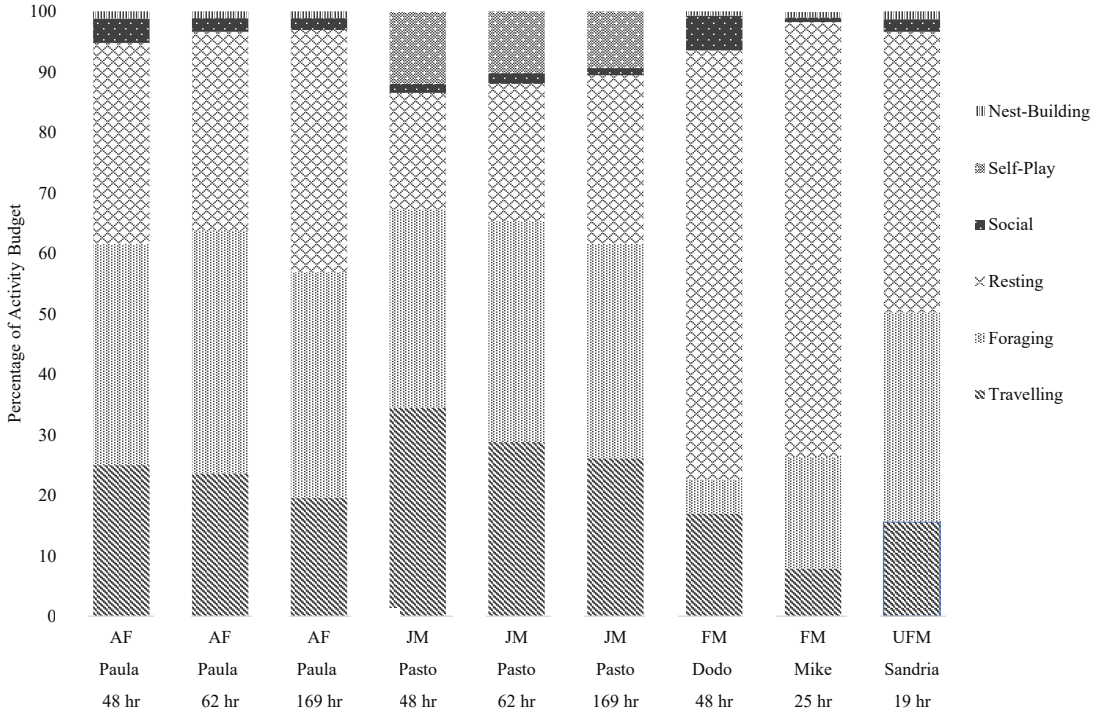

Figure 3. Percentage of the activity budget of Sumatran orangutans (*Pongo abelii*) at Soraya Research Station, Aceh. (AF = adult female, JM = juvenille male, FM = flanged male, UFM = unflanged male)

Analysis of diet composition for each individual showed that bark (BR) was the most consumed food type for the majority of individuals observed, including Paula, Pasto, and Mike, with an average percentage of each reaching 48.3%, 43.8%, and 68.1% (Figure 4A, B, and D). In the other two individuals, Dodo and Sandria, other plants (OP) were the food type with the highest percentage reaching 74.2% and 61%, respectively (Figure 4C, and E). Generally, bark (BR), Fruits (FR) and other plants (OP, including lianas, ferns, and epiphytes) were the main types of diet of Sumatran orangutans in SRS with a frequency of 40.6%, 28.9%, and 15.6%, respectively (Figure 5). Moreover, the diet composition variation in the observation months is provided in Figure 6. We found that bark is their most preferred food during the observation period, particularly in February 2022 (56.2%), January 2022 (48.8%), and December 2021 (39.8%). In March, the orangutans shifted diets to other plants (liana and epiphytes), with the highest

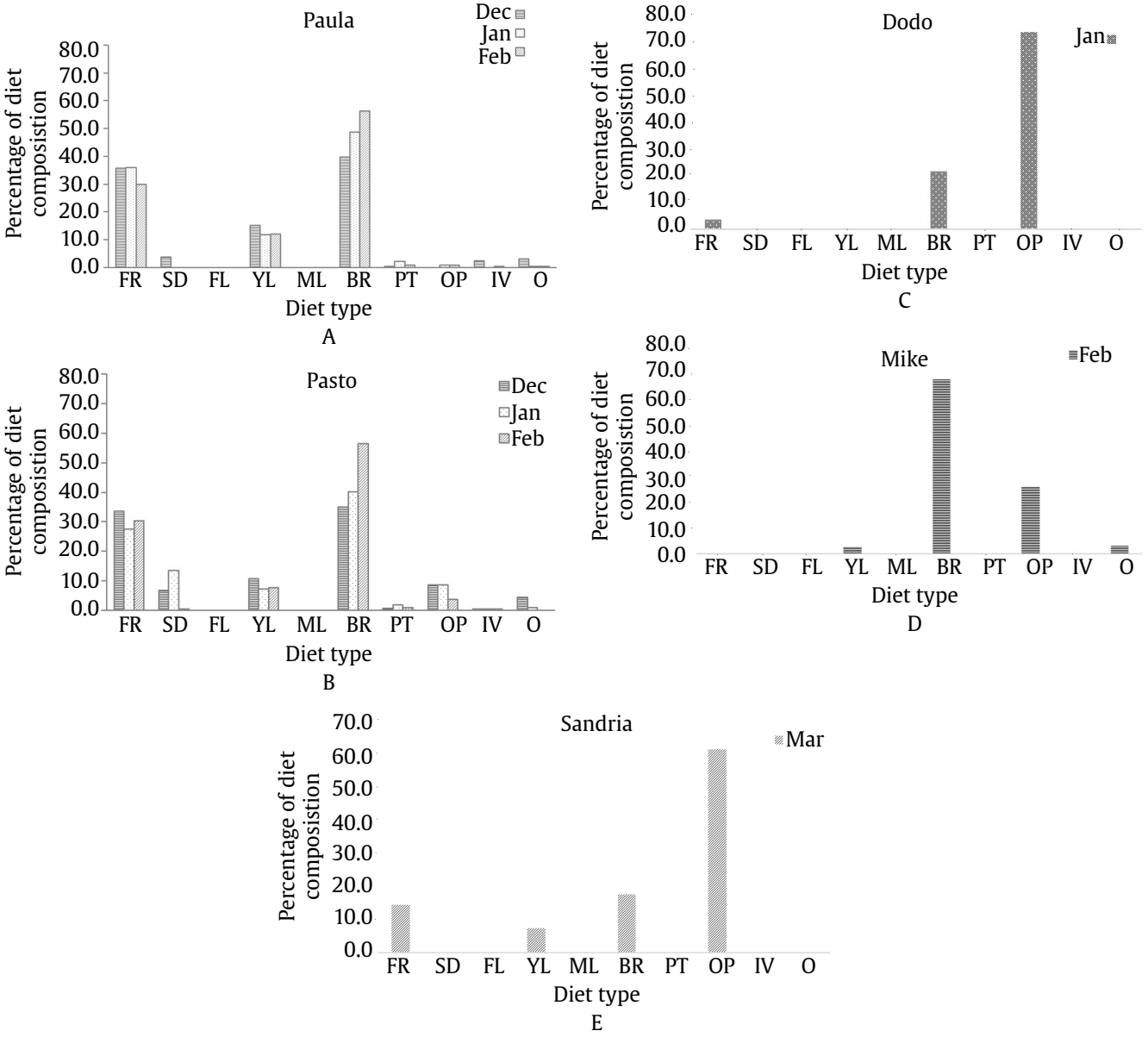

Figure 4. Percentage of diet types on Sumatran orangutans (*Pongo abelii*) by individuals in SPS, (A) Paula, (B) Pasto, (C) Dodo, (D) Mike, and (E) Sandria. (FR = fruit, SD = seed, FL = flower, YL = young leaf, ML = mature leaf, BR = bark, PT = pith, AT = other plants, IV = invertebrate and Vertebrate, O = others)

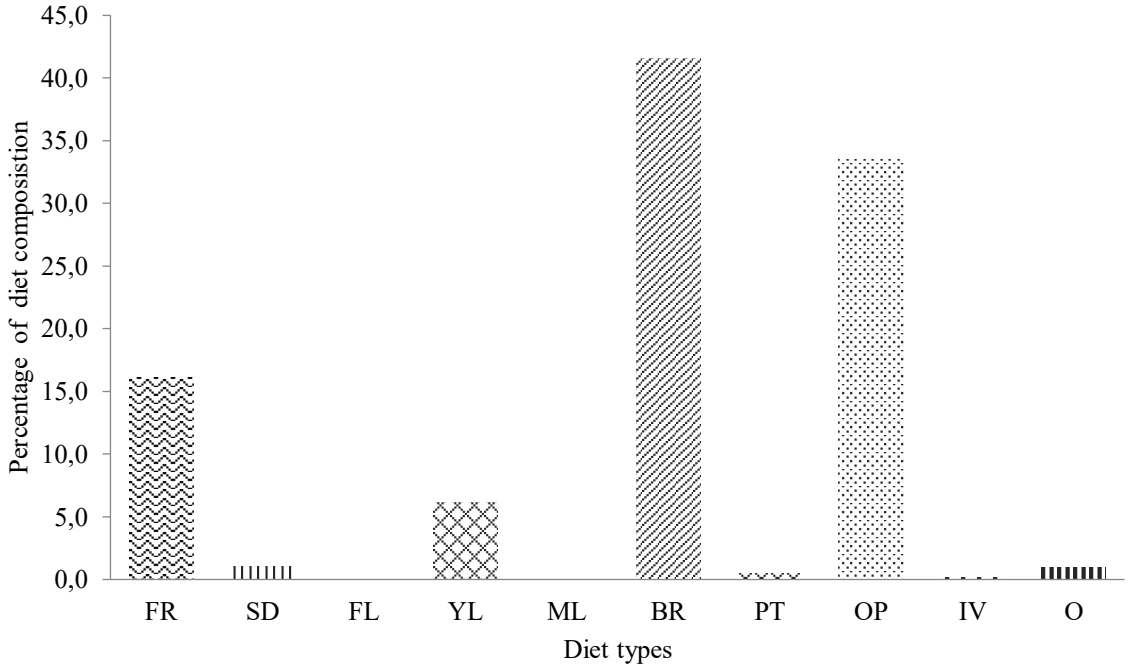

Figure 5. Percentage of diet types on Sumatran orangutans (*Pongo abelii*) at Soraya Research Station periods December 2021-March 2022. (FR = fruit, SD = seed, FL = flower, YL = young leaf, ML = mature leaf, BR = bark, PT = pith, OP = other plants, IV = invertebrate and vertebrate, O = others)

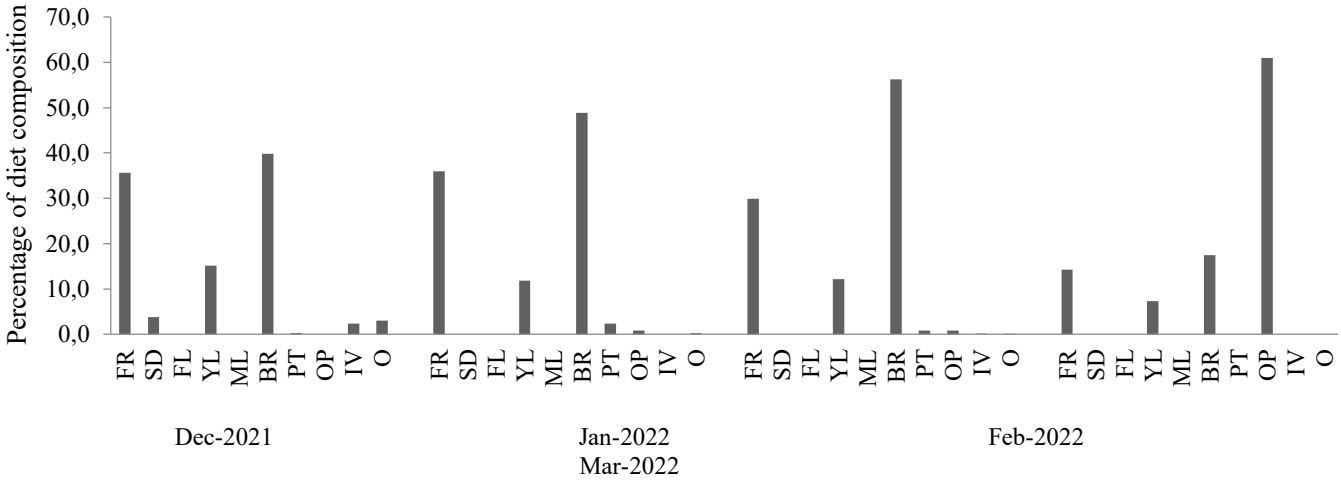

Figure 6. Percentage of diet types variations on Sumatran orangutans (*Pongo abelii*) between months during the study period (December 2021-March 2022. (FR = fruit, SD = seed, Fl = flower, YL = young leaf, ML = mature leaf, BR = bark, PT = pith, OP = other plants, IV = invertebrate and vertebrate, O = Others)

percentage of 61%. Our data also shows that the highest fruit consumption was in January (36.0%), while the lowest was in March (14.3%).

3.4. Environmental Factors

According to the analysis of environmental factors, including temperature and rainfall periods from January 2017 to March 2022, tSRS hasno significant variation between monthly and annual temperatures The yearly average temperature is 26.6 degrees Celcius per year. The year with the highest temperature is 2020, reaching 30 degrees Celcius (Figure 7A). Furthermore, analysis of rainfall showed that the daily average of rainfall at SRS was categorised as low, with an average of 5.4 mm. The highest daily average rainfall was in 2018, reaching 9.2 mm, while the lowest was found in 2021, only reaching 2.8 mm (Figure 7B).

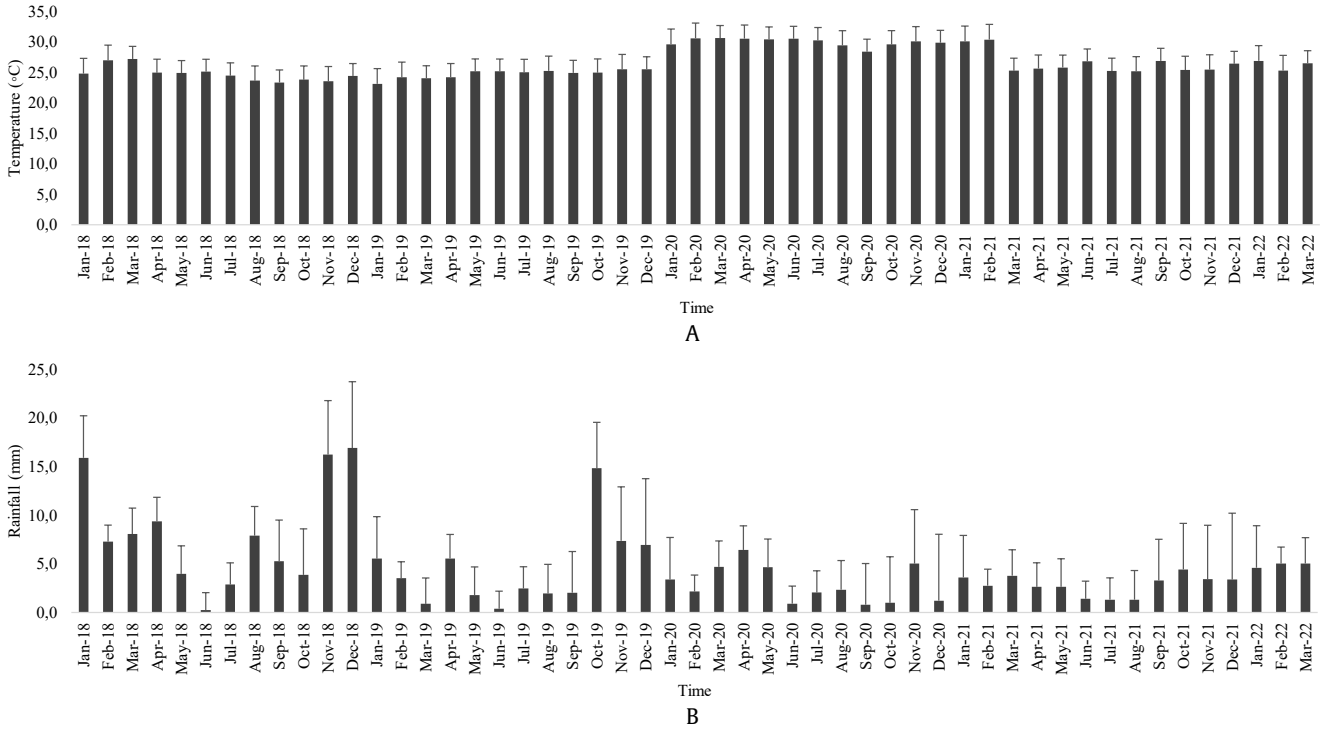

Figure 7. Average temperature (A) and rainfall (B) at the Soraya Research Station period January 2017-March 2022

4. Discussion

Orangutans in Soraya Research Station (SRS) show their adaptation to low fruit availability with an alternative food source and high resting behaviour. As frugivorous, orangutans prefer fleshy fruits in their diets, such as *Garcinia parvifolia, Garcinia microcarpa*, and *Garcinia celebica* from the genus Clusiaceae (Onrizal and Auliah 2019; Russon *et al.* 2009). This fruit usually grows at 1-1,500 m asl (Uji 2007). SRS is dominated by the genus Euphorbia (12 species), Dipterocarpaceae (11 species), Meliaceae (8 species), and Moraceae (7 species) (Iqbar 2018).

Based on our observation, the Sumatran orangutans in SRS consumed inverse diets compared to other Sumatra locations, such as Ketambe and Suaq Balimbing. Sumatran orangutans at SRS prefer bark as their primary alternative food, whereas Keambe and Suaq Balimbing prefer fruit as their primary food. Sumatran orangutans in Ketambe and Suaq Balimbing consumed a high percentage of fruits at 66.2% and 67.5%, respectively (Morrogh-Bernard *et al.* 2009). Diet composition is also affected by the season, such as the fruiting season. In Borneo, orangutan fruit consumption reaches 64-100% during periods of high fruit availability. However, during periods of fruit shortage, orangutans intensively consume leaves (*Spatholobus* and *Ficus*) as well as bark (*Spatholobus* and dipterocarp) (Kanamori *et al.* 2010). In SRS, the Sumatran orangutans' dominant diet is similar to the Bornean orangutans, who spend more time eating barks. It has been reported that Bornean orangutans, from 16% of their daily feeding time, spent 15% in Kutai and 11% in Tanjung Putting, as well as Segama, eating barks (Delgado and van Schaik 2000).

The high amount of time eating barks on Sumatran orangutans caught our attention. In Bornean orangutans, the adaptation of feeding behaviour as an alternative to the scarcity of diet sources has been reported (Bastian *et al.* 2010; Vogel *et al.* 2009, 2016). Most of them consumed flowers of Pouteria cf. Malaccensis in Tuanan, the bark of *Koompassia malaccensis* and *Xanthophyllum discolor*, leaves of *Blumeo dendron kurzii* and *Nephelium mangayi* in Sungai Lading as their alternatives or fallback diet (Bastian *et al.* 2010). Our finding shows that the Sumatran orangutans consumed more bark of Damli (*Streblus elongatus*) in SRS. The bark contains many components like fibre, water, and lipid fatty acids (Rothwell 2016). The Sumatran orangutans in SRS also consumed plants like green tampang (*Artocarpus dadah* Miq) and bird's nest fern (*Asplenium nidus*).

The high bark consumption by the orangutans acts as their fallback diet at SRS and is thought to be a

form of adaptation to the low fruit availability. Finding dominant diet sources other than fruits shows how the individual orangutans have adapted to the scarcity of diet sources in the area (Harisson and Marshall 2011; Marshall *et al.* 2009). So far, reports on Sumatran orangutan fallback diets are still rare. Our findings might add to this knowledge, particularly for the Sumatran orangutans' diet preference adaptation to their habitat.

The FAI might influence the diet preferences of Sumatran orangutans in SRS in the area. The FAI at SRS is generally low, except for 2021, which had the highest FAI value because of the masting event (Figure 3). A masting event is where trees in the ecosystem bear fruit simultaneously, usually in mixed dipterocarp forests in Southeast Asia. Masting events are hypothesised to be initiated by dry circumstances and abrupt reductions in nighttime temperatures linked to the El Nino Southern Oscillation (Ashton *et al.* 1988). After this occurrence, an ecosystem will face prolonged fruit scarcity (Ashton *et al.* 1988; Cannon *et al.* 2007). The fruit productivity in SRS neighbour areas such as Ketambe and Suaq Balimbing is 25.11% and 30.57%, respectively (Wich *et al.* 2011). A low FAI will drive the orangutans in the habitat area to adapt to other dietary sources.

As a price to pay, because of the lack of fruit availability, orangutans have to choose to limit their moving behaviour and preserve energy by resting more. This resting behaviour is high in our observed flanged males, Dodo and Mike. The observed flanged males in SRS (70.9% and 71.6%) seem to have the highest time spent on resting activity compared to other orangutans population, i.e., at Gunung Palung (57%), Kinabatangan (56.7%), Mentoko (55.6%), and Ulu Segama (52.2%) (Galdikas 1988; MacKinnon 1974; Mitani 1989). The longer time spent in resting behaviour might be due to the orangutans' body sizes, ages, and energy needs when they are active or moving (Morrogh-Bernard *et al.* 2009). In contrast to the flanged male, females and juveniles spend more time daily foraging (Figure 3). Females need more energy than males to maintain their reproduction system (van Schaik *et al.* 2009).

The uniqueness of the SRS's ecology characteristic might not be suitable for orangutans. Nevertheless, SRS can be considered a connected forest between the primary forest (Leuser National Park), the surrounding belt forest area, and other used forest areas. It can be considered a natural habitat for the Sumatran orangutans to meet their daily roaming area needs. The study on activity budget, population, and phenology in SRS needs to be continued. The continuity of the Sumatran orangutans' study in the area will give us more understanding of the species, especially in the bridging area as SRS. Furthermore, studying this particular species in a rapidly changing habitat may show us a new perspective on how adaptable orangutans are to changing environments, migration, and survival behaviour.

Acknowledgements

We thank Leuser Conservation Forum, Aceh, Mr. Ibrahim, and all the staff at Soraya Research Station for their support in conducting this study. We also thank the Forestry Service of Aceh and Forest Police Unit IV of Subulussalam, Aceh, for the research permission.

References

Altmann, J., 1974. Observational study of behaviour: sampling methods. *Behaviour*. 49, 227-267. https://doi.org/10.1163/156853974X00534

Ashton, P.S., Givnish, T.J., Appanah, S., 1988. Staggered flowering in the Dipterocarpaceae: new insights into floral induction and the evolution of mast fruiting in the aseasonal tropics. *The American Naturalist*. 132, 44-66. https://doi.org/10.1086/284837

Bastian, M.L., Zweifel, N., Vogel, E.R., Wich, S.A., van Schaik, C.P., 2010. Diet tradition in wild orangutans. *American Journal of Physical Anthropology*. 143, 175-187. https://doi.org/10.1002/ajpa.21304

Campbell-Smith, G., Campbell-Smith, M., Singleton, I., Linkie, M., 2011. Raiders of the Lost Bark: orangutan foraging strategies in a degraded landscape. *PLoS ONE*. 6, 6- e20962. https://doi.org/10.1371/journal.pone.0020962

Cannon, C.H., Curran, L.M., Marshall, A.J., Leighton, M., 2007. Long-term reproductive behavior of woody plants across seven Bornean forest types in the GunungPalung National Park, Indonesia: Suprannual synchrony, temporal productivity, and fruiting diversity. *Ecology Letters*. 10, 956-69. https://doi.org/10.1111/j.1461-0248.2007.01089.x

Chapman, C.A., Rothman, J.M., Lambert, J.E. 2012. *Chapter 7 : Food as a Selective Force in Primates.* University of Chicago Press, Chicago.

Delgado, R.A., van Schaik, C.P., 2000. The behavioral ecology and conservation of theorangutan (*Pongo pygmaeus*): A Tale of Two Islands. *Evolutionary Anthropology*. 9, 201-208. https://doi.org/10.1002/1520-6505(2000)9:5<201::AID-EVAN2>3.0.CO;2-Y

Galdikas, B.M.F., 1988. Orangutan diet, range, and activity at Tanjung Puting, Central Borneo. *International Journal of Primatology*. 09, 1-35. https://doi.org/10.1007/BF02740195

Hardus, M.E., Lameira, A.R., Menken, S.B.J., Wich, S.A., 2011. Effects of logging on orangutan behavior. *Biological Conservation*. 146, 177-187. https://doi.org/10.1016/j.biocon.2011.12.014

Harrison, E., Marshall, A.J., 2011. Strategies for the use of fallback foods in apes. *International Journal of Primatology*. 32, 531-565. https://doi.org/10.1007/s10764-010-9487-2

Hill, R.A, Dunbar, R.I.M., 2002. Climatic determinants of diet and foraging behaviour in baboons. *Evolutionary Ecology*. 16, 579-593. https://doi.org/10.1023/A:1021625003597

Iqbar, 2015. Keanekaragaman Tumbuhan Berhabitus Pohon di Stasiun Soraya Ekosistem Leuser. *Prosiding Seminar Nasional Biotik*. 3, 214-220. http://doi.org/10.22373/pbio.v3i1.2681

Kanamori, T., Kuze, N., Bernard, H., Malim, T.P., Kohshima S., 2010. Feeding ecology of Bornean Orangutans (*Pongo pygmaeus morio*) in Danum Valley, Sabah, Malaysia: a 3-year record including two mast fruitings. *American Journal of Primatology*. 71, 1-21. https://doi.org/10.1002/ajp.20848

Knott, C.D., 1998. Changes in orangutan caloric intake, energy balance, and ketones in response to fluctuating fruit availability. *International Journal of Primatology*. 19, 1061-107. https://doi.org/10.1023/A:1020330404983

Lieth, H., 1974. *Phenology and Seasonality Modeling, Vol 8*. Springer, Berlin. https://doi.org/10.1007/978-3-642-51863-8

MacKinnon, J.R., 1974. The behaviour and ecology of wild orangutans (*Pongo pygmaeus*). *Animal Behaviour*. 22, 3-74. https://doi.org/10.1016/S0003-3472(74)80054-0

Marshall, A.J., Ancrenaz, M., Brearley, F.Q., Fredriksson, G.M., Ghaffar, N., Heydon, M., Husson, S.J., Leighton, M., McConkey, K.R., Morrogh-Bernard, H.C., Proctor, J., van Schaik, C.P., Yeager, C.P., Wich, S.A.m 2009. The effects of forest phenology and floristics on populations of Bornean and Sumatran orangutans, In: Wich, S.A., Utami Atmoko, S.S., Setia, T.M., van Schaik, C.P. (EDS.). *Orangutans Geographic Variation in Behavioral Ecology and Conservation*. Oxford University Press, New York, pp. 97-118. https://doi.org/10.1093/acprof:oso/9780199213276.003.0007

Mitani, J.C., 1989. Orangutan activity budgets: monthly variations and the effects of body size, p arturition and sociality. *American Journal of Primatology*. 18, 87-100. https://doi.org/10.1002/ajp.1350180203

Morrogh-Bernard, H.C., Husson, S.J., McLardy, C., 2002. Orangutan data collection standardisation (Designed during orangutan culture workshop, February 2002). San Anselmo: United State of America.

Morrogh-Bernard, H.C., Husson, S.J., Knott, C.D., Wich, S.A., van Schaik, C.P., van Noordwijk, M.A., Lackman-Ancrenaz, I., Marshall, A.J., Kanamori, T., Kuze, N., Bin Sakong, R., 2009. Orangutan activity budgets and diet: a comparison between species, populations and habitats, In: Wich, S.A., Utami Atmoko, S.S., Mitra Setia, T., van Schaik, C.P. (Eds.). Orangutans: geographic variation in behavioural ecology and conservation. Oxford University Press, New York, pp. 119-133. https://doi.org/10.1093/acprof:oso/9780199213276.003.0008

Onrizal, O., Auliah, N.L., 2019. The nutritional content of some fruits as feeding sources of Sumatran orangutans. *IOP Conf. Series: Earth and Environmental Science*. 374, 012023. https://doi.org/10.1088/1755-1315/374/1/012023

Roth, T.S., Rianti, P., Fredriksson, G.M., Wich, S.A., Nowak, M.G., 2020. Grouping behavior of Sumatran orangutans (*Pongo abelii*) and Tapanuli orangutans (*Pongo tapanuliensis*) living in forest with low fruit abundance. *American Journal of Primatology*. 82, e23123. https://doi.org/10.1002/ajp.23123

Rothwell, M., 2016. Selection of tree species for cambium consumption by the Bornean orangutan (*Pongo pygmaeus wurmbii*) [Dissertation]. Selwyn College, University of Cambridge.

Russon, A.E., Wich, S.A., Acrenaz, M., Kanamori, T., Knott, C.D., Kuze, N., Morrogh-Bernard, H.C, Pratje, P., Ramlee, H., Rodman, P., Sawang, A., Sidiyasa, K., Singleton, I., van Schaik, C.P., 2009. Geographic variation in orangutan diets, in: Wich, S.A., Utami Atmoko, S.S., Setia, T.M., van Schaik, C.P. (Eds.). *Orangutans Geographic Variation in Behavioral Ecology and Conservation*. Oxford University Press, New York, pp. 135-156. https://doi.org/10.1093/acprof:oso/9780199213276.003.0009

Singleton, I., Wich, S.A., Nowak, M., Usher, G., Utami-Atmoko, S.S., 2017. *Pongo abelii* (errata version published in 2018). The IUCN Red List of Threatened Species.

Uji, T., 2007. Diversity, distribution, and potential of *Garcinia* species in Indonesia. *Berk. Penel. Hayati*. 12,129-135. https://doi.org/10.23869/bphjbr.12.2.20076

van Schaik, C.P, van Noordwijk, M.A, Vogel, E.R., 2009. Ecological sex differences in wild orangutans, in: Wich, S.A., Utami Atmoko, S.S., Mitra Setia, T., van Schaik, C.P. (Eds.). *Orangutans: Geographic Variation in Behavioural Ecology and Conservation*. Oxford University Press, New York, pp. 255-268. https://doi.org/10.1093/acprof:oso/9780199213276.003.0018

van Schaik, C.P., Terborgh, J.W., Wright, S.J., 1993. The phenology of tropical forests: adaptive significance and consequences for primary consumers. *Ann. Rev. Ecol. Syst.* 24, 353-377. https://doi.org/10.1146/annurev.es.24.110193.002033

Vogel, E.R, Haag, L, Mitra-Setia, T, van Schaik, C.P, Dominy, N.J., 2009. Foraging and ranging behavior during a fallback episode: hylobates albibarbis and *Pongo pygmaeus wurmbii* compared. *American Journal of Physical Anthropology*. 140, 716-726. https://doi.org/10.1002/ajpa.21119

Vogel, E.R., Alavi, S.H., Utami-Atmoko, S.S., van Noordwijk, M.A., Bransford, T.D., Erb, W.M., Zulfa, A., Sulistyo, F., Farida, W.R., Rothman, J.M., 2016. Nutritional ecology of wild Bornean orangutans (*Pongo pygmaeus wurmbii*) in a peat swamp habitat: effects of age, sex, and season. *American Journal of Primatology*. 999, 1-20. https://doi.org/10.1002/ajp.22618

Wich, S.A., Vogel, E.R, Larsen, M.D., Fredrisson, G., Leighton, M., Yeager., C.P, Breaeley, F.Q., van Schaik, C.P., Marshall, A.J., 2011. Forest fruit production is higher on Sumatra Than on Borneo. *PLoS ONE*. 6, e21278. https://doi.org/10.1371/journal.pone.0021278

Wich, S.A., Utami-Atmoko, S.S., Mitra Setia, T., Djoyoshudarmo, S., Geurts, M.L., 2006. Dietary and energetic responses of *Pongo abelii* to fruit availability fluctuations. *Int J Primatol*. 27, 1535-155. https://doi.org/10.1007/s10764-006-9093-5