The Effect of Food Tree Abudance in the Home Range of Adolescent Sumatran Orangutans (*Pongo abelii*) in Suaq Balimbing, Gunung Leuser, National Park, South Aceh

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Abstract

Ranging behavior plays a key role in the spatial and social strategies of Sumatran orangutans (*Pongo abelii*), a species characterized by fission-fusion dynamics and female philopatry. This study aims to analyze the relatedness between home range size and overlap levels with the utilization of food tree abundance in adolescent orangutans with differences in maternal relatedness and sex. This study uses long-term data from 2021–2024 at the Suaq Balimbing Research Station, Gunung Leuser National Park, South Aceh. Home range data were obtained using GPS, while food tree abundance was analyzed using Kriging interpolation. Home ranges were estimated using Kernel Density Estimator with a dyadic overlap approach. Statistical analysis was conducted using Generalized Linear Models to test the influence of home range size on overlap levels with related and unrelated individuals and food tree abundance. The results showed that home range overlap levels were influenced relatedness, with higher overlap is mother-offspring compared to other individuals. Adolescent orangutans will broader their space utilization in areas with low to moderate abundance of food trees. Sex and relatedness factors were more dominant in shaping adolescent ranging patterns compared to food trees. These findings indicate that the space use strategy of adolescent orangutans is not only determined by ecological factors, but also by sex and relatedness, which are more dominant in shaping adolescent ranging patterns.

Keywords: Adolescent, Food abundance, Home ranges, Relatedness, Sumatran orangutan

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INTRODUCTION

Home range is the area used by individuals to fulfill various life needs, including foraging, reproduction, and raising offspring during a certain period of time (Galdikas, 1988). The accumulation of daily ranges over a certain period of time will result in a home range. The size and pattern of individual orangutan home ranges are known to overlap, which is influenced by several factors such as habitat size, food availability, and reproductive aspects (Singleton dan

van Schaik, 2001). In these overlapping areas, competition for resources can occur, especially when food availability is limited (Saputra *et al.,* 2017)**.**
Orangutans are semi-solitary animals that rely heavily on fruit as their main food source (*frugivorous*). Their dietary strategy plays a central role in their spatial movement strategy. As frugivores, orangutans rely on seasonally available food sources, so their habitat use reflects this spatio-temporal distribution (Saputra *et al.,* 2017). When fruit is abundant, orangutans can gather in areas with large fruit trees, leading to increased opportunities for social interaction and tolerance (Rijksen, 1978). Conversely, when fruit is scarce, competition for resources increases, often resulting in more solitary behavior and reduced social contact (Schuppli *et al.*, 2020). Therefore, food availability and social behavior are crucial for understanding orangutan foraging patterns and social strategies (Schuppli *et al.*, 2020).

Forests in Sumatra have a higher abundance of fruit compared to forests in Kalimantan, due to more fertile volcanic soil compared to Kalimantan (Marshall *et al.,* 2009; Wich *et al.,* 2011). These ecological characteristics mean that the size and overlap patterns of home ranges are greatly influenced by multiple factors such as food availability, sex, age, and social relationships that occur more frequently between individuals (Ashbury *et al.*, 2020; Riegger, 2022; Saputra *et al.*, 2017).

Patterns of space use reveal significant differences between males and females. The size of the male's home range is around 3-5 times larger than that of the female in the same population (Saputra *et al.,* 2017). The home range of female orangutans is >850 ha, while that of male orangutans is >2500 ha (Atmoko *et al.*, 2009). Males have large home ranges, often to seek receptive females, while adult females tend to be philopatric, staying close to their birthplace (Ashbury *et al.,* 2020). Males sometimes travel on the forest floor, while females move more in the upper canopy (Fox *et al.,* 2004). High tolerance for the presence of related individuals leads to more frequent social interactions, such as feeding together and sharing feeding trees (*feeding tolerance*) (Knott *et al.*, 2008). Research in Kalimantan shows that adolescent females continue to share space with their mothers even after reaching sexual maturity, demonstrating the importance of kinship relationships in the formation of early home ranges (Ashbury *et al.,* 2020). Conversely, interactions between unrelated individuals, especially between females, tend to be avoided or even antagonistic, significantly reducing the likelihood of overlapping home ranges (Marzec *et al.*, 2016).

Orangutans undergo several stages of social learning, firstly learning skills from their mothers, then learning social behaviors from other individuals, whilst simultaneously acquiring knowledge about their surroundings (Ehmann *et al.,* 2021; Schuppli, 2012). The social system plays an important role in shaping the behavior, interactions, and development of individual orangutans, especially during adolescence (Kunz *et al.,* 2024). At this stage, orangutans often interact with individuals outside their immediate family through joint exploration activities (Schuppli *et al.,* 2020). These activities help them establish their home range, determine their position in the social hierarchy, and gain access to resources such as fruit (Kunz *et al.,* 2024). In addition, intensive social interactions during this period help them develop skills and explore more (Schuppli *et al.,* 2020). Environmental factors, such as fruit availability, also influence social interaction patterns (Kopp dan Liebal, 2018). When fruit is abundant, orangutans gather more frequently at large fruit trees, thereby increasing opportunities for interaction (Rijksen, 1978). Conversely, when fruit is scarce, competition increases, which affects social relationship patterns and the formation of hierarchies within the group (Schuppli *et al.,* 2020)**.**

Based on this unique background, this study aims to examine the influence of food tree abundance on home range overlap levels with related and unrelated individuals, as well as the space utilization strategies of adolescent orangutans.

METHOD

Study Area

This study was conducted at the Suaq Balimbing Research Station, located within the Gunung Leuser National Park, South Aceh Regency, Aceh Province (Figure 1). The station covers an area of 5.2 km² and consists of three main habitat types, riparian, peat swamp, and upland, with an annual rainfall of approximately 3,400 mm (Wich dan van Schaik, 2000). This location has a high orangutan population density of approximately 6.9 individuals/km² (Fox *et al*., 2004). This study uses long-term data collected from 2021 to 2024.

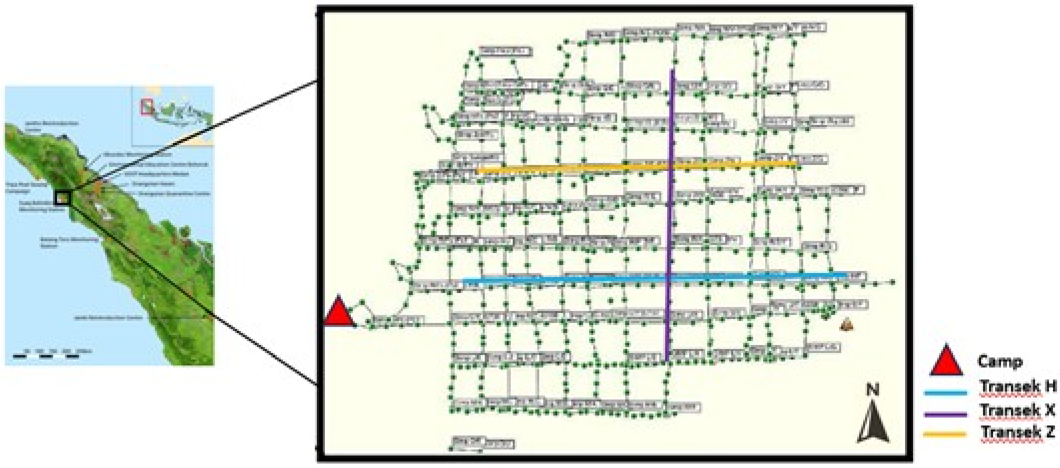


Figure 1. Research Location Map and Phenology Trails at Suaq Balimbing Research Station, Gunung Leuser National Park, South Aceh.

The objects of this study were sumatran orangutans (*Pongo abelii*), consisting of 2 Mother–offspring pairs from one family (Figure 2) and 4 adolescent male and female unrelated individuals (Table 1).

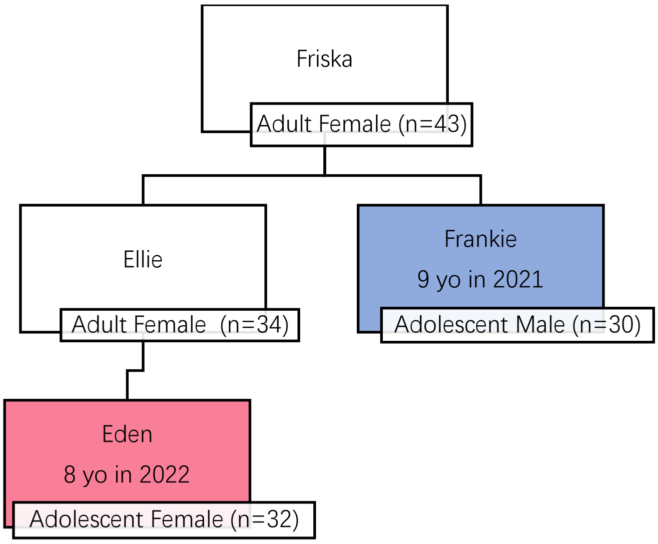


Figure 2. Family Tree of Orangutan Target. Legend: Adolescent Female (pink), Adolescent Male (blue).

Table 1. Information on Adolescent Unrelated Orangutan Individuals

Sex	ID	Age	N Follow
Jantan	Amor	9	11
	Pepito	11	15
Betina	Olala	10	18
	Yulia	17	19

Data Collection

Home Range

Observational data were collected using the focal instantaneous sampling method every two minutes. This method was carried out by observing and following the orangutan from morning nest (when they wake up) until night nest (when they sleep). The length of the orangutan's daily travel path was measured using their travel distance covered by the orangutan during one day, using handheld GPS devices marking waypoints at 30 minute intervals (van Schaik dan van Noordwijk, 2013)

Food Tree Abundance

Food tree abundance was determined based on trees visited by orangutans for feeding activities lasting more than five minutes along their daily movement paths. Each food tree was identified to species and marked with GPS coordinates.

Data Analysis

Orangutan home ranges were analyzed using the Kernel Density Estimator method in ArcGIS 10.8 to estimate home range sizes and map individual movement patterns. The level of home range overlap between individuals was calculated using the dyadic overlap approach, expressed as the proportion of overlapping area (Hutchinson dan Waser, 2007).

$$DyadicOverlap\text{AB} = \left(\frac{Overlap\text{AB}}{\text{Area A}}\right) \text{X} \left(\frac{Overlap\text{AB}}{\text{Area B}}\right)$$

Notes:

OverlapAB = Area overlapped by individual A and individual B
AreaA = Total area explored by individual A
AreaB = Total area explored by individual B

Food tree abundance was analyzed spatially using Kriging interpolation in ArcGIS 10.8 on fruiting trees consumed by orangutans to identify the distribution and extent of productive feeding areas, categorized as high, medium, and low.

Statistical analyses were performed using R (version 4.5.0). Generalized linear models with a Gaussian distribution were employed to test the effects of fruit availability and home range size on food tree utilization, at a significance level of α < 0,05.

RESULT

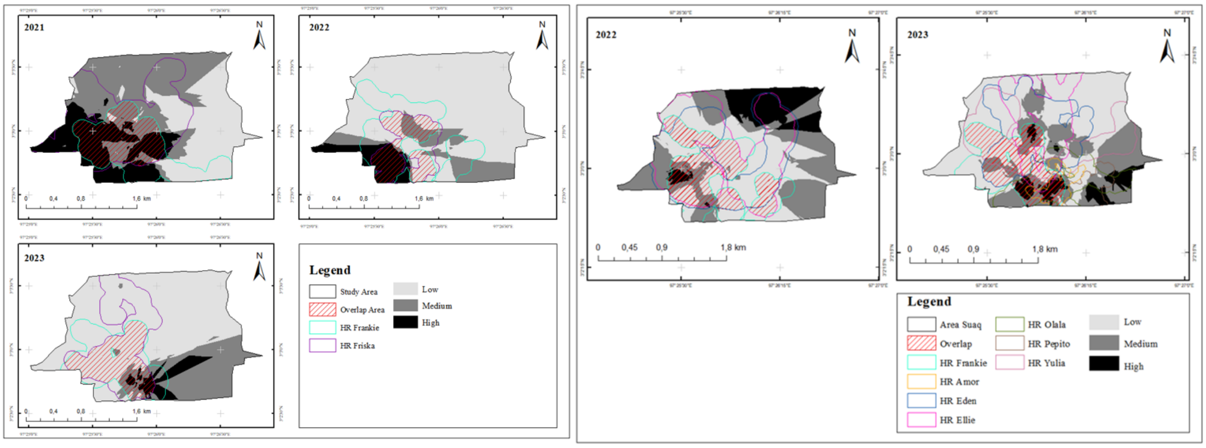
Home Range Overlap

Analysis revealed the presence of home range overlap between adolescent individuals and both related and unrelated. Frankie showed variations in home range size and overlap between individuals (Table 2; Figure 3). In 2021 (n = 11), Frankie had a home range of 128,93 Ha and a fairly high overlap with his mother (66,97). In 2022 (n = 10), the home range area increased to 140,45 Ha. This year, overlap with his mother decreased sharply to 41,4%. In addition, overlap with his mother-lined related individuals was identified to be greater, ranging from 61,26% (nephew) to 69,56% (sister). In 2023 (n = 9), Frankie's home range area decreased to 109,21 Ha, but overlap with his mother increased again to 68,44%. This year also saw overlap with other individuals detected within a wide range, from 0,93% to 89,47%.

Table 2. Home Range Overlap (%) Between Frankie and Other Individuals Across Years.

Year	Individual A	Individual B	Relatedness	HR Overlap (%)
2021	Frankie (n=21)	Friska (n=12)	Mother	66.98
2022	Frankie (n=10)	Friska (n=9)	Mother	41.40

2022	Frankie	Ellie (n=14)	Sister	69.56
2022	Frankie	Eden (n=7)	Nephew	61.27
2023	Frankie (n=9)	Friska (n=12)	Mother	68.43
2023	Frankie	Ellie (n=9)	Sister	26.81
2023	Frankie	Eden (n=22)	Nephew	44.04
2023	Frankie	Amor (n=11)	Unrelated	12.56
2023	Frankie	Pepito (n=13)	Unrelated	0.93
2023	Frankie	Olala (n=9)	Unrelated	27.48
2023	Frankie	Yulia (n=4)	Unrelated	42.12



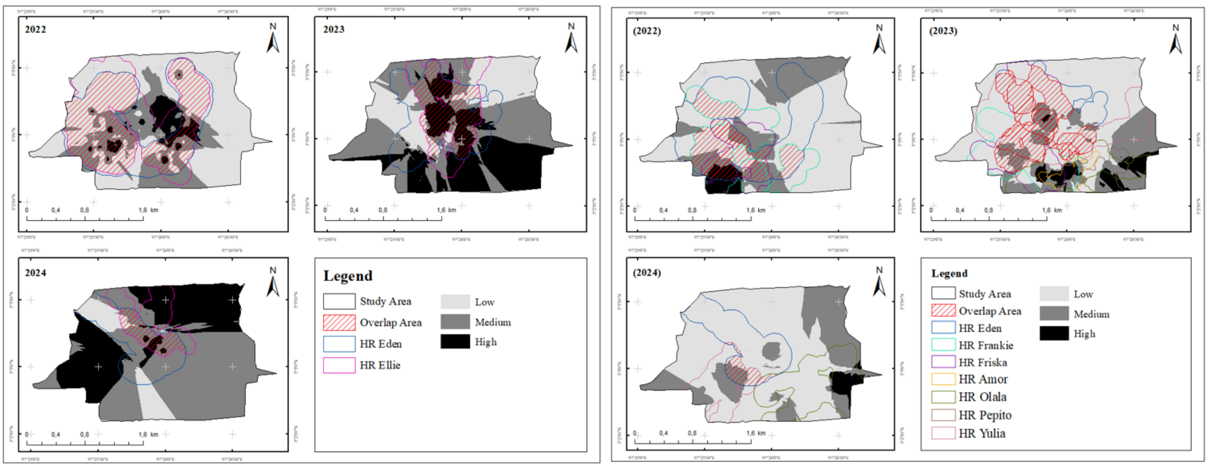
(a) (b)

Figure 3. Overlap of Frankie's Home Range with Mother–offspring (a) and Unrelated (b) and Utilization of Abundant Food Trees

Eden showed significant changes between years in terms of home range size and overlap patterns (Table 3; Figure 4). In 2022 (n = 7), Eden had the largest home range of 195,11 Ha, and showed very high overlap with her mother (87,65%) and moderate overlap with other mother-line individuals, ranging from 23,88% (grandmother) to 43,44% (uncle). In 2023 (n = 22), while the home range area decreased to 146,9 Ha. In 2024 (n = 3), overlap with her mother decreased to 53,07%, and overlap with other individuals showed a wide variation, ranging from 2,28% to 55,25%. In 2024, Eden's home range area shrank again to 85,24 Ha, accompanied by a decrease in overlap with her mother to 29,79% and low overlap with unrelated individuals, ranging from 2,25% to 16,57%.

Table 3. Home Range Overlap (%) Between Eden and Other Individuals Across Years.

Year	Individual A	Individual B	Relatedness	HR Overlap (%)
2022	Eden (n=7)	Ellie (n=14)	Mother	87.64
2022	Eden	Frankie (n=10)	Uncle	43.43
2022	Eden	Friska (n=9)	Grand mother	23.88
2023	Eden (n=22)	Ellie (n=9)	Mother	53.10
2023	Eden	Frankie (n=9)	Uncle	31.95
2023	Eden	Friska (n=12)	Grand mother	55.25
2023	Eden	Amor (n=11)	Unrelated	2.28
2023	Eden	Olala (n=9)	Unrelated	9.40
2023	Eden	Yulia (n=4)	Unrelated	38.96
2024	Eden (n=3)	Ellie (n=6)	Mother	29.79
2024	Eden	Yulia (n=10	Unrelated	16.56
2024	Eden	Olala (n=8)	Unrelated	2.26



(a) (b)

Figure 4. Overlap of Eden's Home Range with Mother–offspring (a) and Unrelated (b) and Utilization of Abundant Food Trees.

Overall, both individuals exhibited greater home range overlap with their own mother compared with other individuals. Statistical analyses revealed that home range size significantly influenced the degree of overlap with their own mother (Frankie p = 0,038; Eden p = 0,049) and other individuals (Frankie p = 0,022; Eden p = 0,029).

Home Range Utilization Based on Food Tree Abundance

Based on spatial analysis of food trees distribution, the abundance of food trees categories in low, medium and high (Table 4). We use the categories to see the pattern of adolescent home range used.

Table 4. Food abundance trees categories.

Year	Focal	Food tree abundance categories (Trees/Ha)		
		Low	Medium	High
2021	Frankie (n=11)	0,10	0,12	0,16
2022	Frankie (n=10)	0,17	0,24	0,44
2023	Frankie (n=9)	0,15	0,18	0,22
2022	Eden (n=7)	0,09	0,11	0,16
2023	Eden (n=22)	0,07	0,08	0,11
2024	Eden (n=3)	0,26	0,27	0,30

Home range utilization based on food tree abundance categories varied among individuals across years (Table 5).

Table 5. Home Range Areas and Distribution of Their Utilization Based on Food Tree Abundance.

Year	Focal	Total Home ranges (Ha)	Home ranges per Food tree abundance categories (Ha)		
			Low	Medium	High
2021	Frankie (n=11)	128,93	27,76	36,69	64,39
2022	Frankie (n=10)	140,45	107,68	27,52	5,13
2023	Frankie (n=9)	109,21	63,74	29,95	15,42
2022	Eden (n=7)	195,11	118,39	60,79	15,83
2023	Eden (n=22)	146,89	33,59	59,75	53,56
2024	Eden (n=3)	85,24	22,10	54,41	8,71

Based on Table 5, Frankie's home range was predominantly in areas of high food tree abundance in 2021, with increased utilization of lower abundance areas in 2022-2023. For

Eden, utilization shifted from low abundance areas in 2022 to medium categories in 2023-2024. Statistical analyses indicated no significant relatedness between home range size and food tree abundance categories, low (Frankie p = 0,88; Eden p = 0,37), medium (Frankie p = 0,77; Eden p = 0,39), and high (Frankie p = 0,56; Eden p = 0,45).

DISCUSSION

The overlapping patterns of home ranges in adolescent orangutans show little differences between male (Frankie) and female (Eden) adolescents, and reflect spatial use strategies influenced by relatedness and individual developmental stages. Frankie, as an adolescent male, the home range is relatively large and accompanied by varying degrees of overlap, both with his mother and other individuals. The overlaps home ranges both with his mother or other mother-lined related individuals gradually decreased in coming years (2021-2023), however, it was opposite with non-related individuals, especially with females. This variation indicates that males begin to develop larger home ranges as part of a dispersal strategy towards the adult phase (Morrogh-Bernard *et al.*, 2011; Singleton dan van Schaik, 2001). In contrast, Eden as an adolescent female, who just step on weaning age, has high overlap home ranges with related individuals, reflects a philopatric pattern, where females tend to remain in or near their birth territory (Ashbury *et al.*, 2020; van Noordwijk *et al.*, 2012). The development of Eden' home ranges were very interesting, while the overlap with her mother and uncle decreases, she gained more with her grandmother and relatively stable with non-related individuals.

These differences in home range overlap patterns between males and females reflect distinct strategies. Related female individuals share overlapping ranges, while males develop larger ranges that overlap with multiple female groups to maximize reproductive opportunities (Meijaard *et al.*, 2001). Male orangutan home ranges contain at least three resident females, indicating that male strategies serve not only for foraging but also for reproduction (Atmoko *et al.*, 2009; Singleton dan van Schaik, 2001).

The findings indicate that both Frankie and Eden exhibited significant home range overlap with unrelated individuals. This suggests that in high density populations, such as Suaq Balimbing (6,9 individual/km²), adolescent orangutans must share space with various individuals (Fox *et al.*, 2004; Wich *et al.*, 2016). However, interaction patterns within these overlapping areas differed substantially based on related individuals. Associations among female individuals were typically confined to a single matriline; encounters with individuals from different matrilines often led to avoidance by one party or even aggression (Marzec *et al.*, 2016; van Noordwijk *et al.*, 2012).

The results of the analysis show differences in home range utilization based on the category of food tree abundance. Both Frankie and Eden show a tendency to utilize areas with lower to moderate fruit abundance, although this is not significant ($p > 0.05$). These findings indicate that although orangutans show a preference for certain areas, other factors such as ecological knowledge, social interactions, and learning from adult individuals may be more dominant in determining their foraging patterns. This pattern of space utilization is consistent with optimal foraging theory, whereby individuals allocate more time to locations with higher energy sources (Sayers *et al.*, 2010). Although they did not expand their total territory, adolescent orangutans showed selective use of space, focusing on food sources with higher food abundance. Vogel *et al.,* 2017 explained that during periods of high fruit availability, orangutans tended to reduce their range, while during periods of low availability, they increased their range.

Differences in space utilization patterns between Frankie and Eden also reflect distinct social learning processes between males and females. Adolescent orangutans remain in an intensive learning phase, acquiring ecological knowledge through various means, including maternal teaching, interactions with other individuals, and innate knowledge from birth (Ehmann *et al.*, 2021; Schuppli, 2012). The social system plays a key role in shaping orangutan behavior, interaction patterns, and individual development, particularly during the adolescent phase (Kunz *et al.*, 2024).

During adolescence, orangutans often interact with individuals outside their immediate family through joint foraging activities, which help them establish their home range, determine their position in the social hierarchy, and gain access to resources such as fruit (Kunz *et al.*, 2024; Schuppli *et al.*, 2020). Intensive social interactions during this period also help them develop skills and engage in more exploration. Adolescent orangutans, who are less experienced than adults, tend to have lower success rates in finding food during periods of low fruit availability, so they more often follow adults to learn (peer) more efficient foraging strategies (Roth *et al.*, 2020).

The results of the study show that in years with high overlap with related, both Frankie and Eden demonstrated more efficient use of space in areas with high food abundance. This indicates knowledge from parents or other adult individuals about the location of productive food trees. In Eden, high consistency in utilizing the same area as related, especially with her mother Ellie, indicates intensive learning about the core area that will become her permanent territory when she is an adult. The philopatric nature of female orangutans causes female individuals to have a high level of tolerance towards other female individuals, especially those within the same lineage (Ashbury *et al.*, 2020; van Noordwijk *et al.*, 2012). In contrast, Frankie shows a wider range with more varied overlap with unrelated individuals, indicating a need to gain knowledge about a wider area that will become his adult home range. This pattern is consistent with the dispersal behavior of males, whereby male orangutans that have fully developed cheek pads will permanently disperse from their birth area, although during adolescence they sometimes return to their birth area (Morrogh-Bernard *et al.*, 2011).

Conditions in Suaq Balimbing, with its high population density (6.9 individuals/km²) and relative stability in fruit availability, provide opportunities for social learning with other individuals. The higher level of social interaction in Suaq compared to populations in Kalimantan allows adolescents to have more opportunities to learn from various individuals (Wich *et al*., 2011). With abundant food, orangutans can gather more often without having to compete fiercely, allowing adolescents to interact more with their parents and other individuals to learn optimal foraging strategies.

CONCLUSION

The results of this study show that adolescent orangutans in Suaq Balimbing exhibit variation in home range size, with males ranging little bit boarder than females. Home range overlap is greater with related than with unrelated, particularly among adolescent females who display philopatric patterns, whereas males show more varied overlaps as part of their dispersal strategy. Adolescent orangutans preferentially utilize areas with medium to high categories fruit tree abundance. These findings suggest that space use strategies among adolescent orangutans in Suaq Balimbing are shaped not only by ecological factors but also more dominantly by sex and relatedness in forming individual ranging patterns.

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