ORANGUTAN (*Pongo pygmaeus ssp. wurmbii*) RANGE PATTERN IN PUNGGUALAS, SEBANGAU NATIONAL PARK, CENTRAL KALIMANTAN, INDONESIA

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ABSTRACT

Punggualas is a logged-over forest in Sebangau National Park (SNP), serving as a primary stronghold for orangutan (*Pongo pygmaeus ssp. wurmbii)* population. Therefore, this study aimed to evaluate orangutan range patterns and distribution within Punggualas forest. The ranging data were collected inside the area of interest (AOI) from February 2015 to December 2019 (P1) and March 2020 to May 2022 (P2). The minimum convex polygon (MCP) area and Kernel Utilization Distribution (KernelUD) of orangutan were estimated using the adehabitatHR package in RStudio 4.2.3, with the Kernel Density (KD) tool in ArcGIS 10.5 used for visualization. The results showed that the largest range size, measuring 259.6 Ha, was observed in the mother-infant pairs throughout the investigation, surpassing the flanged male home range (HR) size of 250 Ha per year reported at the Natural Peat Laboratory, CIMTROP-UPR. The range pattern also varied significantly between the two study periods. During P1, the distribution area was positioned in the northern part of the AOI, shifting to the southeastern during. This indicated that *P. p. wurmbii* range pattern in Punggualas moved to the southeastern part of the grid trails, as shown by MCP and KernelUD. The probability of orangutans using random points across the study area, specifically for food, was adequate from the total basal area (m^2ha^{-1}) and tree species composition. The compression effect became evident as a potential determining factor contributing to rapid changes in range patterns during the study periods.

Keywords: epidemiology triad, kernel density estimation, minimum convex polygon, punggualas, sebangau national park

INTRODUCTION

The Bornean orangutan (*Pongo pygmaeus*) is comprised of three sub-species, namely *P. p. pygmaeus* (West Kalimantan and Sarawak, Malaysia), *P. p. wurmbii* (West Kalimantan and Central Kalimantan) and *P. p. morio* (East Kalimantan, extending north to include Sabah, Malaysia) (Ancrenaz *et al.* 2016). However, the conservation status of this charismatic wildlife on the IUCN Red List has reached the critically endangered (CR) level, indicating a severe and continuous population decline over the past 45 years. The contributing factor to this decline is habitat loss, which leads to habitat fragmentation and increases the number of poachers and killings of orangutan (Santika *et al.* 2017b; M. Voigt *et al.* 2018; Wich *et al.* 2012) and forest fires (Erb, Barrow, Hofner, Utami-Atmoko & Vogel 2018).

During the 1970 to 2000 period, Sebangau forest experienced logging concessions, with an influx of illegal activities in various forest areas, particularly in the Katingan Catchments, including Punggualas, until early 2005 when the government intervened with law enforcement

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actions. Both authorized logging concessions and illegal logging activities have resulted in orangutan habitat loss and fragmentation in the Sebangau peat forest ecosystem. These past activities are evident in the form of semi-permanent railways and canal networks used to transport logs out of the forest, which are still visible in the areas or through high-resolution satellite imagery. During the logging concessions, the railways were used to access the targeted timber, making frequent return visits to log secondary species. However, canal is currently being used for alternative purposes such as granting access to non-timber forest products including jelutong tap, medicinal plants, or fishing harvesting in the interior forests. These developments have created the orangutan-human interface in Sebangau National Park (SNP).

Orangutan has the ability to adapt to human-dominated landscapes (Rayadin & Spehar 2015). However, these conditions are ideal for pathogenic organisms such as parasites, bacterial, and virus transmission, posing a threat to orangutan and human (Herrera, Chakraborty, Rushmore, Altizer & Nunn 2019; Nurcahyo, Konstanzová & Foitová 2017; Philippa & Dench 2019; Rondón *et al.* 2017). Several studies stated that the source of pathogenic transmission was from tourists, researchers, the local community (Woodford *et al.* 2003), and orangutan release, including translocation (Kilbourn *et al.* 2003; Mul *et al.* 2007). Furthermore, anthropogenic activities are increasingly implicated as drivers of pathogenic potential (Allen *et al.* 2017; Bengis *et al.* 2004; Daszak, Cunningham & Hyatt 2000; Han, Kramer & Drake 2016; Jones *et al.* 2008). The hypothesis of Maria Voigt *et al.* (2018) suggested that the absence of an explanation for reported orangutan deaths in their natural habitat, made it necessary to consider the existence and spread of deadly infectious diseases, as discovered in the group of apes in Africa. This leads to the consideration of the factors that determine the transmission of pathogenic agents such as parasites, bacteria, and viruses in wild orangutan.

Bordes, Morand, Kelt and Van Vuren (2009) reported that the important determinants of parasite transmission were host mobility and home range size. Mammals, such as orangutan, are host to a wide array of gastrointestinal parasites, often acquired through contact with infectious stages present in soil, feces, or vegetation, suggesting the influence of range behavior on their spread (Nunn, Thrall, Leendertz & Boesch 2011). The details on how range use behavior might influence the spread of fecally transmitted parasites are also described, specifically the term of "territoriality benefits" and the "fecal exposure" hypothesis. Furthermore, several field parasitologists have identified the important roles of home range in parasite dynamics (Foitová, Huffman & Wisnu 2009; Labes *et al.* 2010).

In this study, Burt home range definition as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" was used to prevent any misinterpretation (Burt 1943). These activities depend on the life stage, sex, and habitat of animals. Home range estimated by studies that are not very intensive, short, or restricted to a small area is considered to represent core areas (Singleton & Carel P. van Schaik 2001). This indicates that the core area of home range is the most frequently used by an animal.

A previous study showed that orangutans had fixed home range, spanning from 100 to 900 ha for females and up to 2,500 ha for adult males (Singleton, Knott, Morrogh-bernard, Wich & Schaik 2009). The peat swamp forests of Suaq Balimbing, Aceh, Sumatra, and Tanjung Puting National Park, Central Kalimantan, have the highest recorded home range. For example, a single female orangutan may require at least 1500 ha for self-support and their offspring, while males need more than 4000 ha. These ranges include a variety of habitats, offering unique benefits due to different fruiting patterns (Cattau, Husson, & Cheyne, 2015; Saputra, Perwitasari-Farajallah, Suci Utami-Atmoko, Ariyanto, & van Noordwijk, 2017). Several investigations have identified that the male range is significantly greater compared to females due to the food availability. Despite the increase in deforestation, the orangutan population has shown the opposite trend (Santika *et al.* 2017a; Maria Voigt *et al.* 2021, 2018; Wich *et al.* 2012).

The investigation into orangutan daily range size and pattern in Punggualas has been initiated by Rukmawardani & Imron (2021). The results study suggested understanding pattern and range size positively benefit future forest rehabilitation. However, there is no information regarding the potential overlap between the vast area of orangutan and the subsistence activities of communities surrounding Punggualas. Therefore, this study aimed to estimate orangutan range size, pattern, and the determining factors influencing the range pattern shift in Punggualas forest, particularly in relation to food availability.

MATERIALS AND METHODS

Study locations

This study was conducted in Punggualas, a logged-over forest, covering approximately 1.320 Ha, located in the western part of SNP, as presented in Figure 1. This location is an active site for orangutan studies since 2010 and is allocated as a focal point of eco-tourism development for orangutans. From January to December 2018, tourist visit data to Punggualas reached a total of 260 visitors (Kartini, PEH TN Sebangau: Pers. Comm.).

Range Observations

Range data within the area of interest (AOI) was collected from Feb 2015 – Dec 2019 (P1) and Aug 2020 – May 2022 (P2). Due to the COVID-19 pandemic lockdown, the observations in 2020 were only conducted from August to September and continued from May to December 2021. A standardized method was used for orangutan studies, indicating the orangutans follow protocol (H. Morrogh-Bernard, Husson & McLardy 2002).

Behavioral data were collected during nest-to-nest focal animal follows, using two-minute instantaneous sampling to record activity and feeding. All observed behavior was recorded in 2-minute intervals and completed as the focal built night nest by a team of 2-3 personnel. Observations were terminated when individuals moved beyond the boundaries of the observation grid. Subsequently, names were assigned to individuals when consecutive days extended beyond four days, with their sex-age class as presented in the datasheets.

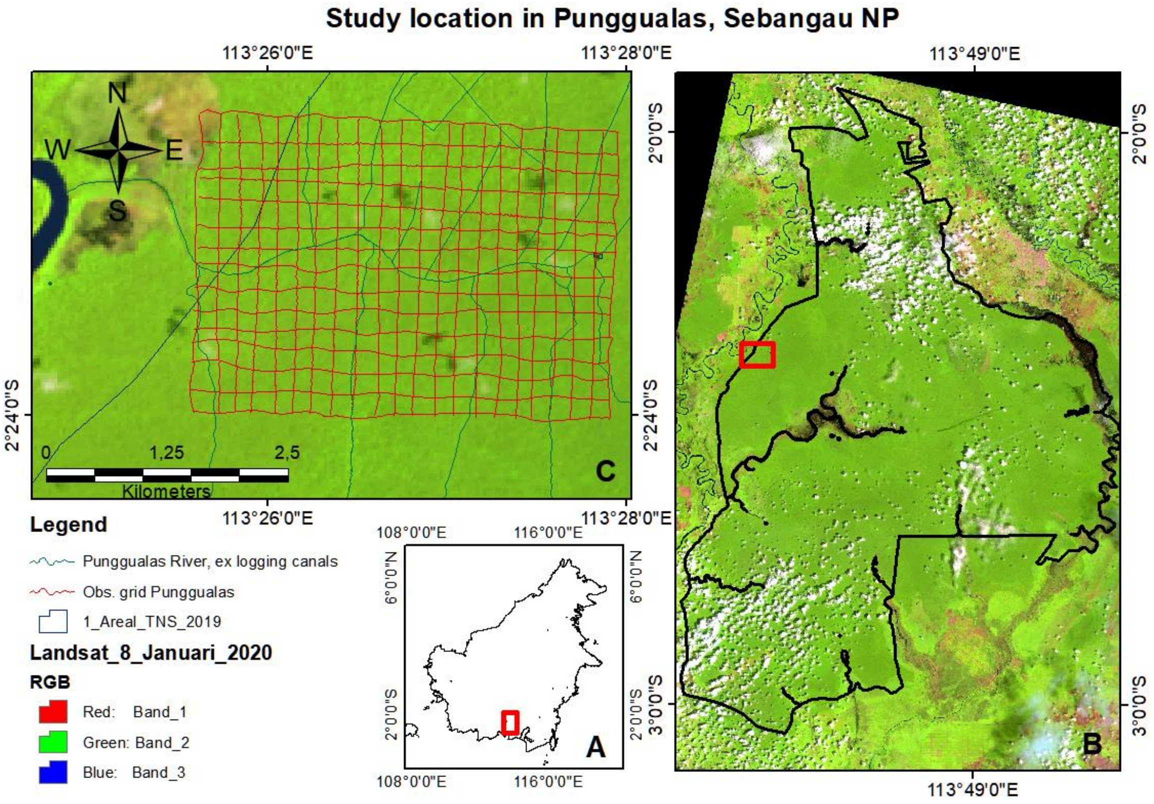

Figure 1 Map of the study area in SNP:(A) Borneo Island; (B) SNP; and (C) Orangutan observation grid in Punggualas

Range data were collected using a handheld GPS unit (Garmin GPS78) to record the location of the focal at 30-minute intervals. Regarding range size, the focus was extensively on nest-to-nest follows, without specifying additional criteria such as a minimum of 1000 hours followed for estimations. Subsequently, orangutan position points data were extracted, analyzed, and nest-to-nest observation of 21 orangutan were completed, as representative of three sex classes, consisting of two adolescent females (FA), five flanged-male (FM), and 13 mother-infant (MI), respectively. Table 1 describes individual estimated age, Home Range (HR) in (Ha), total hours followed, and habituation status.

Forest Block Sampling

A rapid assessment of the habitat structure was made to determine the comparativeness between the North and South Forest block, based on range results. The point quarter centered quadrat (PCQ) method was used to calculate basal tree area and important value index for each forest block during focal follows. A total of 20 points in the northern forest were assessed, while another 22 points were found in the southern points. The assessment commenced when the focal spent ≥ 10 minutes in a patch tree, as one observer continuously recorded the focal behavior, while the other two operated the PCQ method (Mitchell 2010). The patch tree was tagged during the assessment, followed by the documentation of canopy height and connectivity within a 10 m radius from the focal latest positions.

Data analysis

All range points, updated in each 30-minute interval, were conbined in the recapitulation matrix. Minimum convex polygon (MCP) and Kernel Utilization Distribution (KernelUD) were calculated using the adehabitatHR package in RStudio 4.2.3 (Posit 2023), where the core area was derived from KernelUD with a certain probability. Since this study did not infer specific focal, the matrix excluded range estimates for individuals per annum or seasonal. The distribution was visualized in ArcGIS 10.5 with Kernel Density (KD) tool, which allowed the differentiating of various parts of the animal range according to the intensity of use (Wartmann, Purves & van Schaik 2010). Vegetation data and calculation were carried out using Microsoft® Excel 2019, while graphical figure and color correction were performed using CorelDraw®2021. To identify the items associated with the highest loaded score for each parameter calculated from the PCQ method, Principal component analysis (PCA) was carried out using RStudio 4.2.3 (Posit 2023).

Table 1 Orangutan ID, estimated age, estimated Home Range (Ha), total hours followed, and their habituation status in the study periods

Phase	SC	Est_Age	Orangutan ID	Estimated HR (Ha)	Hours Followed	Remark
Phase-1	MI	24	Marlenda Martinus	241,82295	216	Habituated
Phase-1	MI	21	Jane Jack	192,84975	176	Habituated
Phase-1	FM	29	Brown	149,0408	152	Habituated
Phase-1	FM	22	Coded	123,5825	176	Habituated
Phase-1	MI	23	Vina Vino	123,565	144	Habituated
Phase-1	MI	21	Yulia Yani	108,43875	104	Habituated
Phase-1	MI	22	Nani Nina	92,56	192	Habituated
Phase-1	MI	21	Ibu Anak	84	26	Habituation
Phase-1	MI	26	Rere Reno	51,1972	120	Habituated
Phase-1	FM	21	Damang	37,16015	44	Habituated
Phase-1	FM	20	Kadir	8,49585	6	Habituated
Phase-1	MI	26	Anita_Anton	9	32	Habituated
Phase-2	FM	24	Brown	3	95	Habituated
Phase-2	AF	16	Adolescent_001	5	23	Habituation
Phase-2	AF	18	Adolescent_002	31,216686	99	Habituation
Phase-2	MI	25	Ibu_Anak	71,4011712	25	Habituation
Phase-2	MI	23	Ibu_Anak001	80,034119	83	Habituation
Phase-2	MI	20	IbuAnak003	51,125365	92	Habituation
Phase-2	MI	23	Ibu_anak_2020	26,548	44	Habituation
Phase-2	MI	20	Ibu_Anak_001	23	76	Habituation
Phase-2	FM	21	unk_flanged_male01	23,65411	34	Habituation

RESULTS AND DISCUSSION

Range Size

MCP area was calculated using a value of 80% to include the area used beyond the core home range.

This analysis yielded the estimated home range, in phases 1 and 2, as shown in Figure 2, with the range size of each individual varying from 20 to > 250 Ha. Despite the most representative sex classes, the mother-infant had the highest average range size, approximate (P1), exceeding 250 Ha (P2). A flanged male individual named Brown yielded 149.04 Ha (P1) and less than 5 Ha (P2). The mother-infant had a greater range size than the flanged-male in the same study periods, namely Kadir (FM) in Phase-1 and unk_flanged_male01(FM) in Phase-2. The varying results were attributed to the female behavior and range, which depended on reproductive state, particularly mating and caring for the young. The babysitting lasts for 6 to 8 years before the offspring become independent at the age of twelve (Scott, Knott & Susanto 2019). In these years, the mother imparts and mediates essential skills for the immature offspring (Noordwijk, Sauren, Morrogh-bernard, Atmoko & Schaik 2003). Secondly, the range use may reflect the patch sources, as fully discussed in the subsequent section.

The analysis showed relatively low range estimates for flanged-male but was not significantly small compared to previous studies. The results showed that male ranges are often larger than females, exceeding the grid trails of the study area (Wartmann *et al.* 2010). This indicated the tendency of female orangutans to stay close to their natal location (so-called philopatric), while male orangutan typically dispersed from this area. Based on the dataset, which showed the dyadic in most observations in both phases, also confirmed the co-existence of the philopatric.

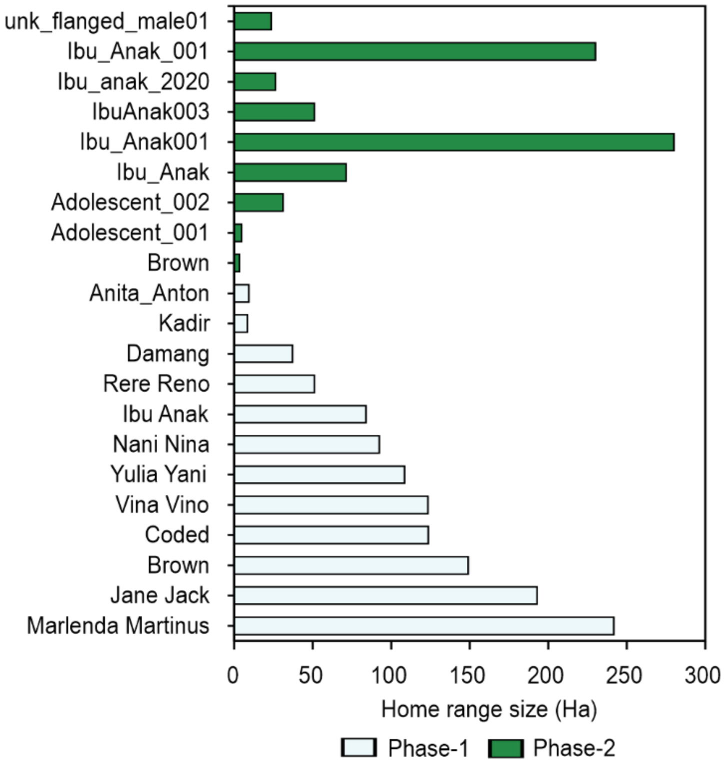

Figure 2 Home range size as per Sex-Classes (SC) in Phase-1 (2015-2019) and Phase-2 (2020-2022) derived from Minimum convex polygon calculations; names provided as appeared in GPS-code; Mother-Infant (MI), Flanged-Male (FM), and Adolescents Female (FA)

Figure 3 shows that the range overlap predominantly among mother-infant sex classes. As shown in Figure 3A, the 12 individuals in phase-1 from 2015 to 2019 were concentric, while in Figure 3B, observed individuals in phase-2 presented that the polygon was dispersed. Individual range that overlaps tend to oppose each other, as indicated by KernelUD, using the 'getverticehr' function for those in Figures 4A and 4B.

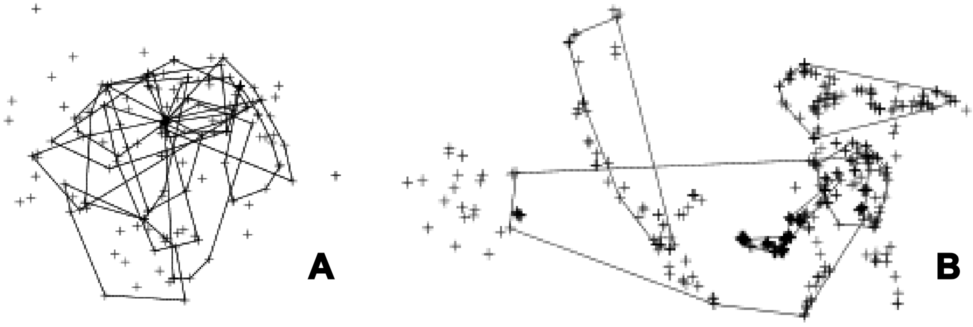

Figure 3 MCP per study periods; P1(A) and P2 (B)

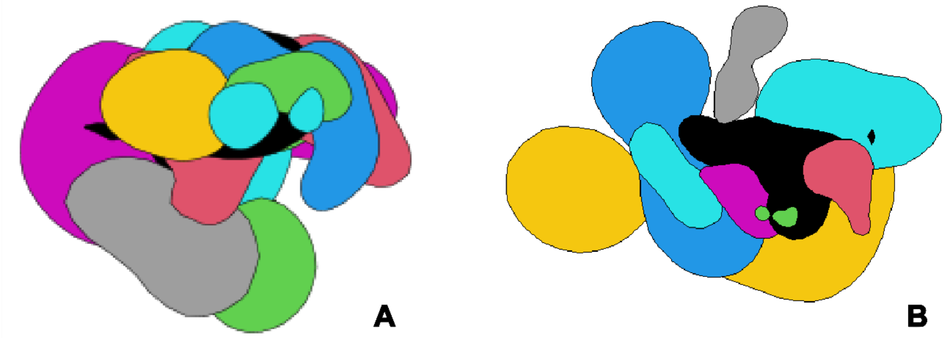

Figure 4 Kernel UD visualization using 'getverticehr' function for each observed individual during P1(A) and P2 (B)

An overlap is a common occurrence among *P. p. wurmbii* in the natural habitat (Wartmann *et al.* 2010). Previous investigations showed that apart from mother–infant dyads, *P. p. wurmbii* were semi-solitaire animals occupying highly overlapping home range. Female home range is assumed to be affected by ecological factors, reflecting the distribution of food sources. Meanwhile, male range use is a response to the distribution of female (Singleton *et al.* 2009; Suci *et al.* 2009), with the compression effect leading to orangutan favoring the fine-scale habitat (Helen C. Morrogh-Bernard, Husson, Harsanto & Chivers 2014; Helen Celia Morrogh-Bernard, Morf, Chivers & Krützen 2011).

According to individual levels, each subset was plotted based on their range size, as presented in Figures 5A and 5B, to determine the residency patterns, including 1) residents, who are consistently present for many years in a particular area, 2) commuters, observed regularly for several weeks or months each year for an extended period. This implied that commuters tended to result in home range with two separate core areas, namely multinuclear, and 3) wanderers, observed infrequently (or once) for at least 3 years, without returning to the area (Singleton & Carel P. van Schaik 2001). Based on this criterion, the only individual in Punggualas, who met the requirements is Brown, the 29-year-old Flanged Male. However, the identification of commuters and wanderers was not possible, particularly in phase-2, where new dyadic pairs were encountered during each sampling period.

The identification was not carried out because 1) the observation area was relatively small, and 2) a longer study period was required, indicating the need to determine home range stability. The datasets engage more *dyads*, with varying range sizes, among the two phases. This indicated that the use of distribution calculated showed the probabilities of where an animal might have been found at any randomly selected time (Powell and Mitchell 2012). Furthermore, it showed that the greater the range size, the more likely an individual has been followed. The problem of home range stability can be solved through a long-term study in an area within defined boundaries set by the movements of the subjects (Singleton & Carel P. van Schaik 2001).

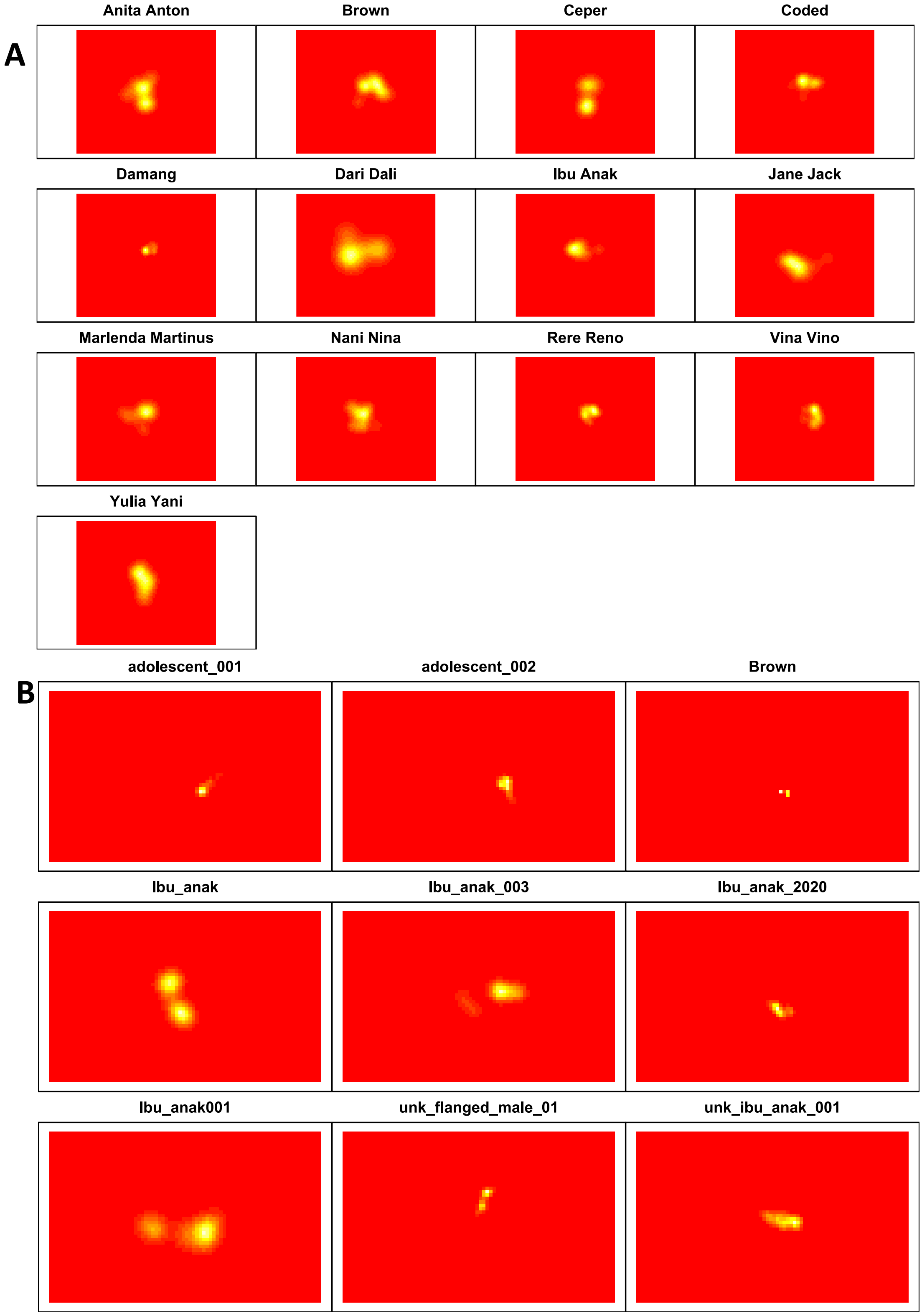

Figure 5 KernelUD as per individual orangutans; (A) Phase-1: 2015 – 2019; and (B) Phase-2: 2020 -2022

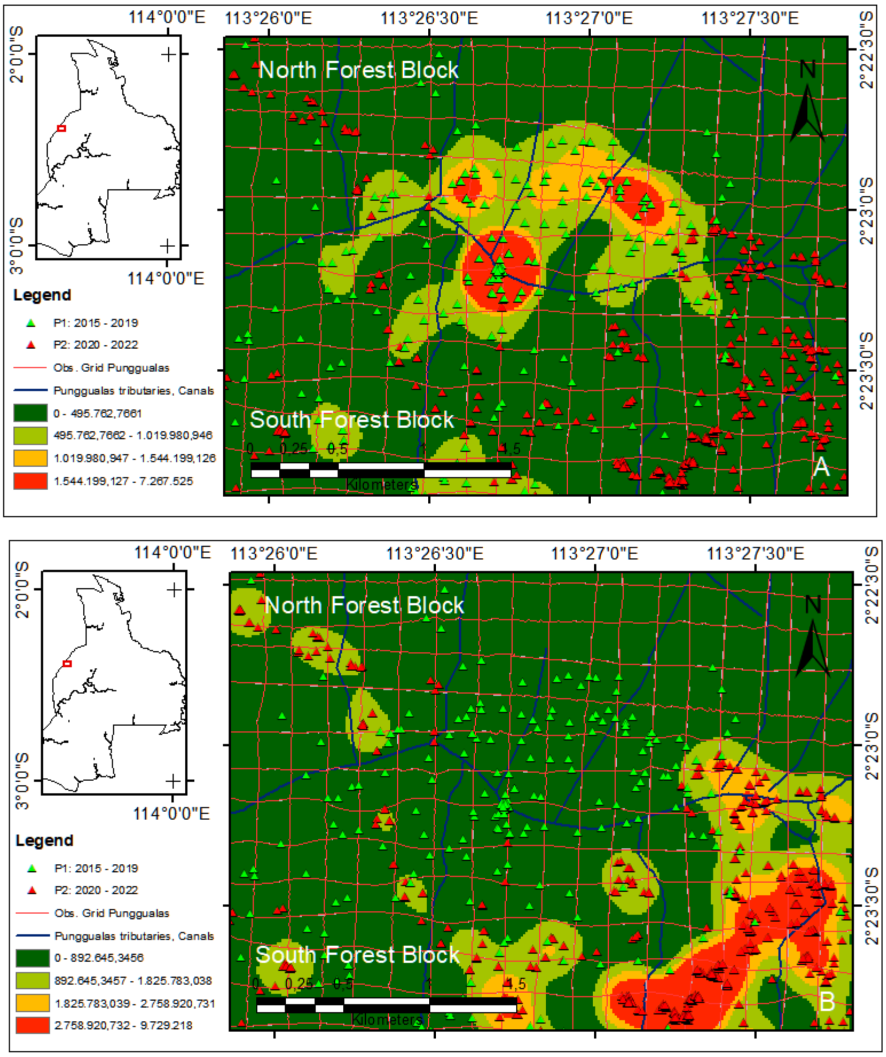

Figure 6 Maps constructed from the orangutan point positions, overlap with the Kernel density estimate: (A) 2015-2019; and (B) 2020 – 2022; North vs South delineated by Punggualas tributaries

Range Pattern

During P1, the distribution area was located within the northern part of the AOI and changed to the southeastern part in P2, as shown in Figure 6. Each red area showed the most overlap in forest areas, indicating a higher probability of hosting various individual normal activities such as food gathering and care for the young. In P1, the most overlap areas were shown by three zones, while a single red area dominated P2. However, a change in pattern was observed, indicating that the orangutan movement corresponded to the tree composition as a determining factor.

The mean basal area (m^2), trees/ha, and total basal area (m^2/ha) were calculated using vegetation data from PCQ. The result presented in Figure 7 showed that each forest block varies slightly, while the southern part tended to have a bigger mean basal area (m^2), total number of trees/ha, and total basal area (m^2/ha). This implied that the southern part of the AOI, featured a greater number of individual trees per ha, particularly *Cryptocarya crassinerva*, *Bluemeodendron tokbrai,* and *Campnospermae coriaceum*. However, the total basal area (m^2/ha) showed the same trend in each AOI, namely *Shorea* sp1.

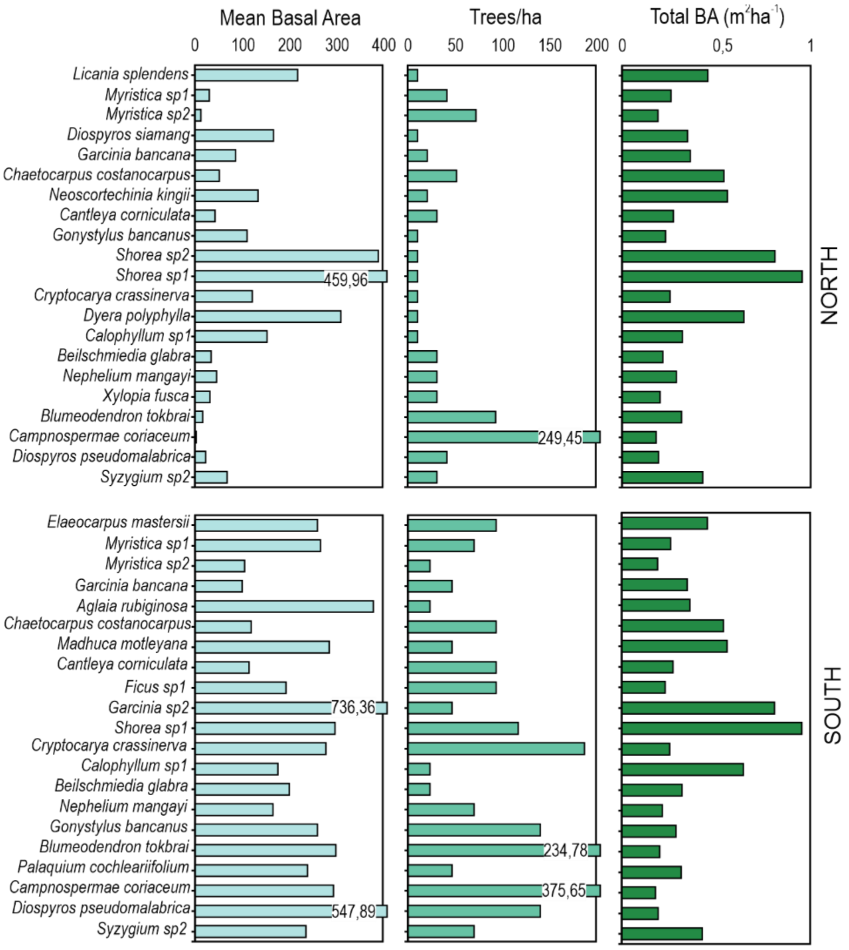

Figure 7 Mean basal area, number of trees/ha, and total basal area (m²/ha) per tree species in the north and south forest blocks

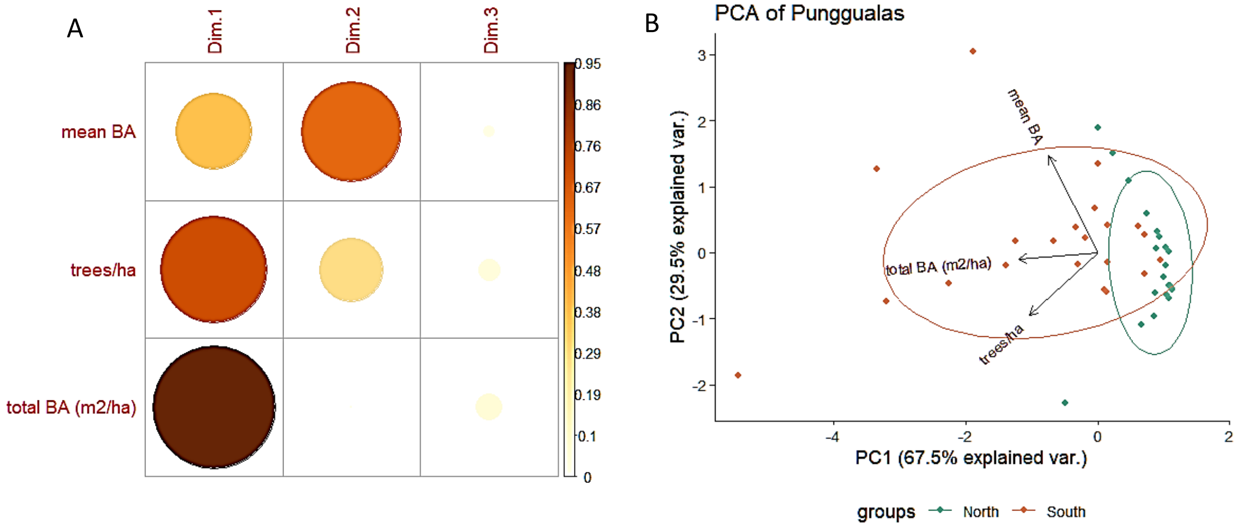

Figure 8 (A) The coefficient correlations mean BA, trees/ha, and total BA (m²/ha) as per dimension; and (B) Biplot Principal component analysis, depicts factor loadings and cluster

The first principal component was strongly correlated with a total BA (m^2/ha), followed by trees/ha and mean BA, respectively (Figure 8A). This indicated whether the North and South Forest blocks yielded, trees/ha, and whether mean BA contributed to the total BA (m^2/ha). PC1 can be considered a measure of total BA (m^2/ha), while PC2 coefficient value of mean BA (0.8388) was perpendicular to the total BA (m^2/ha) and opposed trees/ha. This showed that a higher mean BA value corresponded to a decrease in the contribution to the total variance of trees/ha and total BA (m^2/ha). As for trees/ha, the results produced bias due to only the measurement of each quadrant tree representative. Consequently, when standardized vegetation plots were deployed, different PCA loading biplots would be obtained.

Trees composed of different species such as *Campnospermae coriaceum* (Anacardiaceae), *Blumeodendron tokbrai* (Euphorbiaceae), *Garcinia* sp2 (Clusiaceae), *Cryptocarpa crassinerva* (Lauraceae) and *Diospyros* sp1 (Ebenaceae), were placed beyond elliptical. The result of the principal component analysis in Figure 8 showed that total BA (m^2/ha) loading had the highest eigenvalue. However, mean BA and trees/ha loadings were pointed out in other directions and the probability of orangutans using any random point over the grid trails was adequate from tree species composition.

Figure 9 showed data uniformity despite the differences among mean BA, trees/ha, and total BA (m^2/ha), and variation in tree species, the relative density, coverage, frequency, and important value. Using habitat classification (Morrogh-Bernard *et al.* 2014a), it was discovered that the orangutan used Tall connected A (TCA) and medium-connected (MC). TCA was characterized by the high stem density of large trees (>20 m tall) connected with high canopy (>75%). Meanwhile, MC was characterized by a few tall trees with a high stem density of medium-sized trees and a connected canopy at 10 – 20 m. The interlocked canopy was inadequate to support the range pattern-shifting idea. Recent observations have shown that natural tree falling has been spotted in a regularly visited grid in the Northern and Southern Forest block of Punggualas.

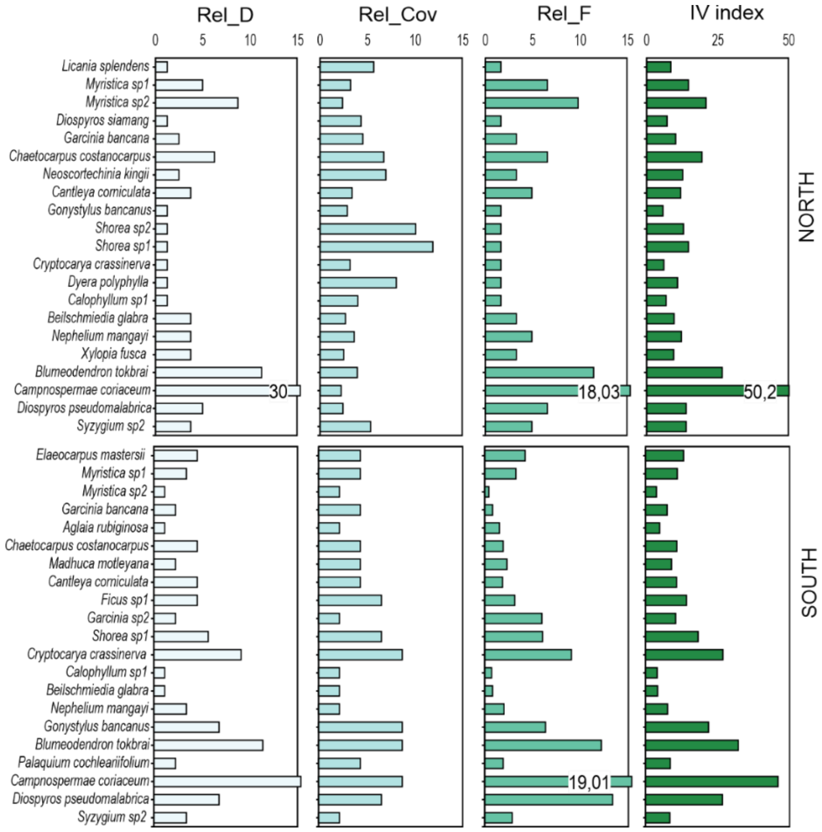

Figure 9 Relative density (%), coverage (%), frequency (%), and important value index (%) as per tree species derived from point-centered quarter method

In addition to tree composition, dietary preferences were also explored as another argumentation. In peat forests, orangutan spent half of the active time feeding compared to those in a mixed-dipterocarp forest. Observations showed that the focal being followed was frequently feeding on young leaves, flowers of *Mezzetia leptopoda* (Annonaceae), and immature fruits of *Nephelium lappaceum* (Sapindaceae). Moreover, recent observations also indicated that the orangutan diet included the flower of *Madhuca motleyana* (Sapotaceae), inner bark, termites, and liana. The fruits from *Willughbeia* sp1 and *cf. Lucinia* sp1, commonly woody lianas found in Punggualas, was observed from several dyad mother-infant and flanged-male.

Punggualas phenology data showed that the *Camnospermae coriaceum* generally had two fruiting periods yearly, first from October/November to February/March, followed by May to June. The general dietary pattern of orangutans during the study period did not always describe the fruit as their dietary preference because seeds, flowers, leaves, and bark were also included as fallback foods. Studies of the nutritional content and its relationship with the energy budget of orangutans in Tuanan, Central Kalimantan, found that young leaves had a higher protein content than fruits (Vogel *et al.* 2017). Basedon the results, confirm that variations in energy absorption were strongly influenced by the range of fruiting periods in the Sebangau habitat. A diet that depended on fibrous vegetation and bark confirmed that *P. p. wurmbii* shapes their mandibulae for dietary preferences (Traylor-Holzer *et al.* 2009). Detail observations in Ketambe Study Areas by (Hardus, Lameira, Menken & Wich 2012) regarding liana-derived resources such as fruit and leaves indicate the critical role of liana in the orangutan diet, specifically for orangutan population in the primary forest.

Table 2 List of observed tree/sapling, liana, and *Ficus* species showing parts eaten by orangutan during P1 and P2

Species	**Family**	**Fruit**	**Seed**	**Flower**	**Leaves**	**Bark**
Campnosperma coriaceum	Anacardiaceae	☐	☒	☐	☐	☐
Xylopia fusca	Annonaceae	☒	☒	☐	☐	☐
Xylopia malayana		☒	☒	☐	☐	☐
Dyera polyphylla	Apocynaceae	☒	☒	☒	☒	☒
Licania splendens	Chrysobalanaceae	☒	☒	☐	☒	☐
Callophylum hosei	Clusiaceae	☒	☐	☐	☒	☐
Callophylum sclerophyllum		☒	☐	☒	☐	☐
Callophylum sp3		☒	☒	☐	☐	☐
Garcinia banana		☒	☐	☐	☒	☐
Diospyros confertiflora	Ebenaceae	☒	☒	☐	☐	☐
Diospyros evena		☒	☐	☐	☐	☐
Diospyros pseudomalabrica		☒	☐	☒	☐	☐
Diospyros siamang		☒	☒	☐	☐	☐
Elaeocarpus mastersii	Elaeocarpaceae	☒	☒	☒	☒	☐
Neoscortechinia kingii	Euphorbiaceae	☒	☐	☒	☒	☐
Castanopsis foxworthyii	Fagaceae	☒	☒	☐	☒	☐
Lithocarpus conocarpus		☒	☒	☐	☐	☐
Litsea cf. resinosa	Lauraceae	☒	☒	☐	☒	☐
Phoebe zsp SE cf. grandis		☐	☐	☐	☒	☐
Koompassia malaccensis	Leguminosae	☐	☐	☐	☐	☒
Magnolia bintulensis	Magnoliaceae	☒	☒	☒	☒	☒
Dactylocladus stenotachys	Melastomaceae	☐	☐	☒	☐	☐
Aglaia rubiginosa	Meliaceae	☒	☐	☐	☒	☐
Parartocarpus venenosa	Moraceae	☒	☐	☒	☐	☐
Horsfidelia crassifolia	Myristicaceae	☒	☐	☒	☐	☐
Myristica sp2		☐	☐	☐	☐	☒
Ardisia sp2	Myrsinaceae	☒	☒	☐	☐	☐
Syzygium sp1	Myrtaceae	☒	☒	☐	☐	☐
Pittosporum sp1	Pittosporaceae	☐	☐	☐	☒	☐
Nephelium lappaceum	Sapindaceae	☒	☐	☐	☐	☐
Nephelium maingayi		☒	☐	☐	☐	☐

Table 2 (Continued)

Species	Family	Fruit	Seed	Flower	Leaves	Bark
Madhuca motleyana	Sapotaceae	☒	☐	☒	☒	☒
Palaquium cochlearifolium		☒	☐	☒	☐	☐
Palaquium pseudorastratum		☒	☒	☒	☐	☐
Palaquium sp		☒	☐	☐	☐	☐
Palaquium sp2		☒	☐	☐	☐	☐
Microcosm sp	Tiliaceae	☒	☐	☐	☒	☐
Willughbeia sp1	Apocynaceae	☒	☐	☐	☒	☐
Ziziphus angustifolia	Rhamnaceae	☒	☐	☐	☒	☐
cf. Lucinea sp1	Rubiaceae	☒	☐	☐	☒	☐
Ficus sp	Moraceae	☒	☒	☐	☐	☐
Ficus sp8		☒	☒	☐	☐	☐

Notes: recorded fruits, are grouped by maturity stages, e.g., immature, semi-mature, or mature fruit.

The observation made in Tuanan, Central Kalimantan, showed the importance of liana in adolescent orangutan (Saputra *et al.* 2017) during the absence of fruiting. The determining factor of liana density in LAHG-CIMTROP UPR Sebangau was highly correlated with tree crown size, shape, and height (Schofield 2015) due to the light penetration to the forest floor.

Another determining factor was found to be crowding, also known as compression. This occurred when orangutan was exposed to the disturbance in a portion of their range, mostly using parts that had not been logged or so-called mosaic, and began to use their home range differently. Since orangutan home range overlaps, many individuals made more biased use of the home range, resulting in population crowding into areas of undisturbed habitat, or 'refuges.' This phenomenon made male orangutans travel further away from the observation grid. To address this issue, additional perspectives were incorporated concerning anthropogenic activities in SNP.

Potential overlap between orangutan range and subsistence activities

Nontimber forest products, known for their aromatic fragrance, so-called gaharu, were mainly produced by the family Thymelaeaceae, specifically *Aquilaria beccariana* van Tiegh, and *Aquilaria filaria* (Oken.) Merr (Giesen 2015; Paoli, Peart, Leighton & Samsoedin 2001; Sitepu, Santoso, Siran & Turjaman 2011). These products were harvested from the Aquilaria genus that had been infected by a particular fungus. This study also documented the activities of villagers, mostly from Karuing, moving back-forth and to the forest, collecting gaharu. Meanwhile, their harvesting methods varied, including the use of a 1,20 m long iron stick pushed into the peat surface to detect the particular sound produced as the stick hit gaharu. After locating the suspected wood, the soil was dug, lifted out of the surface, and taken to the village to be weighed and exchanged for money. The aromatic essence of gaharu was economically beneficial in raw materials, crafted as the bracelet, and occasionally, tasbih.

Recent studies found that some of this aromatic wood was obtained from *Gonystylus bancanus* (Miq.) Kurz, of Thymelaeaceae. The wood is expensive and most wanted during logging concessions in Sebangau ecosystem. Verification has been made for a product claimed as gaharu (Nordahlia 2017), indicating that a product other than the plant genus *Aquilaria* is called pseudo-gaharu. Although the aromatic properties and mechanical structure, the wood are not similar to truly gaharu trees, *Aquilaria beccariana* van Tiegh, and *Aquilaria filaria* (Oken.) Merr.

This study showed the importance of considering some factors such as distance of access and number of days spent in the interior forest should be considered. Some villagers use the observation grid and also encounter the orangutan. According to local sources, these activities were held during the COVID-19 pandemic and continued unto the study in phase-2 (P2). Whether considered a coincidence or not, there was sufficient proof that access to natural resources in the interior forest of SNP contributed to the orangutan range pattern.

Consequently, the Park Authority has now prohibited this gaharu harvesting out of the forest. Recommendations for future study incorporate detailed observations on the orangutan-human interface, including the habitat structure profile, orangutan parasites burden, and the community access into the interior forest.

CONCLUSIONS

In conclusion, this study showed that *P. p. wurmbii* range pattern in Punggualas moved to the southeastern part of the grid trails, as indicated by MCP and KernelUD. The probability of orangutans using any random point over the area, specifically for food was adequate from tree species composition and total basal area (m^2/ha). Additionally, the compression effect became a potential determining factor regarding swift changes in range patterns within the study periods.

COMPETING INTERESTS

The authors declare that there are no competing interests. This study is part of the One-Health showcase, which aims to elucidate the interplay among orangutans, including their behavior, home range, population, intestinal parasites, microbiome, and habitat, referred to as the epidemiological triad in SNP. Therefore, some of the unpublished data will be indicated to support the current study argumentation.

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