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Habitat use of proboscis monkey (*Nasalis larvatus*) in production forests of West Kalimantan, Indonesia

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Abstract. *Wardatutthoyyibah, Pudyatmoko S, Imron MA, Subrata SA. 2023. Habitat use of proboscis monkey (*Nasalis larvatus*) in production forests of West Kalimantan, Indonesia. Biodiversitas 24: 1724-1734.* Proboscis monkeys (*Nasalis larvatus* van Wurmb 1787) are endemic to Borneo and dependent on the presence of wetland forests as their habitat. Recent study shows that many potential habitats of this species are in non-protected areas including logging concessions. We investigate the use of logging concessions for the habitat of proboscis monkeys by determining habitat variables that influence the presence of proboscis monkeys in a selective logging system. We conducted research in seven logged-over areas/LOA during 2009-2015 and eight locations of unlogged forest as proboscis monkey habitat. We applied a logistic regression with the backward stepwise method for selecting environmental variables that influence the presence of proboscis monkeys. Our study showed that proboscis monkeys are no longer present in LOAs, which was indicated by the difference between the habitat characteristics of proboscis monkeys and LOAs. We found that if prosboscis monkeys are present in an area, resource selection was influenced at site level for basal area of trees and poles explained the presence of proboscis monkeys. Reducing the number of trees logged and ensuring connectivity among trees in LOAs could help to reestablish habitat for proboscis monkeys.

Keywords: Concession area, forest production, logged over area, logistic regression, resources selection

INTRODUCTION

The island of Borneo is a big island in the world that hosts many endemic and flagship species such as proboscis monkey, borneon orang utan and borneon elepants. Increasing habitat destruction threatens various wildlife habitats, including proboscis monkey habitat. The proboscis monkeys are protected by the Indonesian Government in Regulation No. 7/1999. In addition to national protection, proboscis monkeys are categorized as an endangered species in the IUCN Red List of Threatened Species (Boonratana et al. 2021) and are including in Appendix 1 CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) trading regulation.

The proboscis monkey's distribution is limited to the island of Borneo, inhabiting various habitat types, such as mangrove, peat swamp forests, riparian forests, dipterocarp forests and heath forests (Mawah et al. 2015; Kombi and Abdullah 2016; Laman and Aziz 2019; Feilen and Marshall 2020; Matsuda et al. 2020). Many protected areas have been established on the island of Borneo; however, the habitat of proboscis monkeys is not limited to those protected areas. Among land use types, protected areas only cover 9% of total potential habitat for this species, whereas concessions play 37% of the total (Wardatutthoyyibah et al. 2019). Out of this percentage, concessions are in the form of logging concessions (4%), ecosystem restorations (5%), industrial tree plantations (10%) and palm oil plantations (18%).

Habitat loss, degradation and fragmentation due to anthropogenic related activities such as agriculture, plantation, mining, logging etc., are important factors affecting the long-term survival of proboscis monkeys. Among provinces in Kalimantan (Indonesian Borneo), various forest concessions in West Kalimantan province play important roles in the habitat of proboscis monkeys. The habitat of proboscis monkeys in West Kalimantan in 2018 was estimated at 8,974 km² spread over a conservation area of ca.908 km² (10%), production forest ca.2,136 km² (24%), oil palm plantation business permits ca.3,517 km² (ca.39 %) and plantations and community agricultural areas ca.1,287 km² (14%), and areas covering other uses ca.1,126 km² (12%) (Wardatutthoyyibah et al. 2019).

As proboscis monkeys are a largely arboreal species (Yeager et al. 1997; Feilen and Marshall 2013), logging concessions have a unique opportunity to contribute to their habitat. While the need for harvesting timber within the habitat of proboscis monkeys can reduce their habitat dramatically, there is a chance of providing more resources for them after such disturbance (Meijaard et al. 2005). More or less 53% (4,457,681 ha) of forest areas in West Kalimantan are categorized as production forests, including areas with permits for timber utilization in natural forest, industrial plantation forest, community plantation forest and ecosystem restoration forest (Sukamto et al. 2021).

Compared to plantation forest concessions that implement land clearing, the concept of a selective logging

system within natural forest concessions is thought to give stakeholders better opportunities for wildlife conservation (Bernard et al. 2016; Kehou et al. 2021). Habitat disturbance in production forest is frequently higher than in conservation areas as selective logging systems can cause changes in plant structure and composition, in turn affecting species richness because of limited resources for wildlife (Bernard et al. 2016; Jati et al. 2018). Despite evidence of the damaging effects of selective logging systems on population dynamics, the effect of disturbance from logging activities particularly logged over area on proboscis monkey behavior appears to be overlooked by researchers.

Throughout the carrying out of logging activities, animals use different strategies by escaping and reoccupying their original habitat (Allred et al. 2011; Prayoga and Imron 2022), sheltering in safer areas (van Mantgem et al. 2015). However, their strategies depend on resource availability in the landscape and the animal's ability to move (van Mantgem et al. 2015). Regardless of whether proboscis monkeys remain in disturbed areas or refuge in safer areas, they must adapt to new habitat conditions, which lead to inevitable changes in habitat and resource selection. Resource selection function (RSF) is a type of modeling that is often used to determine the distribution of wildlife and their probability value habitat usage with used-unused or presence-absence data (Manly et al. 2002). This model is generated from logistic regression analysis, which is valid for predicting actual resources used by wildlife (Johnson et al. 2006).

Understanding the habitat use of proboscis monkey, especially in disturbed habitats such as logging concessions, is necessary and important for long-term conservation planning because this monkey resides mostly outside of conservation areas (Wardatutthoyyibah et al. 2019). In particular, understanding the use of habitat resources at the site level by this endemic primate species on the island of Borneo needs to be solicited. Furthermore, understanding resource selection of proboscis monkey is important to ensure that the habitat of the proboscis monkey is preserved within conservation strategy. We aim to investigate (i) whether proboscis monkeys are present in logged-over areas (LOAs) in logging concessions; (ii) how the remaining population do resource selection in the existing habitat; and (iii) what are the environmental factors that influence resource selection at site level in the LOAs.

MATERIALS AND METHODS

Study area

We conducted our field study from August 2017 to July 2018 in the forest concession of a logging company, PT. Kandelia Alam (PT. KLIA). The logging concession is located in Batu Ampar District, Kubu Raya Regency, West Kalimantan, Indonesia (109º22‘7”-109º41’17” E and 0º40‘7”-0º32‘9” N) and covers a total area of 18,130 hectares (Figure 1). PT. KLIA has been managing the concession using a special forest use permit in the mangrove forest area. As the logging concession is close to the sea, this concession area is affected by tides and affects the dynamic of mangrove forest, secondary swamp forest and swamp shrub in the concession (based on land cover from 2018 LANDSAT data). Elevation range of this concession ranges between 0-31 meters above sea level. PT. KLIA concession is included in climate type A (very wet) based on the Schmidt and Ferguson classification and is included in the agroclimatic zone B1 according to Oldeman (1979) due to the area experiencing a wet period (>2,000mm) of seven-nine months, and a dry period (<100mm) of less than two months. The concession performs forest harvesting through a clear-cutting system, leaving at least 40 trees/ha comprising trees with diameters of >20 cm as part of their sustainability plan.

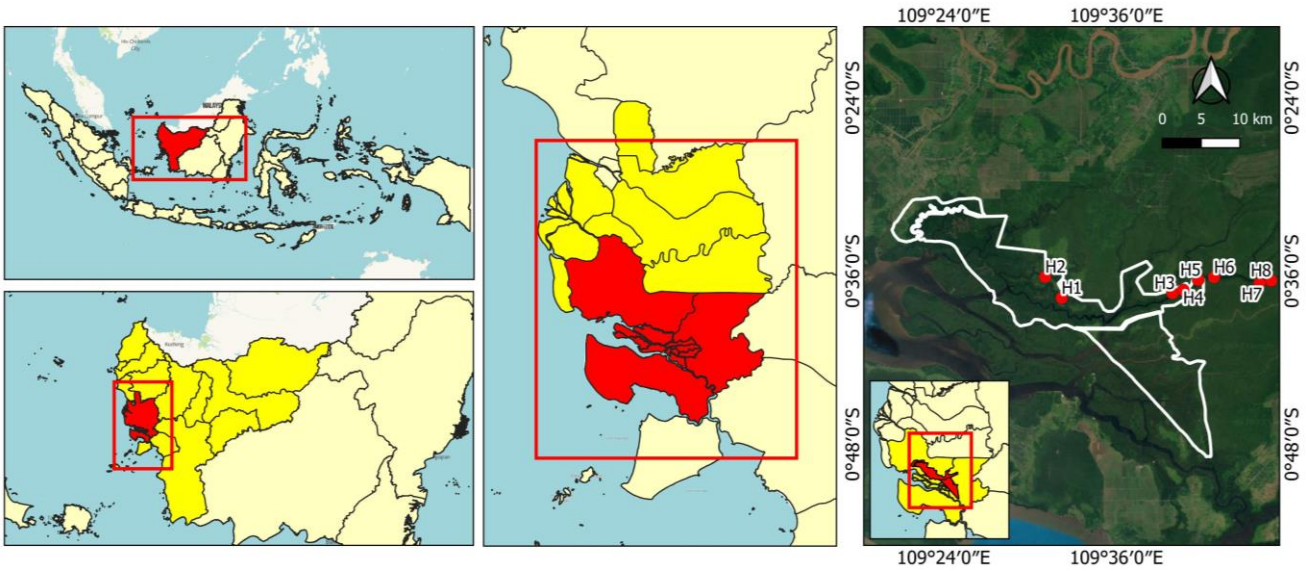

Figure 1. Study area in the PT. Kandelia Alam (PT. KLIA) concession and surrounding area in West Kalimantan, Indonesia. The distribution of the habitat of proboscis monkeys (H1-H8) is indicated with points (H1-H8), and the logged-over areas (LoA block 2009-2015) are represented with dashed areas

Data collection

Proboscis monkeys prefer to sleep on the riverbank, enter the forest to look for food in the morning and return to the trees located by the riverbank to rest in the afternoon (Feilen and Marshall 2014). Therefore, we conducted a riverine survey using boats during the afternoon (3.30-6.30 pm) to determine the presence and distribution of proboscis monkeys and we repeated observations at each location three times. We observed proboscis monkey occurrence over four days for each site to ensure the presence of proboscis monkeys. We stayed with floating camp about ca 1 km from each location of proboscis monkey habitat for four days. If we found an individual during a boat survey, we recorded the coordinates of the monkeys using a Garmin 78S GPS receiver. We also identified individual groups of proboscis monkeys based on unique physical features of the alpha male that have the largest nose and the sex ratio in each identified group. We returned to the proboscis monkey habitat in the morning when proboscis monkeys went to inland forest to collect vegetation data along with abiotic data, i.e., temperature, soil pH and elevation. We also measured distance from rivers, distance from disturbance, intensity of disturbance and river width. These vegetation and abiotic data were collected for each site. The disturbance distance was estimated using the closest location where proboscis monkey presence was recorded to the settlement and site camp of the company; this was done using ArcGis 10.1. We classified disturbance level based on the intensity of human activities, such as frequency of speedboat sightings or presence of fishermen during the study. The classifications were: (0) the proboscis monkeys habitat had never been passed by the community or there was never any human activity during the study; (i) there were human activities, such as transportation or the presence of ordinary people or fishermen with low intensity during the study; (ii) proboscis monkeys were regularly passed by the community or fishermen during the research.

The vegetation data and abiotic components were also collected in the LOA of PT. KLIA at blocks where logging took place three years (2015) to nine years (2009) prior to the research observation (2018), using sampling plots of 20x20 m (0.04 ha) (Table 1). The sampling plots were distributed systematically with 100m of the distance among plots. In total, 381 observational plots of vegetation were collected in our study area, of which 200 plots were in the logged area from 2009 to 2015, and 181 plots were spread over eight locations covering proboscis monkey habitat plots in unlogged forest (Table 2). The data collected for each plot included vegetation type, basal area of trees, basal area of poles, total tree height, total polishing height, branch-free height, pole-free height, number of trees and number of poles. We modified the category for poles by also classifying mangroves, which have diameters of 10-19 cm.

Data analysis

Data on the presence of proboscis monkey across the different sampling sites were summarized descriptively (Table 2). We compared data of the habitat conditions in all LOAs using t-tests for normally distributed data, or the Mann-Whitney U-test for non-normally distributed data. We estimated the Shannon Wiener index to assess vegetation species diversity. We used cluster analysis to find out the similarities in the characteristics of the habitat components of each logging block location and proboscis monkey habitat. Resource selection of the proboscis monkey was analyzed using logistic regression analysis to determine the habitat components that affect the probability of the presence of proboscis monkeys. The best logistic regression model was selected based on akaike's information criterion (AIC). The best equation model was determined based on the smallest AIC value. A step-wise selection method was applied in the logistic regression model procedure, implementing a backward elimination method. Non-significant variables ($p>0.05$) were removed from the logistic regression model. We employed the goodness of fit Hosmer and Lemeshow (Hosmer and Lemeshow 2000) to select the best model, whereas the differences between the model and the observational data were tested using chi-square tests. We conducted all statistical analyses using statistical data processing package R ver 4.0.3 (https://www.r-studio.com/) and we employed cluster analysis and principle component analysis (PCA) to determine the clusters among environmental variables and to explore important variables explaining the resource selection of the monkey.

Table 1. The number of sample plots in the Logged Over Area (LOA) of PT KLIA 2009-2015

Research location	Area (ha)	Sampling intensity (%)	Sample area (Ha)	Number of plots
LoA block 2009 (9yr)	227	0.12	0.2724	28
LoA block 2010 (8yr)	83	0.12	0.0996	10
LoA block 2011 (7yr)	338	0.12	0.4056	41
LoA block 2012 (6yr)	81	0.12	0.0972	10
LoA block 2013 (5yr)	330	0.12	0.396	42
LoA block 2014 (4yr)	249	0.12	0.2988	31
LoA block 2015 (3yr)	303	0.12	0.3636	38
Total	1611		1.9332	200

Note: -yr indicates duration between the year of logging to the research observation (2018)

Table 2. Number of individuals within proboscis monkey group and the groups' habitat location

Location	Number of proboscis monkeys (individual)					Total
	Adult males	Adult females	Subadults	Infant and juvenile	Unidentified	
Logged forest						
LoA block 2009 (9yr)	0	0	0	0	0	0
LoA block 2010 (8yr)	0	0	0	0	0	0
LoA block 2011 (7yr)	0	0	0	0	0	0
LoA block 2012 (6yr)	0	0	0	0	0	0
LoA block 2013 (5yr)	0	0	0	0	0	0
LoA block 2014 (4yr)	0	0	0	0	0	0
LoA block 2015 (3yr)	0	0	0	0	0	0
Unlogged forest						
H1 (Sepada kanan River)	1	0	14	0	0	15
H2 (Sepada kiri River)	1	4	10	0	0	15
H3 (Keluang River Estuary)	1	1	3	0	0	5
H4 (Keluang River)	1	5	3	0	0	9
H5 (Keluang River)	1	3	2	1	0	7
H6 (Keluang River)	1	4	0	0	0	5
	5	0	2	0	0	7
H7 (Tributary of the Keluang River)	1	3	5	3	7	19
	1	1	2	0	6	10
H8 (Tributary of the Keluang River)	1	0	0	1	5	7
Total	16	21	44	5	18	105

RESULTS AND DISCUSSION

Presence of proboscis monkeys at logged over areas

Our survey did not find the presence of proboscis monkeys in the LOAs at PT. KLIA is detailed in Table 1. We found the monkeys in the High Conservation Value (HCV) location of this concession, and we also found one group in a neighboring area of this concession, at PT. Ekosistem Khatulistiwa Lestari. The rest of the populations were found outside of the concession. In total, we detected ten groups of proboscis monkeys, consisting of 105 individuals spread over eight different locations. The distribution of these groups was clustered into three main rivers (Figure 1). Two groups were distributed in the Sepada Kanan River and Sepada Kiri River with a total of 30 individuals; four groups were found along the Keluang River with a total number of 33 individuals; and two groups were distributed in the tributary of the Keluang river with a total of 36 individuals. Each group of proboscis monkeys consisted of seven to 15 individuals (Table 2).

Vegetation composition in study area

The LOA of PT. KLIA is a mangrove forest and is dominated by discontinuous canopy cover (semi-open) and open areas (Figure 2). Therefore, species richness in that location is relatively low. The species found in LoAs were dominated by *Bruguiera gymnorrhiza* (L.) Lam., *Nypa fruticans* Wurmb, *Rhizophora mucronata* Lam and *Rhizophora apiculata* Blume. We found that proboscis monkeys use utilized various habitat types, i.e., mangrove forests, secondary swamp forests and swamp shrubs, during our observation (Figure 3). In total, there are 20 species of plants in these habitats and 14 of them are swamp plant species. The tree species were *Gluta renghas* L., *Oncosperma tigillarium* (Jack) Ridl., *Garcinia* sp, *Macaranga pruinosa* (Miq.) Müll.Arg., *Inocarpus fagifer* (Parkinson ex F.A.Zorn) Fosberg, *Heritiera littoralis* Dryand. ex Aiton, *Hibiscus* sp, *Melastoma candidum* D.Don, *Ficus* sp., *Syzygium* sp., *Tarenna fragrans* (Blume) Koord. & Valeton, *Palaquium rostratum* (Miq.) Burck, *Leea indica* (Burm.fil.) Merr., *Syzygium* sp. There were also six types of mangrove plants, namely *Xylocarpus moluccensis* (Lam.) M. Roem., *N. fruticans, B. gymnorrhiza, R. mucronata, R. apiculate, Sonneratia alba* Sm., *Calophyllum inophyllum* L. The Shannon Wiener index value in the sites across the study area were categorized as low and medium, with a value range of 0.49-1.73, while the biodiversity indices were higher in the proboscis monkey habitat than in the LOAs (Table 3).

Figure 2. Example of vegetation condition in the logged-over area (LOA) of block 2011 (7yr prior to research observation) within PT. KLIA

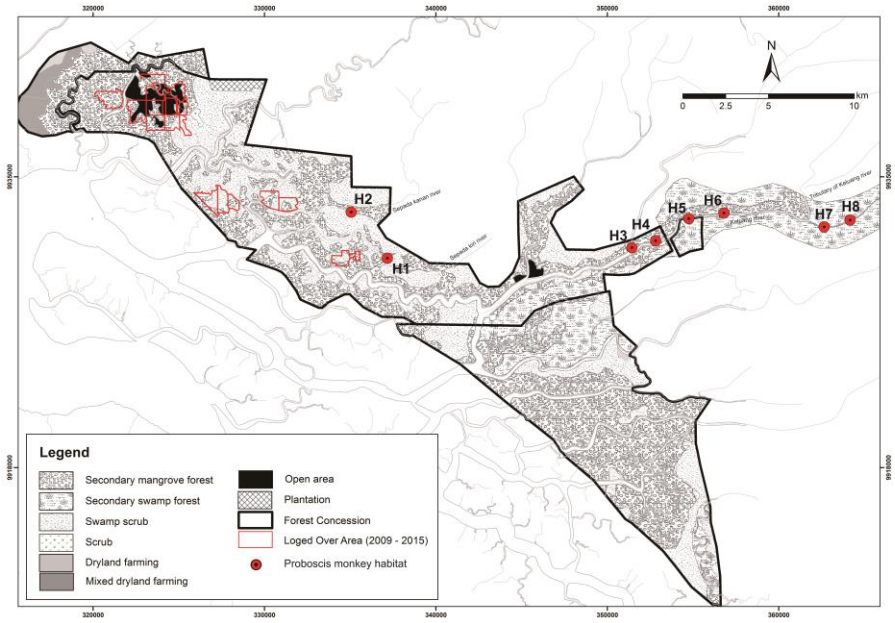

Figure 3. Concession area of PT. KLIA and PT. EKL based on 2018 land cover map generated from ArcGis 10.1

Table 3. Shannon Wiener Index on logging block of 2009-2015 and proboscis monkey habitat (H1-H8)

Location	Shannon Wiener index	Location	Shannon Wiener index
LoA block 2009	0.74	H1	1.73
LoA block 2010	0.53	H2	1.63
LoA block 2011	0.85	H3	0.87
LoA block 2012	0.92	H4	0.29
LoA block 2013	0.89	H5	1.56
LoA block 2014	0.75	H6	1.69
LoA block 2015	0.40	H7	0.85
		H8	0.77

Environmental variables of proboscis monkey's habitat

Eleven biotic and abiotic variables were collected from the logged and from the monkeys' habitat. There were eight variables that had a significant effect on the presence of proboscis monkeys in the study area: basal area of trees ($p<0.01$); basal area of poles ($p<0.01$); total tree height ($p<0.01$); total pole height ($p<0.01$); number of trees ($p<0.01$); number of poles ($p<0.01$); temperature ($p<0.01$); and altitude ($p<0.01$) (Table 4), showing significant differences between logged areas and proboscis monkey habitats. Logged areas tend to have low basal areas because they are dominated by trees with smaller diameters compared to the trees within areas of proboscis monkey habitat. However, the mean height of trees and poles at the LOAs are higher than in proboscis monkey habitat (Figure 4). Some plots even have trees with a height of over 25m which is part of the silvicultural system of the company. These tall trees are parent trees, trees that were left by the company after harvesting. Despite LOAs harbouring fewer number of trees, they have more poles. Whereas, with minimum disturbance, the habitats of proboscis monkeys have more trees, ranging from 125-300 trees per hectare. The temperature variation at the site ranges from 25 to 32°C. As indicated in Figure 4, the temperature in proboscis monkey habitat is lower than in LOAs. The study area is located at an altitude of 0-27 meters above sea level, with the habitats of proboscis monkeys existing at lower elevations than LOAs.

Table 4. Comparison of site conditions between proboscis monkey habitat and logged over areas (LOAs) in the study area

Variable	Habitat			Logged area			p-value
	Mean	Min	Max	Mean	Min	Max	
Basal area of tree (m²/ha)	13.25±7.40	0.75	31.5	11.75±4.94	5.75	35	<0.01*
Basal area of pole (m²/ha)	3.49±4.738	1	35.37	10.43±6.65	1	50.66	<0.01*
Height of tree (m)	12.19±2.75	5	20.8	13.59±6.22	12.3	25.5	<0.01*
Height of pole (m)	6.19±4.72	7	15	13.13±3.11	9	25	<0.01*
Branch free height of tree (m)	3.95±1.60	1.33	8.33	3.79±2.22	1.5	15.5	n.s
Branch free height of pole (m)	1.97±2.00	1	8	3.31±1.46	0.33	8.5	<0.05*
Number of tree (N/ha)	208±110.86	25	450	105±77.97	25	375	<0.01*
Number of pole (N/ha)	170±218.62	100	1500	605±333.02	100	1700	<0.01*
Temperature (ºC)	27.89±1.22	25	32	29.67±1.02	27	32	<0.01*
Soil pH	6.11±0.93	5	8.1	5.89±0.85	4	8.5	<0.05*
Altitude (masl)	5.89±4.22	0	21	13.84±5.39	0	27	<0.01*

Note: n.s: not significant; *: significantly different on p=0.05; **: significantly different on p=0.01

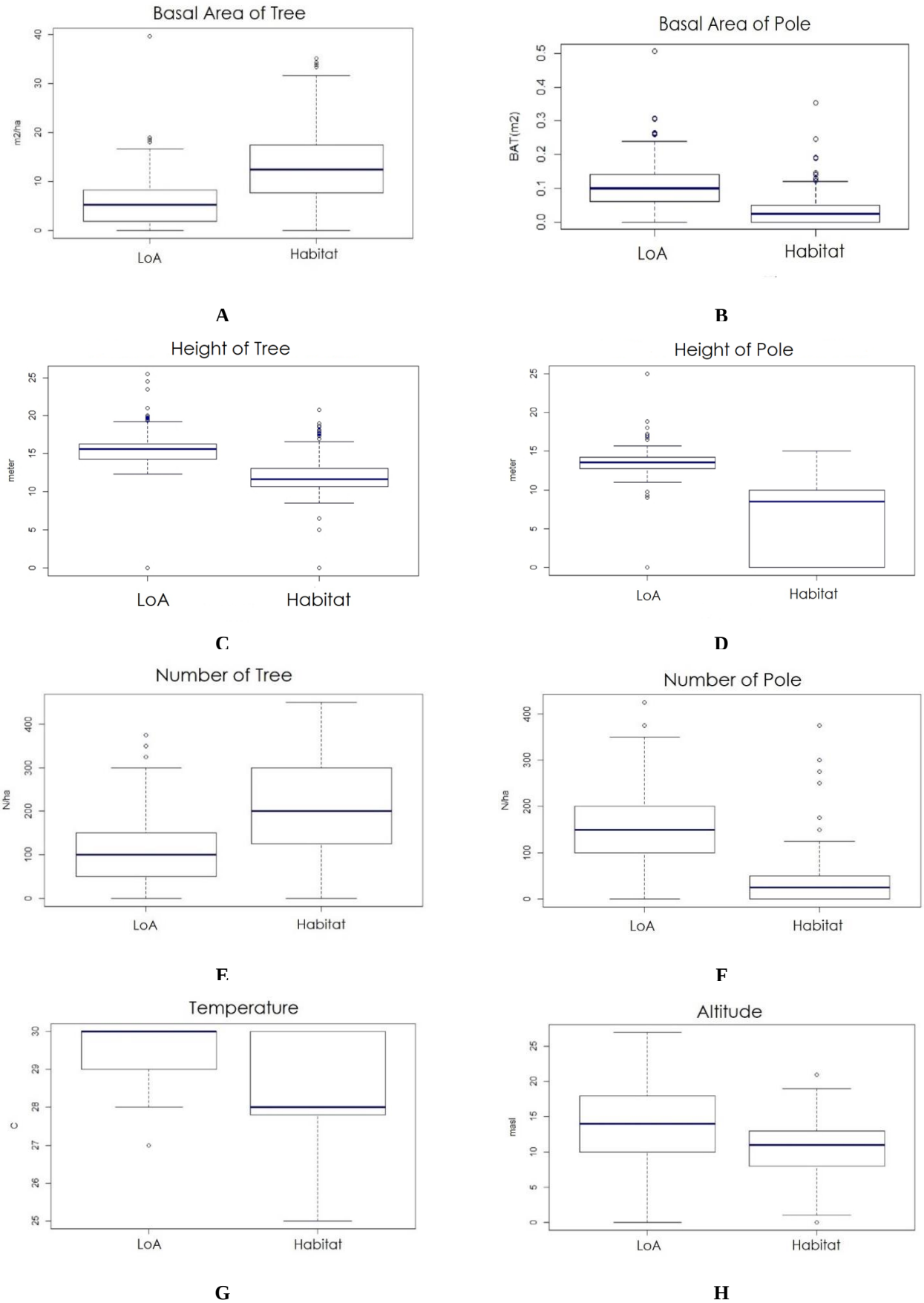

Figure 4. Boxplot of various variable comparisons between logged over areas (LOAs) and proboscis monkey habitat in the study area. A. Basal area of trees per hectare. B. Basal area of poles per hectare. C. Total tree height. D. Total pole height. E. Number of trees per hectare. F. Number of poles per hectare. G. Temperature. H. Altitude. Boxplot were generated from ggplot package on R-studio

Vegetation structures in the LOAs at PT. KLIA were significantly different from the habitat of proboscis monkey. In the LOA, the average basal area of trees was 11.75 m^2/ha with an average tree height of 13.59 m and an average number of 105 trees per hectare, while the average basal area of poles was 10.43 m^2/ha with an average height of 13.13 m and a total of 605 poles per hectare. The condition of the vegetation structure greatly influences the temperature of the surrounding environment, where the average temperature in the LOAs was around 29.67°C and in the monkey's habitat, around 27.89°C (Figure 4).

Environmental variables clustering

Optimizing cluster values using the gap statistic method showed that the optimal number of clusters was two clusters. The first cluster consists of eight LOA locations (3yr, 4yr, 5yr, 6yr, 7yr, 8yr, 9yr) and six proboscis monkey habitats (H1, H2, H3, H4, H5, H6). All these locations have been included in one cluster because they bear the closest resemblance. Meanwhile, the other cluster consists of two proboscis monkey habitats located in the tributary of the Keluang river and these bear the least resemblance to other locations (H7 and H8). Comparison of the mean values of the two clusters has shown that there are significant differences in all variables, such as basal area of tree, basal area of pole, total tree height, total pole height, branch free height of tree, branch free height of pole, number of trees, number of poles, temperature, soil pH, salinity, altitude, distance from disturbance, distance from river, river width, type of land cover and intensity of disturbance (Table 5).

Based on the presence of proboscis monkeys at the study site, it was found that the habitat of the proboscis monkey in the Sepada Kanan River (H1) and the habitat in the Sepada Kiri River (H2) bear the closest resemblance to the logged area (Figure 5). This was probably due to the location of the habitat being closest to other cutting blocks and having the same type of land cover, consisting of secondary mangrove forest and swamp shrub. Furthermore, the second cluster already has the most similar characteristics to the proboscis monkey habitat along the Keluang River, namely H3, H4, H5, and H6. This second cluster location was secondary mangrove forest and secondary swamp forest. The last cluster that has the most different characteristics from other sites were the H7 and H8 habitats. These two habitats were located in the upper reaches of the river, precisely at the tributary of the Keluang river and farthest from human activities. In addition, the width of the river at this location was the smallest river width recorded when compared to other sites. Almost the entire area of this location was secondary swamp forest type. Salinity at this location was also lower and significant difference than other locations ($p<0.01$)

Based on the PCA analysis, there were five components with eigenvalues of >1.0 of the variable correlation matrixes and the eigen value of actual data was greater than the eigen value of simulated data (Table 6). These five factors explained 73% of the total variation in the data. The main factor 1 (TC1) represented about 19% of the data diversity, with the main characterizing variable in the form of vegetation structure at the pole level, i.e., the basal area of pole, the number of poles, total pole height and branch free height of pole. Those four variables were positively correlated because as the height of a pole increases, it will be followed by an increase in its basal area and branch free height. The second main component (TC2) consisted of disturbance intensity and river width. These variables described the positive correlation between river width and disturbance intensity. Disturbance intensity is higher in main river than tributary due to human activity, such as speedboat and fisherman presence. The third main component (TC3) consisted of the basal area of tree, number of trees, pH and distance from disturbance. The fourth principal component (TC4) comprised salinity, altitude and distance from the river with a positive correlation. The fifth main component (TC5) represented tree variables; total tree height and branch free height of tree.

Table 5. Mean environmental variables for each cluster. The difference in the average value of the variables has been tested using the t-test

Variables	Cluster 1 average	Cluster 2 average
Basal area of tree (m^2/plot) **	0.333	0.693
Basal area of pole (m^2) **	0.069	0.027
Total height of tree (m)**	13.387	11.412
Total height of pole (m)**	9.939	5.755
Branch free height of tree (m)*	4.122	3.249
Branch free height of pole (m)*	3.950	3.551
Number of tree/plots**	5.561	10.864
Number of pole/plots**	3.823	1.254
Temperature (°C) **	29.343	27.732
Soil pH**	6.101	6.963
Salinity (%) **	1.044	0.565
Altitude (m asl)**	12.051	10.521
Distance from disturbance (m)**	6535.806	22064.750
Distance from river (m)**	519.541	280.925
River width (m)**	98.215	31.500
Disturbance intensity**	1.692	0.000

Note: *: Significantly different on P=0.05; **: Significantly different on P=0.01

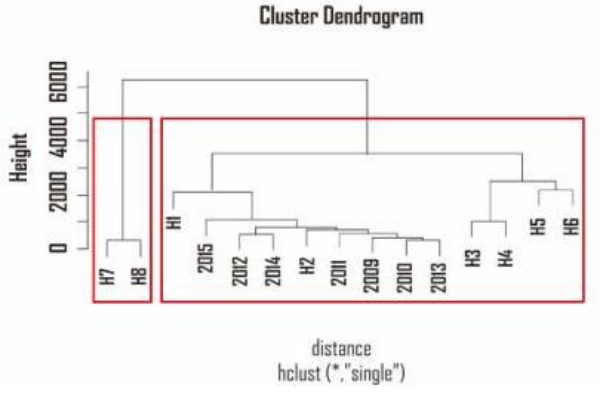

Figure 5. Dendrograms of biotic and abiotic components in the logged area and location of proboscis monkey habitat. H1-H8 are code for habitat of proboscis monkey and 2009-2015 are code for LOAs. Graph generated from PCA analysis at R-studio

Table 6. Summary of the five main components derived from PCA analysis that have demonstrated the factor loading of proboscis monkey habitat and logged-over area (LOA)

Principal component	Eigen value actual data	Eigen value simulated data	Variable	Loading factor	Percent variants explained	Comulative percent
TC1	6.71814008	1.3903165	Basal Area of pole	0.94	19	19
			Total height of pole	0.73		
			Branch free height of pole	0.6		
			Number of poles	0.9		
TC2	2.06572758	1.3270929	River width	0.76	15	34
			Disturbance intensity	0.9		
TC3	1.58531835	1.2695567	Basal Area of of tree	0.84	15	49
			Number of trees	0.88		
			Soil pH	0.53		
			Distance from disturbance	0.55		
TC4	1.33799672	1.2141726	Salinity	0.51	14	63
			Altitude	0.69		
			Distance from the river	0.84		
TC5	1.31854885	1.1630209	Total height of tree	0.77	10	73
			Branch free height of tree	0.9		

Resource selection

Logistic regression analysis has resulted in a predictor model deviation of 69,327 with a df of 370, while the deviation value for the null model was 527,230 with 380 df. The difference in deviation was 457,903 with a df of 370. Of the 14 variables tested, there were ten variables that had a significant effect on the probability of the presence of proboscis monkeys in the study area. The ten variables include: basal area of trees; basal area of poles; total height of trees; total height of poles; number of trees; number of poles; temperature; soil pH; distance from the river; and river width. The elimination process has been carried out in five stages to get the lowest AIC value. The variables that were eliminated gradually were the land cover variables; tree branch free height, tree height and free height of pole branches (Table 7). The smallest AIC value generated from the five iteration stages was AIC=91,327. Therefore, the best model results left ten microhabitat variables that affected the presence of proboscis monkeys in the study area (Table 8). The results of the Hosmer and Lemeshow goodness of fit test on the best model produced a p-value (0.99)>0.05. This result illustrates that the logistic regression model built is a good fit and there is no difference between the observed results and the possible prediction results. The value of the coefficient of determination of the best model in the analysis results can be seen in McFadden's pseudo-R-square value of 86.85. This value has shown that the independent variable is able to predict the probability of the presence of proboscis monkeys by 86.85% and about 13.15% is explained by other variables outside of the model. The logistic regression model to predict the presence of proboscis monkeys at the study site is as bellow:

Where π is the probability of proboscis monkey presence, basal area of trees (X1), basal area of poles (X2), total height of trees (X3), total height of poles (X4), number of trees (X5), number of poles (X6), temperature (X7), soil pH (X8), distance from the river (X9), and river width (X10).

$$\pi = \frac{\exp(75.704 - 8.7666X1 + 23.523X2 - 0.349X3 - 0.203X4 + 0.974X5 - 0.780X6 - 2.459X7 + 1.336X8 - 0.010X9 - 0.034X10)}{1 + \exp(75.704 - 8.7666X1 + 23.523X2 - 0.349X3 - 0.203X4 + 0.974X5 - 0.780X6 - 2.459X7 + 1.336X8 - 0.010X9 - 0.034X10)}$$

Table 7. Beta coefficient estimate, standard error, and P value of 14 predictor variables

Variable	β	Std. error	z value	Pr(>|z|)	Sig
(Intercept)	79.3	21.5	3.69	0.00022	***
Basal area of trees	-8.54	3.53	-2.421	0.0155	
Basal area of poles	22.7	10.4	2.176	0.02959	*
Total height of trees	-0.495	0.152	-3.25	0.00116	**
Total height of poles	-0.139	0.117	-1.192	0.2334	
Branch free height of tree	-0.175	0.195	-0.898	0.36915	
Branch free height of poles	0.426	0.279	1.529	0.12631	
Number of trees	0.929	0.336	2.765	0.00568	**
Number of poles	-0.785	0.284	-2.764	0.00572	**
Temperature	-2.53	0.711	-3.555	0.000378	***
Soil pH	1.2	0.491	2.446	0.01444	*
Altitude	-0.0997	0.0924	-1.078	0.28083	
Distance from the river	-0.00934	0.00232	-4.031	0.0000556	***
Land cover	13.5	1870	0.007	0.99423	
River width	-0.0309	0.00972	-3.178	0.00148	**

Table 8. Resource selection function coefficient estimation of the best model for prediction of proboscis monkey presence

	β	Std. error	Z value	Pr(>|z|)	Sig
Intercept	75.704112	19.682261	3.846	0.000120	***
Basal area of tree	-8.766660	3.232886	-2.712	0.006694	**
Basal area of pole	23.527667	9.935337	2.368	0.017881	*
Height of tree	-0.348787	0.101995	-3.420	0.000627	***
Height of pole	-0.202832	0.096764	-2.096	0.036070	*
Number of trees	0.973966	0.308285	3.159	0.001581	**
Number of poles	-0.780354	0.267381	-2.919	0.003517	**
Temperature	-2.459304	0.658358	-3.736	0.000187	***
Soil PH	1.336129	0.455470	2.934	0.003351	**
Distance to the river	-0.010131	0.002285	-4.435	0.00000923	***
River witdh	-0.034404	0.009209	-3.736	0.000187	***

Discussion

Our current study found that there was no evidence of proboscis monkey presence in the LOAs during the study period. Proboscis monkeys were found in the HCV areas of PT. KLIA which are distributed over the upper Sepada Kanan river, Sepada Kiri river and Keluang river. In addition, one group of proboscis monkeys was also found in an ecosystem restoration concession area (PT. Ekosistem Khatulistiwa Lestari) adjacent to PT. KLIA. Three other habitats were found outside the concession around PT. KLIA. Generally, the habitat of proboscis monkeys was found to be in locations which was far from human activities.

The significance test has shown that there are differences between the biotic and abiotic components at the two locations. Proboscis monkey habitat harbours larger tree basal area, smaller pole basal area and a greater number of trees. In addition to the biotic components, the abiotic components that were significantly different were temperature and altitude, with proboscis monkeys' habitat seeing lower temperatures due to it existing at lower altitudes than the LOAs.

The results of the resource selection analysis have shown that the proboscis monkeys in the study area have selected the existing resources. Proboscis monkey habitat selection was most influenced by the pole basal area (DBH >10cm). Pole basal area can be said to be a major factor in the presence of proboscis monkeys. Presence probability of proboscis monkeys will increase if the basal area of the pole is higher. The increase in basal area of the pole is closely related to food availability. Plants at the pole level with a diameter of below 20 cm are a good source of proboscis monkey food, which is in accordance with previous research that states that the availability of food is one of the determinants in the selection of primate habitat, such as proboscis monkey (Matsuda et al. 2011; Supartono et al. 2016; Atmoko et al. 2021). In addition, the size of the proboscis monkeys' home range and activity budget have been influenced by the availability of resources, particularly fruit availability (Matsuda et al. 2014).

Furthermore, another factor that has influenced the presence of proboscis monkeys is the tree basal area. Tree basal area is negatively correlated with the probability of the presence of proboscis monkeys. Basal area has been related to the number and diameter of trees. Locations that have a smaller tree basal area have been shown to have reduced numbers of trees, but trees have relatively large diameters. Besides proboscis monkeys, some primates are also reported to have habitat preferences in locations with smaller tree basal areas (Sodik et al. 2020). Proboscis monkeys themselves have been known to rely heavily on large trees as sleeping sites. Proboscis monkeys in the Tolak River reportedly prefer the largest and most isolated trees from other trees as sleeping trees. Trees with these characteristics have provided a sense of security against both predators and insect disturbances, such as mosquitoes and sandflies. Such characteristics also make it easier for proboscis monkeys to communicate any threats of predators (Feilen and Marshall 2014, 2017; Thiry and Stark 2016; Bernard et al. 2021).

Proboscis monkeys are arboreal animals that depend on canopy connectivity. Proboscis monkeys have been reported to prefer sleeping trees that have canopy connectivity that facilitate efficient movement within the canopy. Moreover, continuous canopy can be easier for the monkey to access food (Bernard et al. 2011). Logged mangrove areas that apply selective logging produce open areas with little canopy cover, resulting in discontinuous canopy cover. In addition to open conditions increasing the threat of predation, open canopy from selective logging is closely correlated with an increase in air temperature (Oldén et al. 2019). Air temperature appears to have an influence on sleeping trees selection of proboscis monkey. It is because proboscis monkey sleep at riverside than inland habitat at night (Matsuda et al. 2011).) The results of the study have shown that proboscis monkeys prefer habitats with low temperatures. Proboscis monkeys are reported to travel into the forest to escape the hot weather during the day to eat and rest (Matsuda et al. 2009). This is related to its efforts to maintain a balance in body temperature (Savagian and Fernandez-Duque 2017)

Neutral to high soil pH is good for the destruction of organic matter and provides nutrients such as N, P, K, Mg, and Ca that plants need (Cooray et al. 2021). Soil pH showed a positive correlation with proboscis monkey presence. Although there are no studies that directly explain the relationship between soil pH and the presence of proboscis monkeys, we suspect that this is related to the

structure and composition of the plant species that grow in areas of higher soil quality. Proboscis monkeys like locations with high soil pH. Increased soil pH indicates increased retention of soil-based cations, such as Ca^{2+} and Mg^{2+} (Neina 2019). More over, soil pH can directly affect the types of species that can grow. For example, Wakushima et al. (1994) showed that *S. alba* grows in soil with high salinity and high pH and *B. gymnorrhiza* in soil exhibiting varying pH levels. *S. alba* has been reported to be a high preference plant for proboscis monkey food resource selection (Atmoko et al. 2022). However, additional research in the future is required to understand the specific correlation of pH on resource selection of the proboscis monkey.

The results of the study have shown that there is an effect of distance from the river and width of the river on the presence of proboscis monkeys, with both showing negative correlations. There have been many studies that have explained that proboscis monkeys are animals that are very dependent on the river. Proboscis monkeys are said to choose trees that are on the banks of the river as an anti-predator strategy (Feilen and Marshall 2017). Similarly, narrow river widths are also preferred to bolster probosic monkeys' security against predators. Proboscis monkeys are reported to often cross in locations with narrower river widths because they can cross by jumping between branches on the other side of the river (Otani et al. 2020). Apart from being an anti-predator strategy, river width is closely related to the level of human disturbance. At the study site, the location is on a wide main river, often adjacent to community settlements in the downstream area. Proboscis monkey habitat was, however, distributed in the middle to the upper reaches of the river, with the upper reaches of the river almost never being traversed by humans. This is in accordance with the findings of Mediawati et al. (2021) that the distribution of proboscis monkeys tends to be upstream because it avoids human activities on the Manggar River.

In conclusion, this study has found that proboscis monkeys were absent in the LOA, confirming that this primate tends to avoid human disturbance, despite some LOAs being relatively old (up to nine years). We found the habitats of proboscis monkeys exclusively outside of LOAs, and within logging concession areas, which can only be found in the HCV. This highlighted the need to protect HCV forest, and shows that this habitat type exhibits significant importance in supporting the conservation of this endemic species of monkey. When selecting suitable habitat locations, proboscis monkeys select for certain attributes of the sites, including: basal area of trees of over 20 cm; poles with a diameter of 10-19 cm, as part of the components of providing food, rest and shelter; height of trees and poles; number of trees and poles; temperature; soil pH; distance from river; and river width. This shows the degree of complexity required when finding suitable habitat, complexity only provided by HCV forest. Further research is needed in the future regarding the habitat preferences of proboscis monkeys at the study site, given the current high threat to their habitat (Wardatuthoyyibah et al. 2019). Further behavioural studies across different groups of proboscis monkeys using long-term monitoring schemes and using a semi-experimental approach to test canopy bridges will provide a deeper understanding of the ability of proboscis monkeys to move between fragmented blocks, such as what has been found with other species primates (Birot et al. 2019), and enable conservationists to provide tailored management recommendations.

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