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Characteristic of Orangutan Habitat in Coal Mining Rehabilition Area in East Kalimantan, Indonesia

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Abstract

The majority of wild orangutans are found outside of the protected areas, including in coal mining areas which generally overlapping with orangutan habitat. Thereby, mining ensured a direct impact on orangutans. Opportunities orangutans to survive in the mining area depends on various factors, one of them is the ability of orangutan to adapt to habitat change. We investigated habitat characteristics in the coal mining area consist of land cover types, species composition, and the structure of vegetation. Data were collected from April to September 2014 in the coal mining rehabilitation area (CMRA) of PT KPC in East Kutai. Mining caused the natural habitat fragmented into smaller patches in the form of CMRA and natural forests remaining. The forest stand in CMRA compiled by the small trees of the same species and age class. It caused the canopy is not always continue. Food trees and nest trees were limited in CMRA. Exotic species dominated in CMRA, namely: Senna siamea, Falcataria moluccana, and Senna surattensis. CMRA is not the good habitat for orangutan if seen from the aspect of either structure or vegetation composition. The quality of habitat can be improved by modifying the structure and vegetation composition, build the ecosystem corridors, increase public awareness, and involve various stakeholders at the landscape level.

Keywords: Pongo pygmaeus morio, forest structure, food tree, nest tree, conservation

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Introduction

Bornean orangutan faces a high risk of extinction in the wild due to ±78% of the wild population found outside of protected areas, namely: 29% in logging concessions, 19% in oil palm plantation concession, 6% in industrial timber plantation concessions, and 24% outside concessions (Wich *et al.* 2012). The main threats to the orangutan survival are habitat loss, habitat degradation, forest fires, habitat fragmentation, illegal hunting, lack of awareness, and climate change (Meijaard *et al.* 2001; Ancrenaz *et al.* 2016). Based on spatial models, Struebig *et al.* (2015) predicted many of orangutan habitat is no longer suitable in the future because of climate change. The number of bornean orangutan population is not precisely known. Wich *et al.* (2012) estimated the number of bornean orangutan populations are 104,700 in an area of ±155,000 km², the populations predicted are continuously declining to 47,000 orangutans in 2025. If there are no right conservation efforts, within the next 50 years many populations will be decreased or become extinct (Abram *et al.* 2015). The combined impacts of habitat loss, habitat degradation, and illegal hunting have caused the bornean orangutan populations declined sharply so that the bornean orangutan has been upgraded from "endangered" category becomes "critically endangered" on the Red List of Threatened Species IUCN (Ancrenaz *et al.* 2016).

Expansion of the area for economic development in many sectors can not be prevented because the human population continues to increase. It poses a major threat to orangutans and another species, either through the direct cause such as hunting and killing as well as the indirect causes such as degradation and fragmentation of habitats (Meijaard *et al.* 2001; Hockings & Humle 2010; Soehartono *et al.* 2009). The coal mining areas in East Kalimantan developed rapidly after the weakening of the era of forests exploitation and the timber industries. Since that time, the mines sector has been a major driver of economic development in East Kalimantan. East Kutai Regency has the largest coal reserves (52.67%), followed by Kutai Kertanegara (21.01%), and smaller reserves distributed in other regencies/cities. Interpretation of Landsat imagery in 2014 showed that the land has been used for mining only 0.7% of 22,410.51 ha of the total area of

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East Kutai or ±20% of the total area of the mining concession permits. Although the mining areas are relatively smaller than oil palm plantations which reached 296,119.33 ha (±9.28%), the impact of open pit mining on biodiversity could result in tremendous damage.

Coal mining concessions in East Kalimantan are generally overlapping with orangutan habitat. Thereby, operations and infrastructure development ensured a direct impact on orangutans. Opportunities orangutans to survive in the coal mining area depends on various factors, one of them is the ability of orangutan to adapt, especially to changes in food resources. According to Campbell *et al.* (2008), foraging behavior and mating behavior can affect the fitness of animals directly, whose success is strongly influenced by moving behavior. In the habitats has changed, behavioral flexibility is very important for animals because it can improve the fitness of the animals that lived in the area (Reader & MacDonald 2003; Sol 2003). Psychological research showed that orangutans have the mental qualities to adapt to habitat changes, since orangutans are able to learn, make conclusions, set up and dismantle the equipment, have long-term memory, and it can understand the environment signs (Meijaard *et al.* 2001). In a certain degree, bornean orangutan (*Pongo pygmaeus*) has an ability to survive in the degraded habitat. For example, changes diet from fruit to an alternative food (*fallback food*) such as bark (Ancrenaz *et al.* 2007) and increases the terrestrial activity in a habitat which impaired canopy of anthropogenic (Ancrenaz *et al.* 2004). KPC (2011) and Rayadin and Spehar (2015) have confirmed the existence of orangutan population in the coal mining area, especially in any coal mining rehabilitation areas in East Kutai. During our research, we have documented 39 different individuals in the nine rehabilitation areas. They consist of 17.95% adult males, 38.45% adult females, 10.26% adolescents, and 23.08% infants). It's confirmed that bornean orangutan has an ability to adapt in those areas.

The aim of this research is to describe the characteristics of bornean orangutan (*Pongo pygmaeus morio*) habitat in the coal mining rehabilitation areas about changes in land cover, floristic composition, forest structure, food plants, and nest trees.

Methods

Study site The research was conducted in Coal Mining Rehabilition Area of PT Kaltim Prima Coal, which is well known as CMRA, East Kutai Regency, East Kalimantan Province, Indonesia. Data were collected from April to September 2014 which focused on Taman Payau CMRA (0° 36' 58"N, 117° 30' 58"E) and Gajah Hitam CMRA (0° 33' 26"N, 117° 30' 32"E). The both CMRAs are the land reclamation of coal mines which planted more than 10 years (Figure 1).

Data collection Variables which are used to describe habitat characteristics of orangutan habitat in CMRA consist of land cover types, species composition of trees with diameter at breast height (dbh) ≥ 5 cm (excluding shrubs), the vertical and horizontal structure of forest stand, orangutan food tree, and orangutan nest tree.

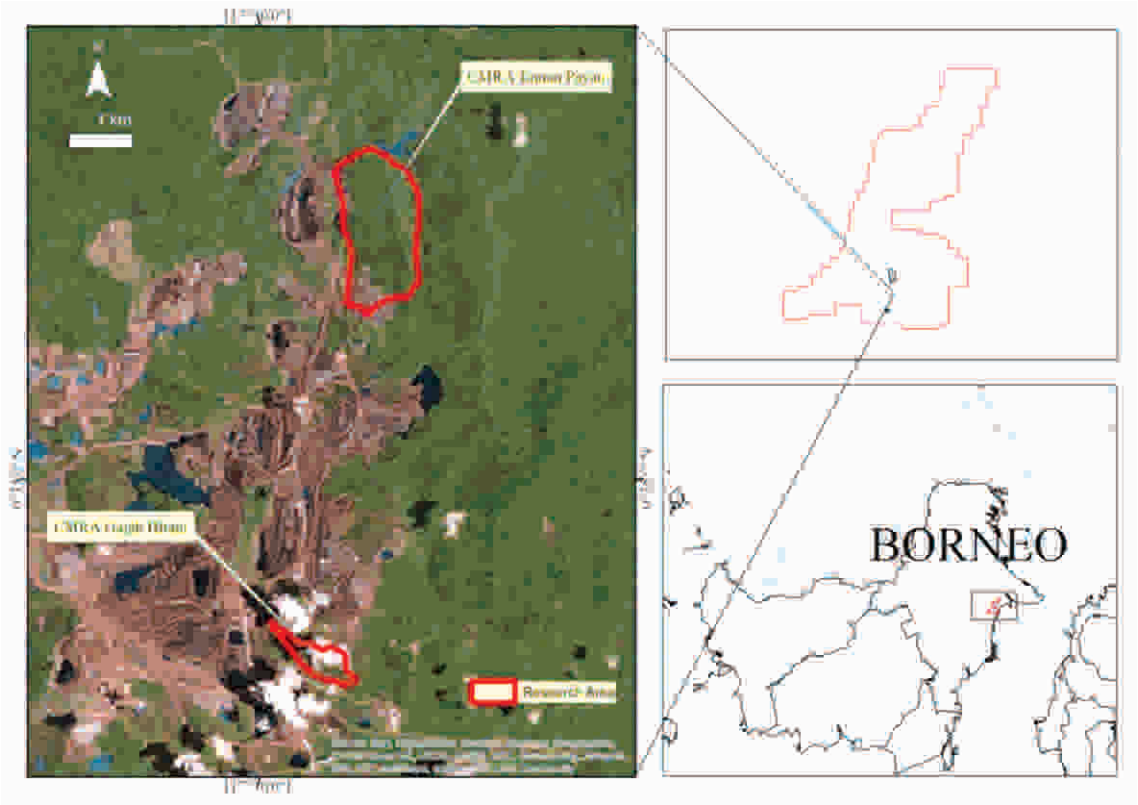

Figure 1 Location of coal mining study area.

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The data of land cover types was obtained through remote sensing, the method used was a visual classification to four Landsat imagery 8 path/row 116/59 acquisitions February 7th and March 11th, 2014 and path/row 116/60 acquisitions February 7 and July 1st, 2014. Four imageries were used to eliminate the appearance of clouds and cloud shadows on each imagery.

The trees composition data collection used a botanical sample plot of 0.2 ha (100 m x 20 m) in each CMRA. Sample plots were developed purposively. Each plot was subdivided into 20 m x 20 m quadrat for easy sampling of trees (dbh ≥ 5 cm). Thus, we used the total botanical plot of 0.4 ha and quadrats of trees were 10 quadrats. The total area of 0.4 ha sample plots have been considered to represent the condition of the forest stand was relatively homogeneous. We have recorded the species, number, and dbh of all trees (dbh ≥ 5 cm) for each quadrat. We also recorded species of plants lifestyles/habitus other than trees found in the study area. An expert helped for identified species. If possible, we identified each plant to species level or to genera level when the species could not be identified. Most of the trees in CMRA is not difficult to identify the species because these trees were cultivated and their species were known clearly.

The structure data collection used the same botanical plot. We were determined the number, total height (h), diameter at breast height (dbh), height of clear bole (hcb), the height of maximum crown width (hmcw), and the crown width of all tree species in each quadrat (Harja & Vincent 2008). We measured dbh using a phi band. We measured h, hcb, mcw, and crown width using a laser distance meter and a tape measure. Crown diameter was measured in two perpendicular directions. Crown projection diameter was first measured along maximum crown width axis and then perpendicularly to this first direction. The average was used for crown width. The radius projection of crown measured with eight radiuses to get a more accurate prediction of crown width. Tree parameters to be measured can be seen in Figure 2.

The data of food tree for orangutan was obtained based on the direct observation, the worker interview, and observed the after-eating signs of orangutan. Data of nest tree obtained based on direct observation by looking at the existence of nests on trees.

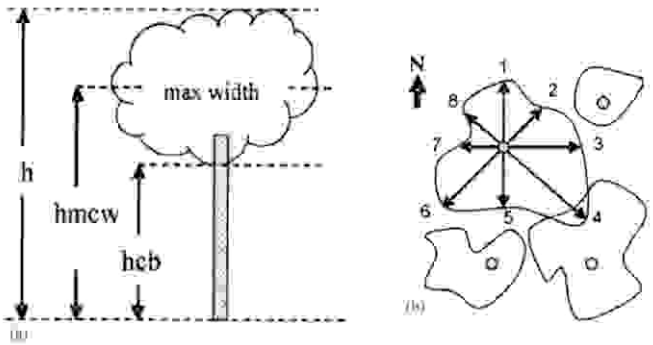

Figure 2 (a) Height measurement and (b) crown radius measurement (Harja & Vincent 2008).

Data analysis We used spatial analysis with the geographic information system to determine the characteristics of the land cover in the study area. Visual classification is used to classify the homogeneous appearance, and then we interpret based on the elements that are recorded on an imagery (color, hue, texture patterns, shapes, sizes, as well as their association with the other land cover). Vegetation analysis is used to determine the composition of vegetation, abundance and distribution of the nest trees, food trees, and other food sources.

Vegetation species diversity and its distribution are the useful variables to assess habitat quality. A good orangutan habitat is usually in the forms of small forest slot mosaic with its different species of woody plants, it also has species fruit trees. Vegetation analysis is used to gain species composition, the tree density (D), frequency (F), basal area (BA), and important value index (IVI). The D of a species is a count of the number of individuals of a species within the botanical plot. Afterwards, the sum of D is calculated in terms of species density per hectare. The F is the probability or chance of finding a species in a given sample area. The BA per tree was formulated with $0.25\pi d^2$ in which d is the dbh and π is the constanta (3.1416). The BA (m^2ha^{-1}), was calculated by summing the BA of all trees found within the botanical plot.

The IVI is the pattern of calculation used to determine the dominant vegetation ecologically for each level of growth in every observation plot. It is the result of summation of relative density (RD, %), relative frequency (RF, %), and relative basal area (RBA, %) (Curtis 1959). The RD = D of a species/total D of all species × 100. The RF = F of a species/sum of F of all species × 100, The RBA = BA of a species/total BA of all species x 100.

The architecture profile analysis is used to obtain the description of vertical and horizontal structure of forest. The structure of forest stand was described in the form of architecture profile by projecting the result of tree measurement, *i.e.,* the total height, clear bole, the canopy diameter, and the position of a tree in the botany plot. The parameters derived from measurement were processed by using the software SexI-FS (Spatially Explicit Individual-Based Forest Simulator), 2.1.0 version to describe the vertical and horizontal structure of forest stand (Harja & Vincent 2008). We divided the height of the canopy into 5 of high-class, namely: 5 m, 5−10 m, 10−15 m, 15−20 m, and >20 m. We also drew the canopy into five layers: A (> 30 m), B (20−30 m), C (4−20 m), D (1−4 m), and E (0−1 m) (Soerianegara & Indrawan 1998).

Results and Discussion

Overall study sites Coal mining area adjacent to the Prevab Orangutan Research Station of the Kutai National Park. Both locations are separated by the Sangatta River as the northern boundary of the Kutai National Park (KNP).

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Taman Payau CMRA is reclamation planted in 1998 with an area of 162.74 ha, while Gajah Hitam CMRA planted in 2002 and it has an area of 22.97 ha. Based on Schmidt-Ferguson climate classification, study areas including type A is very wet. Annual rainfall was in the range of 1,549.5−2,993.4 mm with mean annual was 2,558 mm. The mean annual temperature was 26 ºC between 21 ºC and 34 ºC, The normal wind speed was 2−4 knot hour^{-1} (Ferisa 2014; KPC 2015).

During 2014, Gajah Hitam CMRA suffered nine wet months and three moist months, the average rainfall per rain day was 13.42 mm. Mean monthly rainfall in Gajah Hitam CMRA was 188.2 mm, ranging from 73.0 mm (six rain days) in October until 376.5 mm (19 rain days) in December. Taman Payau CMRA has 10 wet months, one moist months, and one dry months in 2014, maximum rainfall in December (536.0 mm and 21 rain days), while minimum rainfall in October (35.0 mm and 3 rain days). These data were the result of measurement in the study site in 2014, derived from the Environment Department of PT KPC.

Land cover Interpretation of landsat coverage in 2014 showed that the orangutan habitat in the coal mining area has undergone constriction and fragmentation within a period of >30 years. Mining and construction of supporting infrastructure have changed the wet rain forest intact and compact into smaller and isolated patches. Mining activities have led partly of orangutan habitat were lost, and the remaining area is divided into smaller habitat fragment. Of the 90,938 ha concession area of PT KPC, the total area that has been mined is ±26% (24,553.19 ha). The land cover of the 26% PT KPC areas have been mined has presented in Figure 3 and Table 1.

Comparison of land cover by Sihombing (2012) in two periods (2002 and 2012) in the coal mining area of PT KPC showed the degradation of the land cover quality. It is evidenced by the increase in the total degraded area (Table 2).

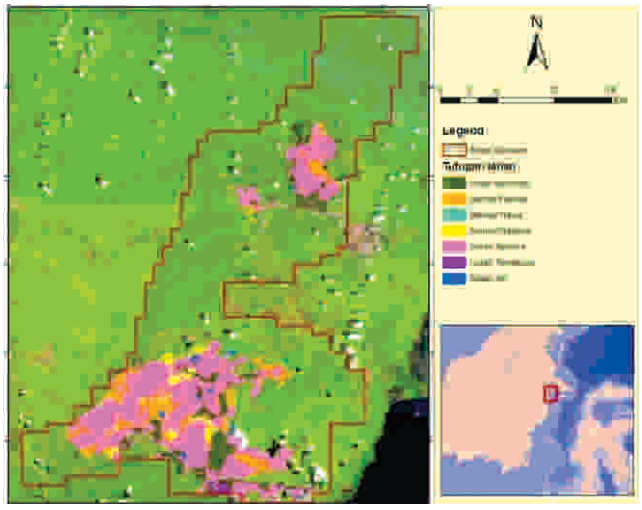

Figure 3 Land cover map in the coal mining area of PT KPC in 2014.

The combined impact of habitat constriction and fragmentation be able to cause the collapse of the ecosystem as a whole (Gunawan & Prasetyo 2003), this case applies to orangutan habitat in the coal mining area. According to Forman (1995), fragmentation begins with dissection, then perforation, fragmentation, and habitat attrition, which causing the habitat becomes unsuitable or have a low suitability. Habitat degradation in the coal mining area started with dissection when the road network built for coal exploration, followed by perforation when concession holders started exploitation coal. In line with the increased production capacity and growing extent of disturbed areas, the frequency of small bags habitat has increased, so fragmented habitats dominated the landscape in the coal mining area. Further small habitat remaining suffered attrition, become smaller and isolated.

Reclamation and revegetation by concessionaires led to the emergence of new bags habitat, it has the structure and floristic composition is very different from the natural habitat. Ultimately, coal mining operations have produced a landscape with some land cover types, namely: remaining natural forests, CMRA forest with trees dbh ≥5 cm, CMRA with small trees (dbh <5 cm), pit, road network, office area, water, etc.

Land cover changes have caused a large negative impact on the orangutans and another biodiversity. Despite massive habitat destruction occurred in coal mining area, orangutans are known to survive in patches of natural forest remaining and have confirmed colonize some CMRA. The remaining natural forests in the mining area generally have lost the big trees which are very important for the orangutan as food resources and place to build the nest. The structure and floristic composition in CMRA are tended to be similar, almost the same as the forest plantations. Floristic composition and structure of forest stands in CMRA will be described hereinafter.

Floristic composition Most of the total numbers of trees which frames the forest stand in Taman Payau CMRA and Gajah Hitam were trees from exotic species (79.83%) and there was only 20.17% of local species. There were at least 18 species of tree from 16 genera and 9 different families met in both botany plots. The both study plots are dominated by johar (*Senna siamea*) Johar has the highest density (405 trees ha^{-1}), the biggest basal area (2.15 m^2 ha^{-1}), and the most prevalent distribution. Summary of botanical analysis of trees (dbh ≥5 cm) in Taman Payau CMRA and Gajah Hitam is presented in Table 3, while the analysis results in each CMRA is presented in Table 4 and Table 5.

Some species of trees in Taman Payau CMRA and Gajah Hitam have a very low density and distributed randomly, that was why these species were not found in the botanical plot. A number of species found within study plot of Taman Payau are 9 species from 9 genera and 7 families, while outside the plot, there are 8 species of trees, namely: *S. surattensis, Vitex pinnata, Acasia auriculiformis, Terminalia catappa, Swietania mahagoni*, *Delonix regia*, *Gmelina arborea*, and *Hibiscus macrophylla*. Thus, in Taman Payau CMRA, there are minimum 17 species of trees from 16 genera and 12

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Table 1 Land cover types in the mined area (26% of PT KPC concession) based on interpretation of Landsat 2014

Disturbed area	Area (ha)	Area (%)
Water	458.96	1.87
Swamp	30.60	0.12
Secondary forest (including CMRA)	4,462.49	18.17
Built -up land	129.30	0.53
Bare soil	14,610.61	59.51
Grassland mosaic	1,348.98	5.49
Shrub	3,512.24	14.30
Total	24,553.19	100.00

Tabel 2 Comparison of land cover 2002 with 2012 (ha) in the mining area of PT KPC, Sangatta (Sihombing 2012)

Land cover types	2002	2012	Total change
Secondary forest	16,302.79	11,742.45	-4,560.34
Shrub	10,775.97	10,891.73	+115.76
Mangrove	1,685.59	1,349.51	-336.08
Swamp	0.00	441.94	+441.94
Water	0.00	290.95	+290.95
Built-up land	893.26	1,443.24	+549.98
Bare soil	3,948.31	7,646.90	+3,698.59

Note: Area of analysis = 33,806.72, − = Area reduce, + = Area increase

families. This number is more than that of research conducted by Rayadin (2012) which only found three species of trees within botany plot in which the width was the same as Taman Payau CMRA. The number of tree species found within the botany plot of Gajah Hitam were 11 species from 10 genera and 8 families, while outside the botany plot, there were eight species of trees, namely: *A. auriculiformis*, *Ficus* sp., *Geunsia pentandra, Mallotus dispar, Neolamarckia cadamba, Samanea saman, Syzygium* sp., and *V. pinnata*. Thus, there were minimum 19 species of trees from 17 genera and 11 different families in Gajah Hitam CMRA.

The research results in CMRAs showed that the orangutan habitat were lack of tree species compared to its natural habitat. Niningsih (2009) recorded that there are 78 species consisting 59 genera and 35 families in natural habitat in Prevab Area KNP, while Wahyudi (2009) found there are 98 species from 82 genera and 38 families in that area. In general, orangutans prefer natural habitat, intact, and have the higher food availability (van Schaik 2001; Soehartono *et al.* 2009). The higher the diversity of vegetation, it will provide food more abundant and varied for orangutans. Changes in composition floristic ensured a serious impact on orangutans. In CMRA, only five of the 28 species that are orangutan food trees. Yet, five of these species were not the dominant in CMRA, even three species of them confirmed were not important food trees for the orangutan (Niningsih *et al.* 2016), it was because orangutan prefers fruits with soft pulp (Meijaard *et al*. 2001; Kanamori *et al.* 2010). Orangutans have to adjust their food composition on species available in the mining area to survive (Campbell *et al.* 2008). According to Suhud and Saleh (2007), if fruits availability is reduced in an area, the orangutan will migrate to other areas or they try to adapt to change their feeding behavior as an adaptation to environmental changes. Twenty three of the total 28 species found in the both CMRAs are cultivated and the others growing naturally. Trees growing naturally were pioneer trees, such as, *Macaranga gigantea, M. hypoleuca,* and *Mallotus dispar*. Soendjoto *et al.* (2014), recorded a lot of plant species growing naturally are able to grow and progressed in less than two years after reclamation and re-vegetation on the reclaimed coal mining land of PT Adora Indonesia, because their seeds, rhizomes, or seedlings are dormant on the surface and in the top soil. According to Whitmore (1975), the seed dispersion of pioneer tree species is very effective. Pioneer species is often characterized as having early and frequent flowering and the copious production of small and easily dispersed seeds (Swaine & Whitmore 1988). Pioneer species vary in a range of ecophysiological and demographic traits, yet many species successfully colonize and co-occur in the forest (Davies 1998). The pioneer species that grown naturally can use as an indicator that the succession in progress in CMRAs.

Non-tree vegetation in CMRAs are also the important habitat component for any wild animals as food source and cover. It was grew both cultivated and naturally. Whereby, the result its showed in Table 6.

Food plant Orangutans were primarily frugivorous, spending a majority of their total foraging time feeding on fruits (Morrogh-Bernard *et al.* 2009). The fruit was preferred over leaves and vegetable matter (Bastian *et al.* 2010). Orangutans in Danum Valley spent 60.9% of the feeding times on fruits (Kanamori *et al.* 2010). Orangutan at Tuanan River Lading spent 71% and 61% of their total foraging time

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Table 3 Summary of botanical analysis of trees (dbh ≥5 cm) in CMRA Taman Payau and Gajah Hitam

Species	Family	RD	RF	RBA	IVI
Senna siamea Lam.	*Fabaceae*	46.02	16.67	36.00	98.69
Falcataria moluccana (Miq.)	*Fabaceae*	8.81	16.67	46.85	72.32
Senna surattensis (Burm.f.)	*Fabaceae*	21.88	8.33	7.81	38.02
Mallotus dispar (Blume)	*Euphorbiaceae*	11.36	8.33	5.05	24.75
Macaranga gigantea (Rchb.f.&Zoll.)	*Euphorbiaceae*	1.42	8.33	0.34	10.10
Ficus uncinata (King) Becc.	*Moraceae*	1.99	6.67	0.52	9.18
Croton argyratus Blume	*Euphorbiaceae*	1.14	6.67	0.50	8.30
Vernonia arborea Buch. -Ham	*Asteraceae*	1.99	5.00	0.54	7.53
Samanea saman (Jacq.) Merr.	*Fabaceae*	1.42	5.00	0.71	7.13
Hopea seminis Slooten	*Dipterocarpaceae*	1.14	3.33	0.21	4.68
Carallia suffruticosa Ridl.	*Rhizophoraceae*	0.57	3.33	0.08	3.98
Syzygium hirtum (Korth.)	*Myrtaceae*	0.57	1.67	0.37	2.60
Artocarpus heterophyllus Lam	*Moraceae*	0.28	1.67	0.60	2.55
Cratoxylum sumatranum (Jack) Blume	*Hypericaceae*	0.28	1.67	0.12	2.07
Macaran ga hypoleuca (Rchb.f.&Zoll.)	*Euphorbiaceae*	0.28	1.67	0.12	2.07
Alstonia scholaris (L.) R. Br.	*Apocynaceae*	0.28	1.67	0.08	2.03
Leucaena leucocephala (lam.) de Wit	*Fabaceae*	0.28	1.67	0.07	2.02
Guioa pleuropteris (Blume) Radlk.	*Sapindaceae*	0.28	1.67	0.04	1.99

Note : RD (relative density), RF (relative frequency), RBA (relative basal area), IVI (important value indeks of trees)

Table 4 Summary of botanical analysis of trees (dbh ≥5 cm) in CMRA Taman Payau

Species	Family	RD	RF	RBA	IVI
Senna siamea Lam.	*Fabaceae*	38.17	15.63	40.74	94.53
Falcataria moluccana (Miq.)	*Fabaceae*	11.45	15.63	41.04	68.12
Mallotus dispar (Blume)	*Euphorbiaceae*	30.53	15.63	12.62	58.78
Macaranga gigantea (Rchb.f. & Zoll.)	*Euphorbiaceae*	3.82	15.63	0.86	20.30
Ficus uncinata (King) Be cc.	*Moraceae*	5.34	12.50	1.31	19.15
Vernonia arborea Buch. -Ham	*Asteraceae*	5.34	9.38	1.35	16.07
Samanea saman (Jacq.) Merr.	*Fabaceae*	3.82	9.38	1.76	14.96
Alstonia scholaris (L.) R. Br.	*Apocynaceae*	0.76	3.13	0.21	4.10
Guioa pleuropteris (Blume) Radlk.	*Sap indaceae*	0.76	3.13	0.11	4.00

Note : RD (relative density), RF (relative frequency), RBA (relative basal area), IVI (important value indeks of trees)

Table 5 Summary of botanical analysis of trees (dbh ≥5 cm) in CMRA Gajah Hitam

Species	Family	RD	RF	RBA	IVI
Senna siamea	*Fabaceae*	50.68	17.86	32.84	101.37
Falcataria moluccana	*Fabaceae*	7.24	17.86	50.71	75.81
Senna surattensis	*Fabaceae*	34.84	17.86	13.02	65.72
Croton argyratus	*Euphorbiaceae*	1.81	14.29	0.83	16.93
Hopea seminis	*Dipterocarpaceae*	1.81	7.14	0.3 5	9.30
Carallia suffruticosa	*Rhizophoraceae*	0.90	7.14	0.13	8.18
Syzygium hirtum	*Myrtaceae*	0.90	3.57	0.62	5.09
Artocarpus heterophyllus	*Moraceae*	0.45	3.57	0.99	5.02
Cratoxylum sumatranum	*Hypericaceae*	0.45	3.57	0.20	4.22
Macaranga hypoleuca	*Euphorbiace ae*	0.45	3.57	0.20	4.22
Leucaena leucocephala	*Fabaceae*	0.45	3.57	0.12	4.14

Note: RD (relative density), RF (relative frequency), RBA (relative basal area), IVI (important value indeks of trees)

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Table 6 Vegetation other than trees observed in CMRA Taman Payau and Gajah Hitam

Species	Family	Habitus	Native	Planting
Ardisia villosa	*Myrsinaceae*	Liana	√	
Caladium sp.	*Araceae*	Taro	√	
Calliandra calothyrsus	*Fabaceae*	Schrub		√
Calopogon ium coeruleum	*Fabaceae*	Liana		√
Centrosema acutifolium	*Fabaceae*	Liana		√
Costus speciosus	*Zingiberaceae*	Ginger	√	
Derris sp.	*Fabaceae*	Liana	√	
Desmodium triflorum	*Fabaceae*	Liana		
Dillenia suffruticosa	*Dilleniaceae*	Schrub	√	
Hornstedtia minor	*Zingib eraceae*	Ginger	√	
Melastoma malabathricum	*Melastomataceae*	Schrub	√	
Merremia peltata	*Convolvulaceae*	Liana	√	
Poikilospermum suaveolens	*Urticaceae*	Liana	√	
Saccharum spontaneum	*Poaceae*	Herbaceous	√	
Spatholobus ferrugineus	*Fabaceae*	Liana	√	
Piper ad uncum	*Piperaceae*	Schrub	√	
Loranthus sp.	*Loranthaceae*	Epifit	√	
Mikania scandens	*Asteraceae*	Liana	√	

feeding on fruits (Bastian *et al.* 2010).

In CMRAs, most of the trees found in CMRAs are unusual crop for orangutan which eaten in its natural habitat. There were only five species of trees is known as the orangutan food tree in their natural habitat, namely, *Croton argyratus, Syzygium* sp., *Ficus* sp., *M. gigantea*, and *G. pentandra*. However, it must be remembered that the five species of trees were not the dominant species in that area. In addition, the trees were not the species of important food plants for orangutan. Therefore, it could be assured that the 5 species of trees were not the reliable species for orangutan to survive in CMRA.

Based on the direct observations and interview result several workers, it found that orangutan adapted to eat species of the trees growing there. Several species eating by orangutan, among others, johar (*S. siamea),* sengon (*Falcataria moluccana*), lamtoro (*Leucaena leucocephala*), flamboyan (*D. regia*), akar belaran (*Merremia peltata*), kaliandra (*Calliandra calothyrsus*), *Calopogonium caeruleum,* and *Centrocema acutifolium*. It species were exotic species that are not found in the natural habitat of orangutan. The plants were also not the fruit trees which had soft flesh favored by orangutan (Meijaard *et al.* 2001).

According to Ancrenaz *et al.* (2007), bornean orangutan species at a certain degree had an ability to survive at disturbed habitat by eating alternative/fallback food available in that area. For example, when the natural food was not enough, orangutan living within and outside the palm tree plantation and they ate young palm (Yuwono *et al.* 2007; Ancrenaz *et al.* 2010), orangutan living at and around the pulp and paper plantation ate the bark of *A. mangium* (Denis *et al.* 2010; Meijaard *et al.* 2010), orangutan living in the area of agriculture changed their active eating time and ate the crop yield that belonged the society, like star fruit, jack fruit, durian and pete (Campbell-Smith *et al.* 2011). Marshall and Wrangham (2007) define fallback food as foods whose use is negatively correlated with the availability of preferred foods. Fallback foods shape primate food processing adaptations, that the dietary importance of fallback foods is central in determining the expression of a variety of traits (Harrison & Marshall 2011). Bornean orangutans typically consume bark and leaves as fallback food in Borneo, while sumateran orangutans with greater importance of figs (Harrison 2009; Vogel *et al.* 2008; Wich *et al.* 2006). The behavior flexibility shown by orangutan seemed one of the adaptation ways towards the less productive forest in Borneo (Hockings & Humle 2010).

Nest tree Trees are not only the important food sources for the orangutan, but they are also the important need as the place build a nest (Prasetyo *et al.* 2007). According to Santosa and Rahman (2012), there were three dominant ecological variables that influence the presence or absence of orangutan nests, namely, the distance of nest trees with nearby sources of feed, the number of food tree close to the nest, and the presence of food trees near the nest.

This research also identified five species of trees used by orangutan as nest trees in Gajah Hitam CMRA and there were eight species of trees in Taman Payau CMRA used as nest trees. Therefore, there were minimum 10 species of trees used by orangutan as nest trees in both CMRA (see Table 7).

The above result showed that in CMRA where there were lack of trees, orangutan used the trees growing there and orangutan did not specifically choose the species of trees

Jurnal Manajemen Hutan Tropika Vol. 23, (1): 37–49, April 2017
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Scientific Article
ISSN: 2087-0469

used as nest trees. Rayadin *et al.* (2013) agreed with this in which species of johar (*S. siamea*), the most dominant ones in the research location was the most species of trees used by orangutan as nest trees.

In richer habitat of tree species, a number of trees used by orangutan as nest trees were more various. For example, the sub species of morio in KNP Prevab area used minimum 49 species of trees as nest trees and there were 80 species in Bhirawa forest, Kutai Kertanegara Regency (Niningsih 2009). In Sebangau Central Kalimantan, there were minimum 52 species of trees used as nest trees by *Pongo pygmaeus wurmbii* (Cheine *et al.* 2013). Rayadin & Saitoh (2009) recorded there were 31 tree species in 20 families used as nest tree by *Pongo pygmaeus morio* in East Kalimantan.

Forest structure Orangutan is arboreal mammals spending their time mostly on the trees, like eating, drinking and sleeping. This behavior is very influenced by the structure of vegetation in their habitat. The structure of vertical of forest would affect the height of orangutan to do an activity and horizontal structure would affect orangutan significantly when orangutan moved.

Thoroughly, the density of trees with dbh ≥ 5 cm in Taman Payau CMRA and Gajah Hitam was 880 trees ha^{-1}, the average dbh of ± 12 cm, basal area of ± 14.96 m^2 ha^{-1}. Trees arranging the stand in CMRA were almost in the same age. Therefore, they tended to have almost the same diameter, height, and canopy.

Small diameter trees (dbh ≤ 20 cm) dominated significantly in CMRA. There were a lot number of trees with dbh 5.1−10 m in both CMRA, while trees with dbh >20 cm were in small percentage. This condition was very different from the natural habitat of orangutan in Prevab KNP, in which there were big size trees with dbh >50 cm. The distribution of dbh from both CMRA can be seen in Figure 5.

Taman Payau CMRA had tree density of ±655 trees ha^{-1}, the average dbh of ± 13.25 cm, basal area of ± 11.97 m^2 ha^{-1}. CMRA Gajah Hitam had tree density of ± 1105 trees ha^{-1}, the average dbh of ± 11.57 cm, basal area of ± 17.95 m^2 ha^{-1}. The height of trees with dbh ≥ 5 cm in Taman Payau CMRA was around 4.5−17.2 m with the average height of ± 9.89 m. Of the number of trees found within the botany plot, there were as much as 52.34% that were in the height class of 5.1−10 m and 41.41% was in the height class of 10.1−15 m. The distribution of tree height with dbh ≥5 cm in Gajah Hitam CMRA was not too different. The height was about 1.7−18 m with the average height of ± 10.75 m. Of the trees found in botany plot of Gajah Hitam, as much as 3.50% was in the height class of 5.1−10 m and 50.22% was in the height of 10.1−15 m. Vertical structure from the stand in both CMRA can be seen in Figure 6.

Vertical structure of forest in the area of research was very different from the previous condition before there was a mining activity. This area was wet tropical rain forest which was very dense inhabited by orangutan (Meijaard *et al.* 2001). There were five layers of canopy in the natural habitat in Prevab Kutai National Park, *i.e.*, A (>30 m), B (20−30 m), C (4−20 m), D (1−4 m), and E (0−1 m) layers (Niningsih *et al.* 2016). At the moment forest stand in CMRA had only three layers of the canopy with C stratum as the top canopy layer.

Horizontal structure of stand was very important for orangutan because the ability of orangutan to move from one tree to another depended on the continuity of canopy. Canopy continuity was very determined by the density and diameter of canopy from trees in the same height class.

Canopy diameter from trees with dbh ≥5 cm in CMRA was around 0.96−18.65 m with the average canopy diameter of ±5.70 m. Trees with canopy diameter of <5 m and 5.1−10 m were the most, *i.e.,* 46.70% and 46.42%. Trees that had canopy diameter of 10.1-15 m and 15.1−20 m were very few, only ±5.44% and 1.43% of the number of trees. This condition is different from the natural habitat in KNP which contained trees had canopy diameter wide (Ferisa 2014; Niningsih *et al.* 2016).

Figure 7 presents the stand horizontal structure in Taman Payau CMRA and Gajah Hitam. The figure shows the forest canopy in both CMRA that is not always continue because the trees arranging the stand were not dense enough and their canopy was not wide enough. Canopy discontinuity was also caused by the present of liana in CMRA. In the natural habitat of orangutan, woody liana was the important

Table 7 Species and family of trees used for nest by orangutan in CMRA Taman Payau (TP) and CMRA Gajah Hitam (GH)

Species	Family	TP	GH
Delonix regia (Hook.) raf.	*Fabaceae*	√	-
Falcataria moluccana (Miq.)	*Fabaceae*	√	-
Gmelina arborea Roxb.	*Verbenaceae*	√	√
Hibiscus macrophyllus Roxb.	*Malvaceae*	√	-
Leucaena leucocephala (lam.) de Wit	*Fabaceae*	√	-
Macaranga gigantea (Rchb.f. & Zoll.)	*Euphorbiaceae*	-	√
Mallotus dispar (Blume)	*Euphorbiaceae*	√	-
Senna siamea Lam.	*Fabaceae*	√	√
Syzygium sp.	*Myrtaceae*	-	√
Vitex pinnata L.	*Verbenaceae*	√	√

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Scientific Article
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Figure 4 Orangutan nest observed in *Senna siamea.*

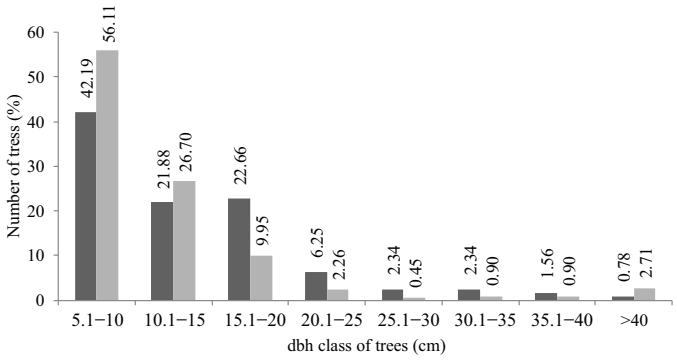

Figure 5 The distribution dbh of trees in Taman Payau and Gajah Hitam.Taman payau (■), Gajah Hitam (■).

connecting equipment for orangutan to move if the canopy of trees did not intersect each other (Richard 1952; Rijksen 1978). In the area of Mentoko and Prevab, KNP, the trees forming the C stratum mostly associated with epiphytic and liana (Ferisa 2014).

Forest structure and support availability have important effects on orangutan locomotion (Manduell *et al.* 2012). Forest canopy discontinuity can certainly make orangutan go down to the ground to move from one tree to another. According to Ancrenaz *et al.* (2014), the increase of terrestriality would increase the risk of hunting and the new disease exposure because big ape was vulnerable towards most human disease. Moreover, it could be said that one of the reasons why bornean orangutan still kept the arboreal behavior was because orangutan wanted to decrease the risk of human activity exposure.

Implication Orangutan habitat characteristics in CMRAs are very different from those of natural habitat. CMRA is not the good habitat for orangutan if seen from the aspect of either structure or vegetation composition. Coal mining has removed the large trees are very important for the orangutan as the food resources, nest site, and as the tools to arboreal movement (Felton *et al*. 2003).

Orangutan habitat in the coal mining area are fragmented into smaller patches, some of them suffered isolation (insularization). Fragmentation and isolation of patches can cause the ability of orangutans to move between patches is decreasing. Orangutans are isolated in the small patch is very susceptible to inbreeding depression, genetic drift, and other problems associated with small populations (Gunawan & Prasetyo 2013; Indrawan *et al.* 2007; Aguilar *et al.* 2008). Small populations are also vulnerable to the threat of demographic change (rates of death and birth) and environmental changes (disease, predation, competition, food, and natural disasters) (Indrawan *et al.* 2007). In the CMRA, the fruit trees and woody lianas which are important food resources for orangutans were very restricted (Morrogh-Bernard *et al.* 2009). Analysis of the orangutan habitat characteristics in the coal mining area indicates that it need for efforts to increase the habitat carrying capacity approach the natural habitat.

CMRA is very lacking on fruit trees and habitat enrichment with the fruit trees can improve the quality orangutan habitat in the future. Ideally, the choice of plants should consider the ecological characteristics of the species (Dennis *et al.* 2011), among other things: a food source has been known, the food source for other species, fast growing species, as well as climatic and edaphic is suitable. Unfortunately, the most of the fruit trees which the natural food of the orangutan are unknown its ecological characteristics because it has never been cultivated or observed its increment and growth. The species of fruit trees recommended are the species is favored by orangutans but it is disliked by humans. Enrichment with tree species that its bark favored by orangutans is not recommended because of the tree which its bark consumed by orangutan will be death.

Sengkuang tree (*Dracontomelon dao*) is one of the species recommended for planting in the CMRA. Although the increment and age begin to bear the fruit of this species is unknown, sengkuang is the fruit which favored by the orangutan in the Prevab and Mentoko, KNP (Rodman 1977; Campbell 1992; Ferisa 2014). Sengkuang trees can found in almost all area of East Kalimantan, especially in riparian areas. It showed that sengkuang is suitable in edaphic and climatic. In addition, seeds of the sengkuang are not difficult to get. Figs (*Ficus* spp.) also highly recommended. Figs are most important food to many primates and the staple food for the orangutan (Mackinnon 1974; Rijksen 1978). Three species of *Ficus* (*F. rubiginosa*, *F. uniglandulosa,* and *F. pubilimba*) were consumed most frequently by orangutans in Prevab area (Niningsih 2016).

Orangutan movement between habitat fragments assumed was very limited in this study and was not enough to prevent the effects of isolation. The company must make sure that each habitat patch, especially CMRA connect with the more spacious natural forests or other CMRA to prevent isolation. Orangutan needs the corridor to move from one patch to another patch (Luckett *et al*. 2004; Nasi *et al*. 2008). Wildlife corridors are one of the strategies for orangutan conservation in the mining area to prevent the effect of the

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Scientific Article
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habitat patch isolated on the orangutan.

Effective corridor is a corridor that has enough suitable habitat for the target species (orangutans) for lives permanently or passes normally (Harrison 1992). The minimum width of corridors for orangutans based on home range orangutans and sufficient to prevent the penetration of vegetation at the corridor edge (Harrison 1992). Construction of a corridor requires restoration as in low-quality habitat patches will be connected. The manager must plant the food trees and nest trees of the target species (orangutan) along the corridor (Bond 2003). Food trees, nest trees, and canopy connectivity are very important to consider in managing the corridor.

Conclusion

Coal mining operations caused the natural habitat of the orangutan which originally compact and intact fragmented into smaller patches in the form of CMRA and degraded

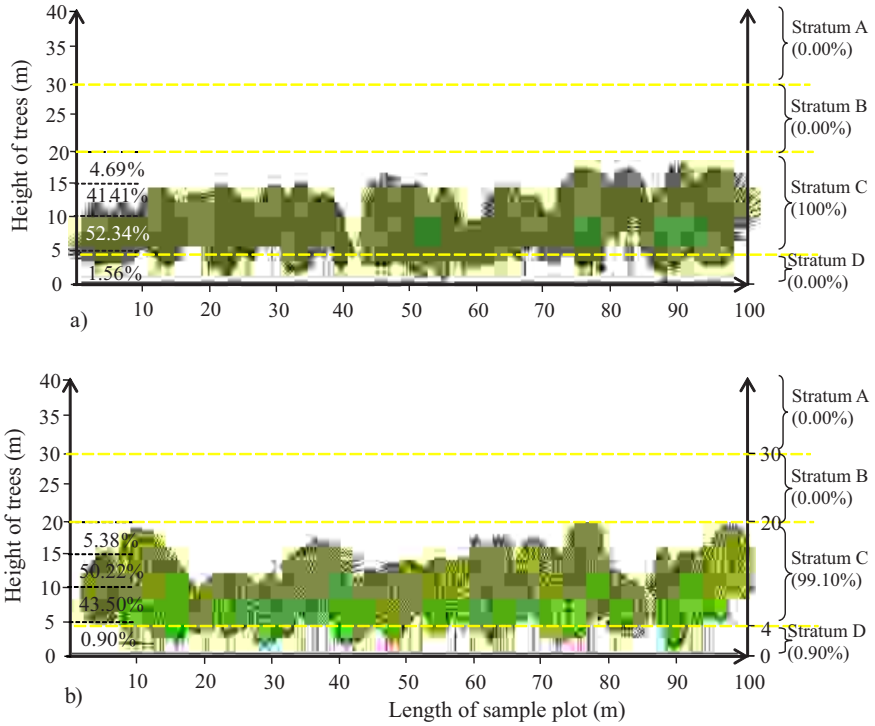

Figure 6 Vertical profile of forest in CMRA Taman Payau (a) and Gajah Hitam (b).

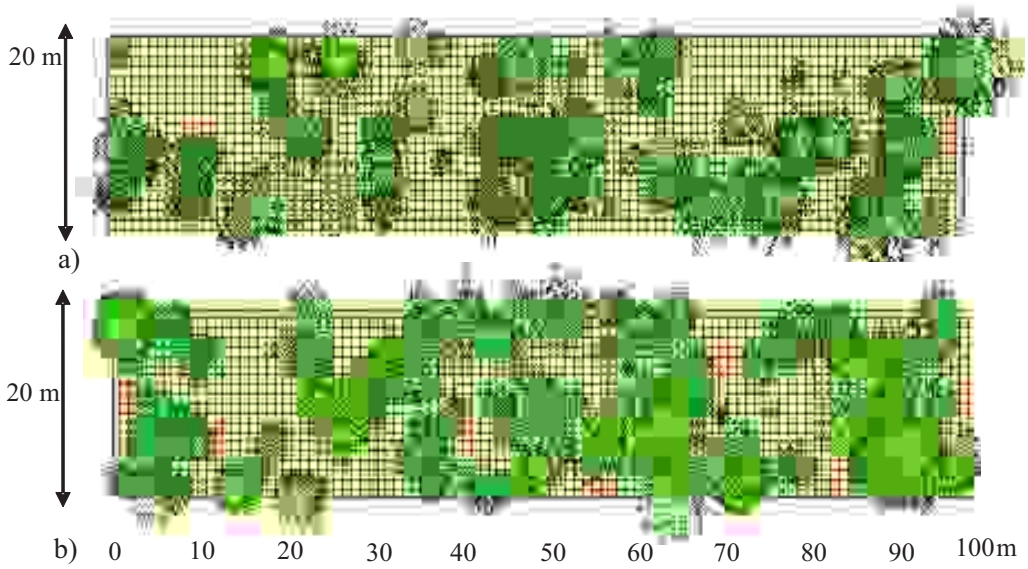

Figure 7 Horizontal profile of forest in CMRA Taman Payau (a) and Gajah Hitam (b).

forests remaining that surrounded by large disturbed area. The structure of forest stands in the CMRA tended similarly and the forest canopy is not continued. It is because of the forest compiled by the small trees of the same species and the same age class. Exotic species dominate in the CMRA, no fruit tree and woody liana in that area. The most dominant species in the CMRA were *S. siamea*, *F. moluccana*, and *S. surattensis*. CMRA is not the good habitat for orangutan if seen from the aspect of either land cover as well as the structure and vegetation composition. The quality of habitat can be improved by modifying the structure of stand and vegetation composition, build the ecosystem corridors, increase public/workers awareness, and involve various stakeholders in the orangutan conservation at the landscape level. One of the ways recommended is to enrich with various fruit tree species whose fruit is favored by orangutan but contrary for the human. Habitat enrichment of tree species whose bark was liked by orangutan is not recommended.

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