#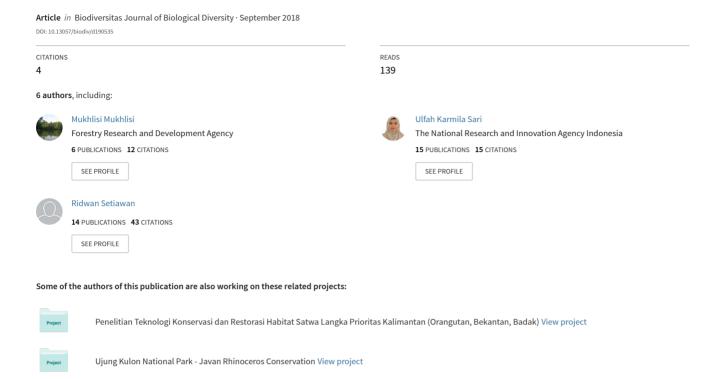 Habitat utilization of the Sumatran rhinos (Dicerorhinus sumatrensis harrissoni) in Kutai Barat forest, East Kalimantan, Indonesia

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Habitat utilization of the Sumatran rhinos (*Dicerorhinus sumatrensis harrissoni*) in Kutai Barat forest, East Kalimantan, Indonesia

**MUKHLISI[1,♥], TRI SAYEKTI NINGSIH[1], ULFAH KARMILA SARI[1,] YUYUN KURNIAWAN[2],
RIDWAN SETIAWAN[2], AHMAD MUSLIM[2]**

[1]Research and Development Institute for Natural Resources Conservation Technology. Jl. Samboja-Sepaku No.42, Sungai Merdeka, Semboja, Kutai Kartanegara 75271, East Kalimantan. Tel.: +62-542-7217663, Fax.: +62-542-7217665, ♥email: muci_musci@yahoo.co.id
[2]WWF Indonesia, Graha Simatupang Tower 2 Unit C, 7th-11th Floor Jl. T.B. Simatupang, South Jakarta 12540, Jakarta, Indonesia

Abstract. *Mukhlisi, Ningsih TS, Sari UK, Kurniawan Y, Setiawan R, Muslim A. 2018. Habitat utilization of the Sumatran rhinos (*Dicerorhinus sumatrensis harrissoni*) in Kutai Barat forest, East Kalimantan, Indonesia. Biodiversitas 19: 1842-1850.* Sumatran rhino population in Kutai Barat forest faces a high threat of extinction. Conservation efforts can be developed more effectively and efficiently by understanding the condition of their natural habitat. This study aimed to analyze various factors influencing habitat utilization of the Sumatran rhino in Kalimantan, specifically in Kutai Barat forest. We used past survey data of rhino presence carried out by WWF from 2014 to 2016. GPS coordinates were recorded for all signs of rhinos, such as camera trap images, footprints, bites mark on food plant, dung piles, urine, scratch, twisting, and lying signs. Rhino occurrence GPS coordinates were plotted on a map of the Sumatran rhino's habitat distribution in Kutai Barat using a grid of 2 x 2 km² size. Spatial analyses were run using ArcGIS 10.6. We used a habitat selection index formula to analyze habitat preference and biner logistic regression to develop Resources Selection Function (RSF). We found that the preferred habitat of the Sumatran rhino was in the secondary forest with medium and high vegetation densities. The most influential habitat variables on the presence of Sumatran rhinoceros in the Kutai Barat forest were the slope and distance from wallow. The Sumatran rhinoceros were more likely to be found in the sloping areas and the areas closer to the wallows.

Keywords: Conservation, habitat, Kutai Barat, secondary forest, Sumatran rhino

INTRODUCTION

The Sumatran rhino (*Dicerorhinus sumatrensis*) is the world's most threatened species of all rhinoceroses (Nardelli 2014; Mays et al. 2018). IUCN has listed the species as critically endangered (CR) (Havmoller et al. 2015). D. sumatrensis was, in the past, widely distributed throughout Southeast Asia and South Asia. The population now has just concentrated in Sumatra and Borneo Islands, which are a part of Indonesia (Miller et al. 2015). Illegal hunting and habitat loss are some main contributors causing the sharp decrease of rhino's population during the last 30 years from 800 individuals to less than 100 individuals (Nardelli 2014; Miller et al. 2015).

Numerous records reveal that the Sumatran rhinos mainly occur in coastal swamp forest, lowland, and mountain forest (van Strien 1985; Pusparini et al. 2015). According to Plair et al. (2011), the Sumatran rhino is a solitary species. However, this species could occasionally be found in a small group consisting of two or more individuals (van Strien 1985; Plair et al. 2011). The Sumatran rhinos appear to exhibit habitat preferences influenced by food abundance, topography, the source of minerals and water, and human presence (van Strien 1974; van Strien 1985; Pusparini et al. 2015; Kretzschmar et al. 2016). Therefore, within the utilized habitat, different environmental factors may interact to affect their presence. Putra (2014), for instance, found that the distance from roads and slope significantly affected habitat utilization of the Sumatran rhinos in Aceh. Similarly, Rusman (2016) recorded that the Sumatran rhino in Bukit Barisan National Park preferred to live close to the river, far from settlements, and relatively flat areas.

The Kalimantan forest harbors the smallest number of the Sumatran rhino population worldwide (Miller et al. 2015). A review of available literature indicates that only 7-15 individuals occur in the forest of Kutai Barat and Mahakam Ulu, East Kalimantan Province (WWF 2014). The patchy forest is a considerable factor for this phenomenon. In fact, the fragmented forest of Kutai Barat is only able to maintain 1-3 individuals of the Sumatran rhinos. Those rhinos inhabit a logging concession characterized by lowland secondary forest, with Dipterocarpaceae growing in abundance (Mukhlisi et al. 2017). Nevertheless, rhinos do not use entire habitat as their home range. Spatial evidence of the rhino presence in the Kutai Barat forest shows that this species is interested in a particular area within their home range (WWF 2014; field observation). This, in turn, has led to the suggestion that habitat utilization of the Sumatran rhinos in Kutai Barat is also affected by environmental gradients.

Study on ecology of the Sumatran rhinos in Kalimantan is limited. Previous studies have only focused on food ecology (Atmoko et al. 2016; Mukhlisi et al. 2017). WWF (2014) documented the distribution of the Sumatran rhino population in Kutai Barat and Mahakam Ulu forests. Regarding habitat utilization, studies have dealt with this issue in Sumatera (Putra 2014; Pusparini et al. 2015;

Rusman 2016). Accordingly, there is a need to understand habitat preferences and utilization of the Sumatran rhinos in Kalimantan, particularly in the Kutai Barat forest. Since the Sumatran rhinos show different responses to environmental conditions (Pusparini et al. 2015), research related to this field is urgent to enrich ecological information.

Research on habitat utilization of the Sumatran rhinos can help ecologists and managers determine strategies for ex-situ and in-situ conservation. Preferred habitat with an optimum condition is definitely capable of maintaining a sustainable population. Knowledge of habitat preferences can be applied to assist habitat and population management of the Sumatran rhinos in the wild such as Intensive Protection Zone (IPZ), which is an exclusive area for in-situ conservation with strict protection (Pusparini et al. 2015; Rusman 2016). In addition, information on habitat preferences is also beneficial to support the establishment of restricted breeding areas and corridors. This study, therefore, aimed to analyze various factors influencing habitat preferences of the Sumatran rhinos in Kalimantan, particularly in the Kutai Barat forest.

MATERIALS AND METHODS

Study area

The Kutai Barat forest was situated in Kutai Barat District, East Kalimantan, Indonesia. The forest was located in two active logging concession areas identified as one of the rhino's habitat patches in East Kalimantan (WWF 2014). In general, forest cover in the study area can be classified as lowland dipterocarp forest, with comprised of 177 tree species (Mukhlisi et al. 2017). The annual average temperature was around 26.5-27 °C, whereas the annual rainfall was 350 mm for the last 30 years (BMKG 2018).

Procedures

Information on the rhino presence was derived from the last survey carried out by WWF during 2014-2016. Evidence of habitat use was denoted by the presence of footprints, bite marks, dung piles, urine, scratching, twisting, and lying signs. Each presence sign was recorded in the form of GPS coordinates. In total, 294 coordinates were representing the rhino's signs (Ginanjar 2016, pers.com). The habitat components were divided into eight variables including distance from roads ($X1$), rivers ($X2$), wallows ($X3$), salt licks ($X4$), slope ($X5$), elevation ($X6$), Normalized Difference Vegetation Index/NDVI ($X7$), and soils ($X8$) (Santosa et al. 2013; Putra et al. 2014; Pusparini et al. 2015; Rusman 2016). To simplify the analysis process, each variable was classified (Table 1). We considered the distance from roads, rivers, wallows, salt licks, and elevation as interval data. Meanwhile, slope and NDVI were categorized as ordinal data.

Figure 1. Study area of the Sumatran rhinos (*Dicerorhinus sumatrensis harrissoni*) in Kutai Barat forest, East Kalimantan, Indonesia

The observed signs were plotted onto the map of Sumatran rhino habitat distribution in Kutai Barat District. The result then was overlaid with each map of habitat variable using ArcGIS version 10.6. The problem emerged when we described habitat features of each sign on the combined map. To overcome this, we divided each habitat variable map into grid cell of 2 x 2 km^2 before overlay operation. We assigned each grid cell with 1 (Y = 1) if there was a sign for rhinos and 0 (Y = 0) for the opposite. A 2 x 2 km^2 grid cell was based on the estimate of the lowest Sumatran female rhino's home range (Putra 2014). Totally, the study site was covering an area of 44,272.03 Ha. There was 18,352.01 Ha with the rhino's presence signs and 25,920.02 Ha with no sign of rhinos.

Distance from roads, rivers, wallows, and salt licks were analyzed using Euclidean Distance tools in ArcGIS 10.6. Two variables-slope and elevation-were extracted from DEM, which was derived from Shuttle Radar Topographic Mission (SRTM) at a resolution of 30 m. NDVI was assessed from Landsat 8 using the following equation with acquisition 9th Sept 2016 Path 117 Row 061.

$$NDVI = (NIR-RED)/(NIR+RED)$$

NDVI shows the degree of vegetation density as Rusman (2016) also used the same variable for analyzing the availability of rhino food in Sumatra Island. Finally, to understand the real condition of each habitat variable, we did fieldwork in 2016. For particular variables such as wallow, we did detail measurement of water pH, length, width, and distance from rivers or the nearest water spring. We also carried out a 1500 mL water sample collection on salt licks and rivers for mineral content analysis.

Data analysis

We employed a Chi-Square test with a confidence level of 95% to know the relationship between habitat types and habitat use frequency. In this paper, we categorized habitat types into the shrub and secondary forest. Furthermore, to analyze habitat preferences of rhinos, we used the formula of Neu et al. (1974):

$$\text{Selection index } w = \frac{r}{a}$$

$$\text{Standardised index } B = \frac{w}{\sum w}$$

Where: w is habitat selection index, r is rhino occurrence frequency, and a is the proportion of habitat used. For the selection index, we would conclude that rhinos will prefer to employ a particular habitat if w > 1. With regards to standardized index (B), this index always has a value of 1. Therefore, it will show the comparison of habitat selection index within each tested habitat.

A multicollinearity test was used to detect correlation among independent variables of habitat. No multicollinearity will happen if p > 1 or variance inflation factor (VIF) is less than 10. Once there was no indication of multicollinearity, the Resources Selection Function can be identified based on logistic regression as the following formula (Manly et al. 2002):

$$\pi = \frac{Exp\ (\beta o + \beta 1X1 + \beta 2X2 + \cdots \beta pXp)}{1 + Exp\ (\beta o + \beta 1X1 + \beta 2X2 + \cdots \beta pXp)}$$

Where: π is the probability of the presence of rhinos, β0 to βp are coefficients estimated from the available data, and X1 to Xp are habitat variables. To this end, all statistical processes were run using PSPP, an open source statistical software.

RESULTS AND DISCUSSION

Distribution of habitat utilization

According to the map of observed signs of rhinos during 2014-2016, we argue that rhino habitat was stretching from the east to the west of the Kutai Barat forest (Figure 2 and 3). Habitat utilization pattern of rhinos resulted from animal preference and adaptation. Particularly adaptation, this term is interesting since the forest was experiencing severe human pressure. From Landsat imagery, it was clear that the forest is adjacent to coal mining, palm oil plantations, settlement, and agricultural areas (Figure 2). The condition leads to forest fragmentation resulting in patchy forest separated from rhino habitat in the northern part of Mahakam Ulu District. Besides, illegal hunting and rampant logging tended to increase considerably. The fact eventually caused rhinos to select safe and secure habitat with good quality. Distribution of habitat utilization by rhinos in the study site is presented in Table 1.

The road networks in the study site were the consequence of industrial timber operations in the past. Some of them were still active, whereas others were no longer used. Nevertheless, roads significantly affected the habitat preferences of the Sumatran rhinos. Table 1 indicates that rhinos preferred to utilize habitat with distance < 2,000 m from road networks. Santosa et al. (2013) found a strong correlation between Javan rhino and roads since their food plants were more abundant near road networks. Gaps in the forest created by roads allow pioneer species to regenerate, providing food preferred by rhinos such as *Macaranga* spp, *Homalanthus populneus, Ficus obscura*, and *Pternandra rostrata* (Atmoko et al. 2016; Mukhlisi et al. 2017). Although roads have a substantial effect on rhino behavior, it seems that human presence could also influence the rhino habitat use. Rhinos will avoid roads frequently used by human (Pusparini and Wibisono 2013; Putra 2014; Pusparini et al. 2015).

Three main rivers (Piraq, Naja, and Tenaik) flow around the Kutai Barat forest, containing numerous small streams. Those rivers are mostly perennial. Visual observation revealed that rhino signs were mostly found near the river (< 1,000 m). This finding supports the fact that behavior of rhinos in the wild is affected by water availability. Rivers play an important role in providing a source for drinking, wallowing, and bathing, which in turn will influence habitat preference of rhinos (van Strien 1974; Ng 2001; Putra 2014; Pusaprini et al. 2015; Rusman 2016). Rivers may facilitate a temporary water hole

creation which is often used by animals such as rhinos for maintaining body temperature, skin protection, and avoiding insect bite (van Strien 1974; Ng 2001). We also noticed that rivers are crucial for defecation. Feces and urine resulted from this process let rhinos communicate with each other. Chemical components released through excretion are beneficial for detecting age and sex of other individuals (Linklater et al. 2013).

The average length and width of wallows were approximately 1.70-4.80 m and 1.40-4.70 m, respectively. Measurements were recorded on 11 out of 123 wallows which were identified during 2014-2016 (Table 2). The average size of wallows seemed to be small as a consequence of the small body size of the Sumatran rhino. However, wallows made by the Sumatran rhino in the Kutai Barat forest were larger than those made by a captive bred rhino in Selangor, Malaysia (Ng 2001). Ng (2001) reported that the size of wallows was around 1.25-4.00 m in length and 1.20-3.70 m in width. The difference could be due to the use of wallows by other animals and rolling behavior expressed by rhinos. The Sumatran rhino needs at least 2-3 hours for wallowing before foraging (Ng 2001). According to this finding, it is plausible to conclude that the distance from wallows is vital for rhino presence. Van Strien (1985) reported that the Sumatran rhino would create a wallow in every 50 m of its movement.

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Figure 2. Distribution of rhino's signs in Kutai Barat forest, East Kalimantan, Indonesia

Figure 3. Signs of rhino presence in the Kutai Barat forest, East Kalimantan, Indonesia. A. Dung piles, B. Wallow, C. Scratch, D. Footprint, E. Bites mark on food plant (Photo by RS/WWF Indonesia)

Salt licks are beneficial for many animals like rhinos since they can provide a source of minerals. Van Strien (1974) and Matsubayashi et al. (2006) revealed that three main minerals found in a salt lick are magnesium (Mg), potassium (K), and phosphate (P). Those minerals can help rhinos maintain their digestive system. Minerals such as sodium (Na) and potassium (K) are also useful in balancing ions in the body. To know the mineral content of rhino habitat in the Kutai Barat forest, we tested several locations such as rivers, wallows, and salt licks (Table 3).

Table 2 shows that P, Na, and Mg concentration in rivers, wallows, and salt licks were higher than other mineral compounds. This current study also indicates that wallows had the highest level of salt mineral. On the other hand, the mineral content of salt licks particularly P, Na, and Mg were higher than those found in rivers. This phenomenon indicated that the source of salt mineral for rhinos was not only from salt licks but also from wallows. Apart from those given locations, food plants can provide salt mineral for rhinos. This reason might explain the fact that signs of rhinos were mostly found within the distance of > 2,000 m from salt licks. The visit rates to salt lick seemed to increase in the dry season or for unhealthy rhinos. van Strien (1985) stated that the frequency of visits

of rhinos to a mineral source was one visit/month, but females with their young tended to be more frequent. For adult rhinos, the visitation to salt mineral sources is essential for social life (van Strien 1985).

The slope is mostly flat in the study site. Moderate slope ranging between 8-25% is an ideal habitat for the Sumatran rhinos, supporting feeding and moving activity. An area with moderate slope will allow sunlight to penetrate deeply to the forest floor. The process will accelerate the regeneration process of forest floor vegetation. Furthermore, forest gaps are more likely to occur in an area with 15.01-25% in the gradient due to soil instability and fall trees. Similar to forest floor vegetation; the forest gap can stimulate pioneer tree species to regenerate and grow rapidly, affecting the abundance of rhino's food plants. Rhinos also avoid higher slopes because it is a part of their energy storage strategies. Consequently, it is common that rhinos will follow contour lines (van Strien 1985; Santosa et al. 2013). Previous studies found that the most encountered gradient of the Sumatran rhino in Aceh was less than 40%, whereas their relatives in Bukit Barisan Selatan National Park preferred to live in areas typified by a moderate slope (Rusman 2016).

The rhino habitat in the Kutai Barat forest was characterized by lowland tropical forest. However, in general, the Sumatran rhinos were able to tolerate a wide range of elevations up to 2,000 m above sea level (Putra 2014). Furthermore, WWF (2014) found that the Sumatran rhinos in Mahakam Ulu used habitat up to 700 m above sea level. The lack of food availability may constrain rhinos to survive in a habitat with an elevation of > 2,000 m above sea level (van Strien 1985). Interestingly, Pusparini et al. (2015) stated that habitat preference had no strong correlation with elevation. Rhinos in the Kutai Barat forest were absent within elevation > 200 m above sea level. A possible explanation for this discrepancy might be that habitat preferences related to altitude could be specific depending on each site condition, suggesting that temperature decline due to an increase in elevation is not an impediment factor influencing rhino adaptation. One of the issues that emerge from these findings is the food availability which tends to have a more significant impact on the rhino presence.

NDVI is based on the density of the green patch of the area indicated on satellite imagery with the value ranging from -1 to 1 (Rouse Jr. et al. 1974; Xue and Su 2017). According to a land cover map released by the Ministry of Environment and Forestry, the habitat of rhinos in the Kutai Barat forest is classified as secondary forest. Yet, we investigated some areas dominated by shrubs resulted from the past logging. There were at least 53 species of identified food plants in the study site (Atmoko et al. 2016). Furthermore, Mukhlisi et al. (2017) also reported that two vegetation transect ever created around rhino habitat had a relative abundance of 1.79-1. 82 ind. ha^{-1} with dominant species of *Koilodepas brevipes, Palaquium sericeum, Pternandra rostrata, Diospyros* sp*., Dillenia excelsa*, and *Baccaurea lanceolata*.

Table 1. Habitat use distribution by the Sumatran rhinos in the Kutai Barat forest

Variables		Classification	Rhino presence signs (%)
Distance from road	1	< 1,000 m	70.07
	2	1,001-2,000 m	29.93
	3	>2,000 m	0.00
Distance from river	1	< 1,000 m	75.85
	2	1,001-2,000 m	24.15
	3	>2,000 m	0.00
Distance from wallow	1	< 1,000 m	87.76
	2	1,001-2,000 m	10.20
	3	>2,000 m	2.04
Distance from the salt lick	1	< 1,000 m	14.63
	2	1,001-2,000 m	12.93
	3	>2,000 m	72.45
Slope	1	0-8%	0.00
	2	8.01-15%	46.26
	3	15.01-25%	53.74
	4	25.01-40%	0.00
	5	> 40%	0.00
Elevation	1	< 100 m	59.18
	2	100.1-200 m	40.82
	3	200.1-300 m	0.00
	4	>300 m	0.00
NDVI	1	-0.16-0.15	5.10
	2	0.16-0.30	15.99
	3	0.31-0.43	78.91
Soil association	1	Paleudults-Tropudults-Tropaquepts	0.00
	2	Tropaquults-Paleudult-Tropodults	2.04
	3	Tropudults-Dystropepts	32.99
	4	Tropudults-Plinthudults-Paleudulst	64.97
	5	Tropudults-Tropaquepts	0.00

Table 2. Wallow characteristics of the Sumatran rhino habitat in the Kutai Barat forest

No.	Length (m)	Width (m)	Water pH	Distance from the river (m)
1	3.20	2.55	6.33	100
2	4.80	4.70	6.25	125
3	3.50	2.43	6.23	0
4	3.89	2.95	6.15	20
5	2.99	1.90	6.10	30
6	3.20	2.70	6.05	15
7	2.45	1.40	5.64	0
8	1.70	1.40	5.75	6
9	2.50	2.00	5.45	5
10	2.20	2.00	5.10	5
11	3.50	2.70	5.80	4
Mean	3.08	2.43	5.90	28.18
SD	0.861	0.914	0.386	43.030

Table 3. Mineral content of the river, wallow, salt lick

Location	Mineral concentration (mg L⁻¹)					
	P	Na	Ca	Fe	Mg	K
River	1.10	3.22	1.40	0.96	1.41	1.06
Wallow	1.80	4.02	2.30	1.76	3.26	1.86
Salt Lick	1.57	2.94	1.28	0.45	2.19	1.15
Mean	1.49	3.39	1.66	1.06	2.29	1.36
SD	0.357	0.560	0.556	0.660	0.929	0.438

Ultisols are soil orders generally found in Kalimantan. Within this order, there is an association of Tropaquults, Paleudult, and Tropodults which can influence habitat selected by rhinos. The result is consistent with the earlier study in Sabah, Malaysia (Kretzschmar et al. 2016). According to Prasetyo et al. (2001), Ultisols are typified by clay texture, low pH, low organic matter and low base saturation, and being aquatic up to 50 m from the surface. The characteristics of Ultisols appear to support wallowing behavior of rhinos as the soil can be converted easily.

Habitat selection of the Sumatran rhinos

A Chi-Square test revealed that there was a significant correlation ($p < 0.05$) between habitat types and the frequency of rhino occurrence in the Kutai Barat forest. It means that rhinos select a particular type of habitat to fulfill their needs. The difference between the observed and expected frequency also supports the finding. Once a significant correlation occurs, habitat selection index could be conducted (Neu et al. 1974). Table 4 and 5 summarize the result of the Chi-Square test and Neu index.

Table 5 clearly shows that the most selected habitat of the Sumatra rhinos was in the secondary forest although in the real condition their habitat is also composed of shrubs. The secondary forest in the study area is a consequence of regular logging activity of timber plantation. Indonesian laws strictly control logging from natural forest. A tree in timber plantation is allowed to cut if it has reach > 50 cm in diameter. Besides, tree cutting should be conducted within a 25-30 years block rotation. Currently, rhino habitat in the Kutai Barat forest is situated in a block that was last logged

in the 1990s so that vegetation has well regenerated and transformed into an old secondary forest. Unfortunately, illegal logging that sometimes happens is likely to affect the ongoing regeneration process, resulting in the disturbed secondary forest.

van Strien (1985) explained that the ideal habitat for the Sumatran rhinos is old secondary forest without human interference. Therefore, finding rhinos in the secondary forest surrounded by human activity is challenging. Rhinos are known as a cryptic animal, avoiding human contact (Nardelli 2014). This specific characteristic prevents rhinos to present in open areas like shrubs. However, some studies found that rhinos sometimes appear in open areas for foraging and return to the forest for shelter and protection (van Strien 1974; Kretzschmar et al. 2016). This behavior is in line with our analysis towards habitat selection.

The selection probability towards resources in rhino habitat

To detect the most preferred habitat by the Sumatran rhinos in the Kutai Barat forest, we did logistic regression analysis. Before running the analysis, it is imperative to test multicollinearity among habitat variables. Logistic regression analysis can be executed if tolerance value is > 0.1 and VIF (Variance Inflation Factor) < 10. The analysis will produce a model called Resources Selection Function (RSF), and it then can be applied to assess the probability of habitat used. Our finding revealed that there was no multicollinearity so that logistic regression analysis was applied. The analysis used 37 points of rhino presence and 104 points of absence on a 2 x 2 Km² grid. Table 6 and 7 shows the result of the multicollinearity test and logistic regression analysis, respectively.

Based on the stepwise forward run in SPSS (Table 4), we found that slope and wallow had a significant influence on the presence (Y) of the Sumatran rhinos ($p < 0.05$). Therefore, the RSF model was:

$$Y = \frac{Exp\ (-4.098 + 2.175\,Slope + 5.497\,Wallow)}{1 + Exp\ (-4.098 + 2.175\ Slope + 5.497\ Wallow)}$$

Table 4. A chi-square test for the relationship between habitat types and the occurrence frequency of rhinos

Habitat	Size (Ha)	Proportion	Oi	Ei	Oi-Ei	(Oi-Ei)²/Ei	(X²) 0.05
Shrub	8,665.32	0.20	6.00	57.54	-51.54	46.17	
Secondary forest	35,606.71	0.80	288.00	236.46	51.54	11.24	
Total	44272.03	1.00	294.00	236.46	0.00	57.41	3.84

Table 5. Neu selection index of the Sumatran rhino's habitat in the Kutai Barat forest

Habitat	Available habitat		Encountered signs		Neu Index	
	Size (Ha)	Proportion	Recorded	Proportion	Selection (w)	Standardized (B)
Shrub	8,665.32	0.20	6.00	0.02	0.10	0.08
Secondary forest	35,606.71	0.80	288.00	0.98	1.22	0.92
Total	44,272.03	0.40	294.00	1.00	1.32	1.00

Table 6. Multicollinearity test

	Model	Unstandardized Coefficients B	Standardized Coefficients Std. Error	Beta	T	Sig.	Collinearity Statistics Tolerance	VIF
1	(Constant)	1.701	.373					
	Roads (X2)	-.046	.045	-.081	-1.021	.310	.602	1.661
	Rivers (X1)	-.165	.044	-.274	-3.753	.000	.705	1.419
	Wallow (X7)	-.293	.050	-.470	-5.856	.000	.584	1.712
	Salt Lick (X8)	-.182	.079	-.159	-2.318	.022	.801	1.249
	Slope (X3)	.061	.055	.085	1.106	.271	.635	1.574
	Elevation (X4)	-.009	.067	-.010	-.130	.897	.700	1.429
	NDVI (X5)	-.040	.054	-.050	-.736	.464	.806	1.241
	Soil (X6)	.085	.043	.129	2.002	.048	.905	1.105

Table 7. Logistic regression analysis

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	Upper
Step 2[b]	Slope (X3)							1.321	58.685
	Wallow (X7)	5.497	1.324	17.242	1	.000	243.845	27.639	2.151E3
	Constant	-4.098	1.207	11.529	1	.001	.017		

A developed model of RSF fitted for estimating the presence of the Sumatran rhinos in the Kutai Barat forest. A goodness of fit test represented by Hosmer and Lameshow showed a significant value of 0.4447 ($p > 0.05$). A developed model had high accuracy displayed by the value of Area Under Curve (AUC) which was 0.955. The RSF model also suggested that independent variables simultaneously affected the presence of rhinos as shown by the Omnibus test with a value of 0.000 ($p < 0.05$). Furthermore, the value of Cox and Snell R Square and Nagelkerke R Square were 0.514 and 0.719, respectively. Those values informed that independent variables could explain 71.90% of the probability of the rhino presence (Y). It means that other factors explained 28.10% of the rhino presence. Thus, the RSF model was suited to analyze the presence of rhinos.

Unlike linear regression, we could not interpret the result directly. The easiest way to translate the result of regression was through the odds ratio value or Exp (B) and by doing a simulation of the developed model (Lele et al. 2013). According to the RSF model, it could be interpreted that an increase in slope would decrease the probability of the rhino presence as much as 8.803 fold. Meanwhile, for the wallow, an increase in a 1,000 m distance would reduce the likelihood of rhino presence as 243.845 fold. From the simulation of our model, we suggested that the probability of the rhino presence would be higher in slope with a gradient of 8-15% (0.92) and < 1,000 m from the nearest wallow (0.99).

Slope might be a factor restricting natural movement of rhinos. Rhinos are more likely to select habitat with a moderate slope for moving and foraging. It is known that the home range of the Sumatran rhinos was 5-6 Ha day^{-1} (van Strien, 1985). So, to prevent energy loss, moderate slope appears to be preferred. The gradient of slope in the Kutai Barat forest, which is mostly < 25%, seems to support the natural behavior of rhinos. We assume that slope and wallow complement each other. We found it difficult to form a wallow on a steep area since there was no water-bearing capability. Also, wallow construction is influenced by a river which is found frequently in a flat area. In fact, during fieldwork, we found that wallows were often close to rivers with the distance of 28.18 ± 43.030 m.

The Sumatran rhinos exhibited a high frequency of wallowing. This behavior is useful to maintain body temperature and protect rhinos from diseases (van Strien 1974; Ng 2001). Prevention from bathing for an extended period will cause detrimental effects such as inflammation and cracked skin. It even can drive a young rhino to die shortly in a week (van Strien, 1985). Low pH of the water as found in a bathing area is resulted from leaf litter, protecting rhinos from diseases. Based on fieldwork, we argue that wallows were mostly identified near the main rhino trail including the presence signs of rhinos.

For rhinos, wallowing has a crucial role in maintaining body temperature. Wallowing also provides a chance for rhinos to communicate with each other, though rhinos are considered as a solitary animal. Meeting and communication during wallowing are beneficial particularly in a breeding season. According to van Strien (1985), Ng (2001), and Bracke (2011) a wallow was capable of supporting scent marking sexual behavior. The result of analysis on salt mineral concentration suggested that the Sumatran rhinos in the Kutai Barat forest were wallowing in mud containing a high level of salt. There was a correlation between the frequency of wallowing and the need for salt mineral per individual. However, much uncertainty still exists about that correlation so that further research on that issue is urgently needed.

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