Abundance and nutrient content of some food plants in Sumatran rhino habitat in the forest of Kutai Barat, East Kalimantan, Indonesia

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Abstract

The recent discovery of Sumatran rhinoceros proved that the species still exists in Kalimantan. Current attempts to conserve individual rhinos ex situ at a sanctuary in Kutai Barat requires accurate information on the vegetation composition and abundance of food plants in the rhinos' natural habitat. We determined the diversity of rhino food plants in an area where the species was known to occur. We recorded all species of seedlings, saplings, poles and trees at two survey sites, and determined which of these species had been eaten by rhinos. We identified 177 species of plants from 106 genera in our survey area, typical of the lowland dipterocarp forest ecosystem in this region. We identified 36 of these species as food plants of Sumatran rhino, of which the most abundant were *Koilodepas brevipes*, *Gonystylus affinis*, *Diospyros* sp., *Pternandra rostrata*, *Calophyllum* sp., and *Macaranga gigantea*. Furthermore, we conducted an analysis of nutrient contents of 22 of these species that showed signs of rhino bites. We found that all samples had fulfilled the nutrient requirements of the Sumatran rhino (based on standards for horse) except the requirement for phosphorus. The list of food species identified in this study could be used as a reference for habitat enrichment in rhino habitats, particularly at the sanctuary of Kutai Barat, and provides vital information for species recovery programmes.

Résumé

La découverte récente du rhinocéros de Sumatra a prouvé que l'espèce existe encore à Kalimantan. Les tentatives actuelles de conservation des rhinocéros individuels ex situ dans un sanctuaire de Kutai Barat nécessitent des informations précises sur la composition de la végétation et l'abondance des plantes alimentaires dans l'habitat naturel des rhinocéros. Nous avons déterminé la diversité des plantes alimentaires de rhinocéros dans une région où l'espèce était connue. Nous avons enregistré toutes les espèces de semis, de jeunes arbres, des poteaux et des arbres dans deux sites d'étude et nous avons déterminé lesquelles de ces espèces avaient été consommées par les rhinocéros. Nous avons identifié 177 espèces de plantes de 106 genres dans notre zone d'étude, typiques de l'écosystème de diptérocarpacées de basse terre dans cette région. Nous avons identifié 36 de ces espèces comme plantes alimentaires du rhinocéros de Sumatra, dont les plus abondantes étaient le *Koilodepas brevipes*, le *Gonystylus affinis*, le plaqueminier (*Diospyros*), le *Pternandra rostrata*, le takamaka (*Calophyllum*) et le *Macaranga gigantea*. En outre, nous avons effectué une analyse des teneurs en éléments nutritifs de 22 de ces espèces qui présentaient des signes de morsures de rhinocéros. Nous avons constaté que tous les échantillons avaient rempli les besoins en nutriments du rhinocéros de Sumatra, à l'exception de l'exigence de phosphore. On pourrait utiliser la liste des espèces alimentaires identifiées dans cette étude comme référence pour l'enrichissement de l'habitat dans les habitats du rhinocéros, en particulier dans le sanctuaire de Kutai Barat, et fournir des informations vitales pour les programmes de rétablissement de l'espèce.

Introduction

The Sumatran rhino (*Dicerorhinus sumatrensis*) is the smallest of all rhino species and is considered critically endangered according to the IUCN Red List (van Strien et al. 2008). Indonesia has two subspecies of Sumatran rhino, namely *D. sumatrensis sumatrensis*, which is found on Sumatra, and *D. sumatrensis harrissoni*, which is endemic to the island of Borneo (Foose and van Strien 1997). Borneo is the third largest island in the world and is divided into three territories, belonging to Indonesia, Malaysia and Brunei, which occupy 73%, 26% and 1% of the island, respectively. There are very few studies on the habitats and population size of the Sumatran rhino in Kalimantan, the Indonesian portion of Borneo, particularly in comparison with the relatively well-studied Malaysian part of the island. Harrisson (1975) reported that, by the 1970s, Kalimantan's rhino population had been reduced to just 1 or 2 individuals and, a few years later, Rookmaaker (1977) stated that only five individuals remained. Studies conducted after 1980 found no concrete evidence of rhinos in Kalimantan (Meijaard 1996), and many considered the species to be extinct there. Nevertheless, based on anecdotal information some commentators suggested that the population in Kalimantan might still persist, albeit in very low numbers (Meijaard 1996; Foose and van Strien 1997).

Recent surveys using camera field traps have confirmed that the Sumatran is not extinct in Kalimantan after all. A study conducted by WWF Indonesia in 2013 and 2014 estimated that the total area of the rhino habitat in East Kalimantan is ca. 493,000 ha. This is divided into three habitat patches, which in the past were contiguous forest (WWF Indonesia 2014). The total population of rhinos is unknown, but a preliminary survey of two of the patches found between 7 and 15 individuals.

Rhino habitats in East Kalimantan overlap with active timber concessions and it can be assumed that logging activities and conversion of habitat pose a serious threat to the remaining rhinos in the area. Rhinos are also threatened by the many poachers active in the area. Even though rhinos may not be the poachers' main target, their traps could still ensnare rhinos, In response to this threat, a conservation initiative is underway to translocate individual rhinos to a sanctuary in the Kutai Barat forest, one of the three habitat patches identified in in East Kalimantan.

The distribution of herbivorous species is often closely related to abundance of food plants and nutrient content in their habitat. However, studies of plant use by Sumatran rhinos in their natural habitat are still limited. Some studies on the composition of vegetation and food plants have been conducted for the Javan rhino at Ujung Kulon National Park (Mas'ud and Prayitno 1997; Rahmat 2012), and for the Sumatran rhino on the island of Sumatra in the Leuser Ecosystem Area (Putra 2014) and Way Kambas National Park (Arief 2005). Two studies on the species composition of food plants in rhino habitat in Kutai Barat and Mahakam Ulu were carried out by Muslim et al. (2015) and Atmoko et al (2016); but were incomplete because they did not include data on the abundance of food plants and nutrient content. Therefore, this study will improve the ecological data on resource requirements of the Sumatran rhino in Kalimantan.

Data and information on the abundance of food plants and nutrient content for rhinos can provide inputs for conservation management strategies and the design of the rhino sanctuary. Food plant abundance can be a limiting factor because Sumatran rhinos are herbivorous animals and consume approximately 50 kg of vegetation daily, with 97% of their diet consisting of leaves, buds, and twigs (van Strien 1985). For this reason, any attempt to translocate rhinos from the wild to a sanctuary needs basic information on vegetation composition and abundance of food plants in their natural habitat. This information is important and especially needed to develop the overall design of the sanctuary, including the enrichment of some plants species if required.

Materials and methods

Study area

We carried out this study from March to April 2016 in a forest situated in Kutai Barat (West Kutai Regency) in East Kalimantan Province, Indonesia. The study area is one of the three rhino habitat patches identified in the upper Mahakam River watershed in East Kalimantan. Based on images from the camera traps, at least three individual rhinos have been positively identified in this area (Putro 2015).

The research area has flat to gentle topography, at an altitude of <200 m above sea level. The area consists of a mix of dry lands and swamps, and several rivers flow through the area throughout the year. The forests of Kutai Barat suffer from more severe disturbance compared to the other two habitat patches since they are occupied by logging and palm oil concessions.

Data collection

We collected data on vegetation using a line transect method (Kusmana 1997). Two line transects were established in two areas where rhinos had been observed during the previous rhino population survey. These areas are referred to here as Camp A (area surveyed=20×220 m) and Camp B (area surveyed=20×280 m). The placement of transects was determined by the presence of rhino tracks. The physical characteristics of the two transects were similar, in terms of slope, elevation, water and soil pH and water availability (Table 1). Forest cover in both areas was classified as secondary forest.

Table 1. Description of transects at Camp A and Camp B established for the analysis of food plants of the Sumatran rhino in the forest of Kutai Barat, East Kalimantan, Indonesia

Parameter	Camp A	Camp B
Slope	8–25%	0–25%
Elevation	100 to <200 m a.s.l.	<100 m a.s.l.
Water pH	5.95–6.80	5.10–6.15
Soil pH	4.04–5.22	4.27–5.25
Water supply	Available throughout the year (rivers/ streams)	Available throughout the year (rivers/ streams)
Forest cover	Secondary forest	Secondary forest

We divided the total survey area (Camp A + Camp B) into 25 plots of 20×20 m. Within each plot we identified and measured all trees with diameter at breast height (dbh)>20 cm. Within each plot of 20×20 m, 3 subplots were established, of 2×2 m for seedlings, 5×5 m for saplings, and 10×10 m for poles. Within each subplot, all individuals within the respective size class were identified and measured.

We searched for rhino traces in the forest to obtain plant species that had been eaten by rhinos. Food plant species were identified based on the presence of bite marks. Rhinos eat using the sharp incisors of the lower jaw, leaving characteristic bite marks similar to cuts by scissors (Figs. 1 and 2). To confirm these observations, other supporting information such as footprints, dung, scrapes and twisted saplings served as the basis for determining the presence of rhinos and identifying food plant species. A total of 22 plants species with bite marks were analyzed for nutrient values. In this study, nutrient content analysis was done on leaves. Other plant species that showed no bite marks were considered potential food plants based on the results of previous studies on Kutai Barat and Mahakam Ulu (Muslims et al. 2015; Atmoko et al. 2016).

At least 50 g of each sample were dried in an incubator at a temperature of 60°C until they reached a constant weight (Dierenfield et al. 2006). For further analysis, all samples were delivered to the Laboratory of Nutrition and Feed Technology of Bogor Agricultural University. The nutrient parameters used for this study were: dry matter, ash, crude protein, crude fiber, ether extract, nitrogen free extract, calcium (Ca), phosphorus (P), sodium cloride (NaCl), and gross energy. Since the actual mineral requirements of the Sumatran rhinoceros are unknown, we compared nutrient contents of the food plants to standard nutrient requirements for the horse, which has a similar digestive system (van Strien et al. 1985; Lee et al. 1993; Dierenfield et al. 2000).

Results

The composition of vegetation in rhino habitat

A total of 177 plants species (106 genera) were identified during study. Our results showed that the species richness at Camp B is higher (132 species) than in Camp A (113 species). The number of plant species for in each stratum in Camp A were 29, 58, 58 and 37 seedlings, saplings, poles and trees, respectively, whereas at the Camp B the corresponding totals were 39, 96, 55 and 53, respectively.

Abundance and nutrient content of food plant species

In total, 38 food plants (24 species at Camp A and 31 species at Camp B) species were identified as food sources for the Sumatran rhino in the Kutai Barat forest (Table 2). These

Figure 1.
A sign of a rhinoceros bite on *Pternandra rostrata* in the forest of Kutai Barat, East Kalimantan, Indonesia.

Figure 2.
A sign of a rhinoceros bite on *Diospyros* sp. in the forest of Kutai Barat, East Kalimantan, Indonesia.

included 17 species of plants that were distributed across both sites including *Baccaurea lanceolata, Diospyros sp, Knema latericia, Macaranga bancana, Macaranga hypoleuca, Magnolia candolii*, and *Pternandra rostrata*. These species appeared in all transect locations. However, most plant species expressed uneven patterns of regeneration and were not found in each stratum. Our data indicated that the species showing the most even pattern of regeneration (in terms of presence across strata) at Camp A were *Diospyros* sp. and *P. rostrata*, while at Camp B they were *Calophyllum* sp., *Dillenia exelca*, and *K.latericia*.

The Sumatran rhino is a browser and so will be more likely to utilize plants from seedling and sapling stages. The findings revealed rhino food plants in the seedling and sapling strata at Camp A were more abundant (though less diverse) than those at Camp B (see Tables 3 and 4).

The results of nutrient analysis of the 22 food plant species showing evidence of rhino bites indicated that different species contained different concentrations of plant nutrients (Table 5). Values for crude protein, crude fiber, calcium, and phosphorus were compared to the equine requirements for these nutrients established by the National Research Council (2007). Our analysis indicated that all samples had fulfilled the standard requirements for all nutrients, except the requirement for phosphorus. The mean (±SD) phosphorus concentration in all samples was 0.12 ± 0.035%, compared with a required concentration for horse of 0.20–0.30%. *Madhuca pierre* and *Scaphium macropodum* were the two food plant species with the

Table 2. List of rhino food plants species found in transects at Camp A and Camp B in the forest of Kutai Barat, East Kalimantan, Indonesia

No.	Species	Camp A	Camp B
1	*Artocarpus anisophyllus*		+
2	*Baccaurea lanceolata*	+	+
3	*Baccaurea macrocarpa*	+	+
4	*Baccaurea pyriformis*	+	
5	*Bhesa paniculata*		+
6	*Calophyllum sp.*	+	+
7	*Canarium littorale*	+	+
8	*Cleistanthus myrianthus*		+
9	*Croton argyratus*		+
10	*Dillenia exelca*	+	+
11	*Diospyros borneensis*		+
12	*Diospyros sp.*	+	+
13	*Elateriospermum tapos*	+	
14	*Ficus obscura*		+
15	*Garcinia mangostana*		+
16	*Gluta sp.*	+	
17	*Gonystylus affinis*	+	+
18	*Knema latericia*	+	+
19	*Koilodepas brevipes*	+	
20	*Macaranga bancana*	+	+
21	*Macaranga gigantea*		+
22	*Macaranga hypoleuca*	+	+
23	*Macaranga lowii*	+	
24	*Macaranga trichocarpa*	+	+
25	*Madhuca pierre*		+
26	*Magnolia candoloii*	+	+
27	*Melanochylla sp.*	+	+
28	*Melanochylla bullata*		+
29	*Myristica villosa*	+	+
30	*Ochanostachys amentacea*	+	+
31	*Palaquium sericeum*	+	
32	*Pternandra rostrata*	+	+
33	*Santiria sp.*	+	+
34	*Sauraia sp.*	+	
35	*Scaphium macropodum*		+
36	*Spatholobus ferrugineus*		+
37	*Tetracera scandens*		+
38	*Uncaria cordata*		+
	Total	**24**	**31**

Table 3. Abundance of food plants in the seedling stratum at Camp A and Camp B in the forest of Kutai Barat, East Kalimantan, Indonesia

Camp A				Camp B			
No.	**Family**	**Species**	**Density (Ind./ha)**	**No.**	**Family**	**Species**	**Density (Ind./ha)**
1	Euphorbiaceae	*Koilodepas brevipes*	18.18	1	Thymelaeaceae	*Gonystylus affinis*	10.71
2	Thymelaeaceae	*Gonystilus affinis*	15.91	2	Calophyllaceae	*Calophyllum sp.*	8.93
3	Sapotaceae	*Palaquium sericeum*	9.09	3	Dilleniaceae	*Dillenia exelca*	5.36
4	Burseraceae	*Santiria sp.*	6.82	4	Sapotaceae	*Madhuca pierre*	5.36
5	Phyllantaceae	*Baccaurea lanceolata*	2.27	5	Burseraceae	*Santiria sp.*	5.36
6	Calophyllaceae	*Calophyllum sp.*	2.27	6	Rubiaceae	*Uncaria cordata*	5.36
7	Ebenaceae	*Diospyros sp.*	2.27	7	Euphorbiaceae	*Tetracera scandens*	3.57
8	Euphorbiaceae	*Macaranga lowii*	2.27	8	Euphorbiaceae	*Macaranga hypoleuca*	3.57
9	Anacardiaceae	*Melanochylla sp.*	2.27	9	Phyllantaceae	*Baccaurea lanceolata*	1.79
10	Myristicaecaee	*Myristica villosa*	2.27	10	Ebenaceae	*Diospyros sp.*	1.79
11	Melastomataceae	*Pternandra rostrata*	2.27	11	Myristicaeae	*Knema latericia*	
				12	Magnoliaceae	*Magnolia candoloii*	1.79
				13	Myristicaceae	*Myristica sp.*	1.79
				14	Sapotaceae	*Palaquium sericeum*	1.79
				15	Sterculiaceae	*Scaphium macropodum*	1.79

highest phosphorus concentrations (~0.19% in each case), while *Macaranga hypoleuca* was the species with the lowest phosphorus concentration (0.07%).

Analysis of ecological parameters

Shannon-Wiener diversity index values ranged from 2.429 to 4.179 in the different strata of the two transects (Table 6). This was lower on average than values found at rhino habitats in Sumatra: In the Leuser Ecosystem situated in Aceh Province, Shannon-Wiener diversity index values were 4.067–4.352 (Putra, 2014), while Arief et al. (2005) recorded values of 3.49–4.00 in the Way Kambas National Park. Lower diversity, compared to both Sumatra and Kalimantan habitats, was found in the Ujung Kulon National Park in West Java, where Shannon-Wieners index values ranged from 2.058 to 2.521 (Rahmat 2012).

Evenness index values at the two sites were high (Table 6) and ranged, with one exception, from 0.68 to 0.86. High values of this index mean that there are no clearly dominant species in the vegetation community (Morris et al. 2014). The exception was in the seedling stratum at Camp A, where the evenness index value was low (0.3913).

Both Camp A and Camp B appeared to share common physical and ecological characteristics (Table 1). However the Bray-Curtis similarity index showed the low values (25.69–35.93%), indicating a low degree of similarity between the two sites, for all vegetation strata.

Table 4. Abundance of food plants in the sapling stratum at Camp A and Camp B in the forest of Kutai Barat, East Kalimantan, Indonesia

Camp A				Camp B			
No.	**Family**	**Species**	**Density (Ind./ha)**	**No.**	**Family**	**Species**	**Density (Ind./ha)**
1	Euphorbiaceae	*Koilodepas brevipes*	31.82	1	Ebenaceae	*Diospyros sp.*	10.71
2	Sapotaceae	*Palaquium sericeum*	20.15	2	Dilleniaceae	*Dillenia exelca*	8.93
3	Melastomataceae	*Pternandra rostrata*	18.18	3	Phyllantaceae	*Baccaurea lanceolata*	8.93
4	Phyllantaceae	*Baccaurea lanceolata*	9.09	4	Myristicaceae	*Knema latericia*	8.93
5	Ebenaceae	*Diospyros sp.*	6.82	5	Thymelaceae	*Gonystilus affinis*	7.14
6	Magnoliaceae	*Magnolia candoloii*	4.55	6	Calophyllaceae	*Calophyllum sp.*	5.36
7	Phyllantaceae	*Baccaurea pyriformis*	4.55	7	Sterculiaceae	*Scaphium macropodum*	5.36
8	Burseraceae	*Santiria sp.*	2.27	8	Sapotaceae	*Madhuca pierre*	3.57
9	Euphorbiaceae	*Macaranga trichocarpa*	2.27	9	Melastomataceae	*Pternandra rostrata*	3.57
10	Burseraceae	*Canarium littorale*	2.27	10	Euphorbiaceae	*Macaranga bancana*	3.57
11	Myristicaceae	*Knema latericia*	2.27	11	Magnoliaceae	*Magnolia candoloii*	3.57
12	Calophyllaceae	*Calophyllum sp.*	2.27	12	Celastraceae	*Bhesa paniculata*	3.57
				13	Burseraceae	*Santiria sp.*	3.57
				14	Euphorbiaceae	*Macaranga conifera*	1.79
				15	Euphorbiaceae	*Macaranga hypoleuca*	1.79
				16	Euphorbiaceae	*Cleistanthus myrianthus*	1.79
				17	Euphorbiaceae	*Macaranga trichocarpa*	1.79
				18	Olacaceae	*Ochanostachys amentacea*	1.79
				19	Phyllantaceae	*Baccaurea macrocarpa*	1.79
				20	Ebenaceae	*Diospyros borneensis*	1.79
				21	Anacardiaceae	*Melanochylla sp.*	1.79
				22	Myristicaceae	*Myristica villosa*	1.79
				23	Burseraceae	*Canarium littorale*	1.79

Table 5. Nutrient content of 22 food plant species of the Sumatran rhino found in the forest of Kutai Barat, East Kalimantan, Indonesia. The final row shows requirements of some nutrients (protein, fiber, Ca and P) for horse, as recommended by the National Research Council (2007). n.a.=data not available

No.	Species	Dry matter	Ash	Crude protein	Crude fiber	Extract ether	Nitrogen free extract	Ca	P	NaCl
		(g)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	*Melanochylla sp.*	18.38	6.09	12.02	39.23	2.01	40.65	0.76	0.11	0.22
2	*Melanochylla bullata*	59.25	3.21	11.93	42.77	1.35	40.74	1.13	0.17	0.24
3	*Bhesa paniculata*	30.73	5.01	13.96	29.52	2.90	48.61	1.01	0.13	0.65
4	*Garcinia mangostana*	57.03	3.89	10.22	39.05	0.79	46.05	0.75	0.07	0.84
5	*Tetracera scandens*	37.05	12.69	13.23	37.38	2.08	34.62	1.00	0.16	0.22
6	*Dillenia exelca*	43.03	8.48	12.81	17.71	1.14	59.86	0.91	0.09	0.12
7	*Diospyros sp.*	13.16	6.76	15.05	40.05	3.50	34.64	1.14	0.08	0.08
8	*Macaranga gigantea*	40.34	4.34	14.4	28.81	2.21	50.24	0.97	0.12	0.22
9	*Macaranga hypoleuca*	44.55	6.06	11.54	31.96	4.65	45.79	0.60	0.07	0.11
10	*Macaranga trichocarpa*	71.23	8.54	14.68	29.80	3.05	49.93	1.25	0.14	0.22
11	*Cleistanthus myrianthus*	19.26	11.42	12.62	41.85	0.78	33.33	1.35	0.16	0.10
12	*Spatholobus ferrugineus*	36.65	6.44	13.45	43.8	2.05	34.26	1.06	0.14	0.22
13	*Calophyllum sp.*	38.26	2.46	12.89	36.93	2.54	45.18	0.47	0.10	4.84
14	*Magnolia candollii*	51.53	8.19	10.27	37.61	2.21	41.72	1.30	0.14	2.76
15	*Pternandra rostrata*	52.84	7.68	13.44	26.32	0.44	52.12	0.47	0.13	0.11
16	*Artocarpus anisophyllus*	41.68	9.07	13.22	33.45	2.78	41.48	0.86	0.12	0.22
17	*Ficus obscura*	53.32	13.03	12.43	24.62	1.48	48.44	1.14	0.09	0.23
18	*Myristica villosa*	46.89	4.54	13.84	25.95	1.47	54.20	0.60	0.09	0.21
19	*Uncaria cordata*	61.76	5.21	15.14	19.32	2.10	58.23	0.87	0.11	0.11
20	*Madhuca pierre*	36.60	9.18	13.01	26.01	4.34	47.46	0.38	0.19	0.11
21	*Scaphium macropadum*	47.93	5.36	14.92	28.54	0.98	50.20	0.75	0.19	0.10
22	*Gonystylus affinis*	46.37	3.75	10.48	49.36	2.31	34.10	1.38	0.11	0.11
Mean		43.08	6.88	12.98	33.18	2.14	45.08	0.92	0.12	0.54
Standard deviation		14.305	2.958	1.474	8.263	1.100	7.832	0.294	0.035	1.115
Requirement for horse[a]		n.a	n.a	8–15	12–15	n.a	n.a	0.30–0.60	0.20–0.30	n.a

Table 6. Diversity index values of plant communities in transects at Camp A and Camp B in the forest of Kutai Barat, East Kalimantan, Indonesia

Diversity Index	Camp A				Camp B			
	Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree
Shannon-Wiener	2.429	3.669	3.866	3.396	2.429	4.175	3.856	3.700
Evenness	0.3913	0.6761	0.8237	0.8067	0.8103	0.6778	0.8595	0.7629

Discussion

The composition of the Sumatran rhino food plants in this study consisted of 38 species. Of these 38 food plant species, 22 species of rhino food plants were identified based on signs of herbivory on the leaves and twigs. Some of food plants of rhinos were known as exudate plants, belong to the families Euphorbiaceae, Sapotaceae, Myristicaceae, Anacardiaceae, and Calophyllaceae. Sumatran rhinos in Danum Valley, Sabah, Malaysia have also been observed to eat sapwood (Euphorbiaceae), behaviour which Lee et al. (1993) attributed to its high macronutrient content (K, Ca, Mg). The overall composition of food plants in this study was higher than that found by Muslim et al. (2015) in Kutai Barat. He recorded 32 species of rhino food plants. Similarly Lee et al. (1993) identified 31 species of rhino food plants in Danum Valley, Sabah. However, our results showed that the diversity of food plants for Sumatran rhinos in Borneo was lower in comparison with the rhino food plants found in Sumatra, i.e. in the Way Kambas National Park and the Leuser Ecosystem Area, 141 and 149 food species, respectively, were identified (Arief 2005; Putra 2014). Although this research only recorded a low number of food plants in the forest transects, a long-term investigation of food ecology of Sumatran rhinos in Kalimantan would provide new insights into potential food plants for this species in the future.

A number of differences were found in the composition and structure of vegetation communities between Camp A and Camp B. The abundance of rhino food plants was greater (but the diversity lower) in the seedling and sapling strata at Camp A compared to at Camp B (see Tables 3 and 4), while Bray-Curtis similarity analysis indicated low levels of similarity in all strata between the two sites. These differences may reflect factors such as habitat suitability, soil, and microclimate; however, they are also probably attributable to the effects of past disturbance. The study site was a logging concession and the dynamics of forest succession are likely influenced by intensity of harvesting and the practices employed.

Arief (2005) reported that both composition and abundance of food plant species affect the presence of rhino individuals, but abundance has a greater influence. This is plausible since abundance of food plants is linked to the daily nutrient requirement of the Sumatran rhino (van Strien 1985). It is likely that the Sumatran rhinos in Kutai Barat occupy a tropical rainforest characterized by high diversity of plant species, although the abundance of food plants is low. These conditions influence the Sumatran rhinos in Kutai Barat, whose foraging behavior consists of following specific tracks between known food sources. Similarly, van Strien (1985) found that Sumatran rhinos foraging in Gunung Leuser National Park ranged over between 4 and 6 ha each day.

Phosphorus is one of the essential macro-minerals for all animals. A deficiency of phosphorus in rhinos has been reported to potentially cause some health problems. For example, Clauss and Hatt (2006) reported that the African black rhino in captivity suffer from hypophosphatemia and dermatitis, indicating a lack of phosphorous in their diet. The low concentration of phosphorus we found in' the rhinos food plants agrees with results of some other studies (van Strien 1985; Lee et al. 1993; Dierenfield et al. 2000, 2006). However, these studies concluded that the phosphorus concentration of twigs is higher than in leaves, which we analyzed in this study. Dierenfield et al. (2006) also mentioned that twigs and leaves from eight samples eaten by Sumatran rhinos at Cincinnati Zoo did not show different macro-mineral concentrations, except for phosphorus, which was again found to be significantly higher in twigs. Thus our analysis of the food plants does not provide conclusive evidence of a phosphorous deficiency in the diet of wild rhinos in Kutai Barat.

Along with calcium, phosphorous helps build bone and teeth; an adequate supply of both macrominerals is necessary for the Sumatran rhinos' well-being. In horses, when phosphorus is readily available, the ratio of phosphorus to calcium intake is 1:1 (National Research Council 2007). However, when the intake of phosphorus is low, the Ca:P ratio increases to 6:1. In this study, the ratio of Ca:P is equal to 9:1, suggesting that there may well be a deficiency of phosphorus in the rhinos' diet. Some food plant species with high calcium concentrations are *Cleistanthus myrianthus, Magnolia candollii*, and *Gonystylus affinis*. *G. affinis* is one of species that shows the highest abundance in Kutai Barat, mainly in the seedling stratum. While the abundance of *M. candollii* is low, it is well distributed in natural habitats.

Several food plants characterized by hard leaves and twigs contain high crude fiber, for example *G. affinis* and *Diospyros* sp. In the sapling stratum, *Diospyros* sp. grows in abundance in comparison to other species (6.82 to 10.71 ind./ha). The diet of Sumatran rhinos consists of large amounts of fiber, supplement by a moderate protein intake (Clauss and Hatt 2006). The selection by rhinos of plants with a high crude fiber content is closely related to monogastric digestive system in the rhino's body. In the chamber of the digestive system fiber is fermented by microbes in the hindgut organ; this constitutes one of the main energy sources in the rhinos' diet (Clauss and Hatt 2006).

Diospyros sp. and *Pternandra rostrata* are examples of plants species with a high concentration of protein. Both of these plants are abundance in Kutai Barat and were often found with bite marks (Figs. 1 and 2). The protein concentration reported is usually higher in the leaves compared to twigs (Dierenfield et al. 2000, 2006). Rhinos need high protein levels (10–13%), particularly during growth and lactation, to form new cells and to support metabolic processes. In fact, the energy value of food plants samples in this study was 4368.68 cal/g. Any effort to translocate rhinos from the wild to the sanctuary must consider energy values of food available, both in the wild and in the sanctuary. Dierenfield et al. (2000) suggest that if food plants are provided ad libitum in captivity, it is important to do an evaluation of the rhinos' energy intake. From observation, it appears that some individuals among captive Sumatran rhinos are more obese than individuals living in the wild. Sumatran rhinos with obesity problem may be at risk of developing uterine tumours (Clauss and Hatt 2006).

Conclusion

The vegetation in the Sumatran rhino habitat in this study was high in nutritional value, typical of dipterocarp forest ecosystems commonly found in Borneo. However, the number of food plant species and abundance of food plants did not rank highly at either location (Camp A and Camp B), compared to areas occupied by Sumatran rhinos on the island of Sumatra. Additional studies are needed to identify other species of food plants consumed by rhinos in East Kalimantan. Thus, we recommend: (1) a further in-depth study of the rhinos' preferred food plants in order to support food resource management; (2) use of the food plant species that have been identified as a reference for diet provided to the rhinos in sanctuaries; and (3) taking account in the design of rhino sanctuaries of patterns of productivity and cultivation techniques, especially for plants that are highly palatable to rhinos.

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