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Original article

Foraging Preferences and Ecological Carrying Capacity of banteng (*Bos javanicus*) and sambar deer (*Rusa unicolor*) in Huai Kha Khaeng Wildlife Sanctuary, Thailand

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ABSTRACT

This research aimed to investigate the foraging preference, food intake, and ecological carrying capacity of ungulate species in the Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province in Thailand. The research was conducted from October 2017 to March 2018, using twigs-count method. The results showed that a total of 64 plant species, found in the dry dipterocarp forest (DDF) and mixed deciduous forest (MDF), were eaten by banteng (*Bos javanicus*). The result also found that 18 plant species in DDF were eaten by the sambar deer (*Rusa unicolor*). A food preference analysis demonstrated that 22 tree species in DDF and 19 tree species in MDF were favored by banteng. As determined by the indices, only *Helicteres isora, Millettia leucantha, Helicteres angustifolia, Caesalpinia enneaphylla, Tiliacora triandra, Desmodium* sp.*, Hyptis suaveolens, Poaceae* sp*,* and *Pterocarpus macrocarpus* were in high proportion in banteng's diet. Meanwhile, 5 of the 11 species, such as *Bauhinia* sp., *Jasminum* sp.*, Dioscorea* sp.*, Grewia tomentosa,* and *Streptocaulon juventas* preferred by sambar dear, were abundant in both the forest habitats. The results also suggested that DDF provided 5,288.47 ± 1,087.26 (SE) kg of dry forage matter of plants/sq. km/month and MDF provided 4,375.56 ± 404.70 kg of dry forage matter of plants/sq. km/month. A statistical analysis indicated no significant difference between the average dry matter of food plants from DDF and MDF ($t = 0.7869$, *p-value* = 0.4391, $df = 23.67$). If banteng and sambar share similar resources in the area, the DDF would support 4.20 ± 1.69 bantengs/sq. km and 11.45 ± 4.61 sambars/sq. km and MDF would support 3.47 ± 0.63 bantengs/sq. km and 9.47 ± 1.72 sambars/sq. km. The result indicated that the area has a very high potential to support the ungulate population, compared with the results of a previous study. The overall results also showed a high potential of the forests to protect large carnivorous species. Inside the sanctuary, we suggest that steps should be taken that focus on improving the habitats to increase the species population.

Keywords: banteng, sambar deer, ecological carrying capacity, foraging preference, Huai Kha Khaeng Wildlife Sanctuary

INTRODUCTION

Understanding where animals forage, is important for the conservation of multi-species communities (Schweiger *et al.*, 2015). Furthermore, information about the foraging preferences, food intake, and carrying capacity could be applied for management of protected areas (Scotter, 1980). A foraging study provides critical knowledge to understand specific needs of animals via investigating the species and quantity of food consumed by some ungulate species. In addition, an assessment of the carrying capacity is conducted in order to determine the quantity of food available to support the population of some ungulates in the area. Although, there have been studies on the management of carrying capacity for the ungulates worldwide (Mansson *et al.*, 2015), studies on this topic of wildlife management in Thailand are rather limited.

Huai Kha Khaeng Wildlife Sanctuary (HKK) is one of Thailand's protected area, which has a rich biodiversity. HKK covers pristine and healthy forests, and was recognized as a natural world heritage site by UNESCO in 1991, namely Thung Yai-Huai Kha Khaeng Wildlife Sanctuaries (UNESCO World Heritage Centre, 2018). There are two main forest categories in the area, mixed deciduous forest (MDF) and dry dipterocarp forest (DDF), which cover an area of 51.72% of the total area of the sanctuary (Forest Research Center, 1997). The sanctuary is reported to house at least 712 species of vertebrate species, 130 mammals, 360 birds, 81 reptiles, 37 amphibians, and 105 fresh water fish (Forest Research Center, 1997). The two forest types are the prime forest habitat that help to maintain the ungulate population in the area. There are 10 ungulate species that are found in the area (Bhumpakphan, 1996). Among these species, banteng (*Bos javanicus*) and sambar deer (*Rusa unicolor*) represent the most important ungulate species in the sanctuary (Srikosamatara and Suteerathron, 1995; Sukmasuang *et al*., 2000; Sukmasuang, 2004; Simchareon *et al*., 2014). Due to high reproductive rate and are the main prey species for the tiger (Hayward *et al*., 2012; Simchareon *et al*., 2014). The numbers of the two ungulate species, banteng and sambar deer, are also affected by the forest fire management policy, which has been enforced in HKK for more than 20 years (Sirimagorn, 2009). Banteng also is a critically endangered species (Gardner *et al*., 2016), The study of foraging preferences and ecological carrying capacity of the key ungulate species can provide important information about understanding the habitat requirement and carrying capacity. Such information can be used to support the area management of species conservation, especially the conservation policy of large carnivores of the country and to maintain ecosystem function. The studies can help preserve such natural world heritage sites and the findings can be applied to protect other such areas in the country.

MATERIALS AND METHODS

Study area

The HKK Wildlife Sanctuary covers an approximate total area of 2,780 sq. kms. The conservation value of the area is the basis

for declaring the Thung Yai Naresuan and HKK Wildlife Sanctuaries as UNESCO world heritage sites in 1991(ONEB, 1990). Elevation levels in HKK range from 100 m to 1,660 m (Trisurat 2004). HKK hosts several habitat types including a DDF, MDF, and a secondary bamboo forest. The area also includes a dry evergreen forest (DEF) and a hill evergreen forest (HEF) (Forest Research Center, 1997). The MDF occurs on a moderate slope and flat areas. The vegetation in the MDF consists of shrubs and creepers. The DDF is scattered in areas with stress related to severe drought. The dominant tree species in DDF are *Shorea obtusa, S. siamensis, S. floribunda, D. obtusifolius,* and *D. tuberculatus*. The vegetation in DDF consists of grasses, seedlings, cycads, and shrubs. Forest fires, which play an important role in shaping the ecosystem, occur annually in the MDF, usually during the dry season (Johnson, 1998; Sirimagorn, 2009). The DEF is found at elevations between 400-1000 m above sea level and is covered by very tall and thick trees. The ground cover in DEF consists of seedlings, palms, ferns, shrubs, and grasses, such as *Lygodium flexuosum, Entada pursaetha,* and *Homonoia riparia*. The HEF is dominated by trees in the Fagaceae (genus *Lithocarpus*, *Castanopsis* and *Quercus*), Podocarpaceae and Cephalotaraceae family (Forest Research Center, 1997).

The annual temperatures in HKK range between 8-38°C, with the lowest temperature in January and the highest in April. The mean annual rainfall is 1,375 mm. The dry season spans from November to April with a mean rainfall of 298 mm, while the wet season occurs during May to October with a mean rainfall of 1,088 mm (The Western Forest Complex Ecosystem Management Project, 2003; Western Forest Complex, 2004). The area is home to large carnivores including tiger (*Panthera tigris*), leopard (*Panthera pardus*), and dhole (*Cuon alpinus*) and important herbivores including banteng (*Bos javanicus*), sambar deer (*Rusa unicolor*), gaur (*Bos guarus*), wild pig (*Sus scrofa*), and red muntjac (*Muntiacus muntjak*) (Petdee, 2000; The Western Forest Complex Ecosystem Management Project, 2003; Simcharoen, 2008; Simcharoen *et al*., 2014).

Field sampling

The twig-count method (Shafer, 1963) was applied to collect samples from two sites: Site 1 in MDF, and Site 2 in DDF, during October 2017 to March 2018 in. Five and four 100 m long transects were randomly established in the DDF and MDF sites respectively. In addition, 2 m × 5 m sampling plots were constructed at 20 m intervals along the line transects, with 25 plots in DDF and 20 plots in MDF, for a total of 45 plots. All the plot was located around the HKK Head Office, within a radius of 3 km. The identification of species consumed by animals was investigated based on the observation of the consumed plant parts within the plot. The plant species was identified based on the guidelines of the Office of the Forest Herbarium (2014). Moreover, during this study, the identification of ungulates species was based on size and shape of the species' tracks, dung or pellet of the animals surrounding the plot, which clearly showed a differences between banteng and sambar deer.

The browsed plant species were investigated and identified based on which ungulate species consumed them in the sampling plots. For all species, the number of removed plant parts (from the ground to 2 m above ground) were counted. In addition, the same forage plant species, which were not consumed, as well as the species which were not browsed, were also counted. Thirty twigs of adjacent forage species which were grazed by the animal, with a similar average diameter, were collected. Fresh twig samples were labeled and weighed. The twig samples were then dried in an oven at 60° C until they were completely dry (the weight did not change). The final dry weight was recorded and further used for carrying out the capacity calculation.

Frequency of plant species

This term refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage occurrence. It was studied by sampling the study area at several places at random and recorded the name of the species that occurred in each sampling units. It is calculated by the equation:

Frequency (%) = (Number of quadrats in which the species occurred x 100)/ Total number of quadrats studied

Foraging preference

Krueger (1972); Rosiere *et al*. (1975); Petrides (1975) described the foraging preference as the quotient of percentage of foraged species in the diet divided by percentage of the same foraged species in the environment. In other words, a Preference Index can be estimated based on the following equations:

Preference index = percentage of a forage plant consumed by the animal/percentage of plant availability at the site

where,

Percentage of forage plant consumed by animal = (dry weight of the forage plant consumed by the animal x100)/dry weight of all forage species consumed by the animal

Percentage of the plant available at the site = (dry weight of the forage plant at the site x 100)/dry weight of all forage species at the site

If the preference index is greater than 1, it indicates a degree of attractiveness. In contrast, if the preference index is lower than 1, it indicates a degree of unattractiveness. A preference index of 1 demonstrates that a species is eaten in proportion to its abundance in the environment.

Carrying capacity

The carrying capacity refers to the forage dry matter available per unit of dry matter required for a particular animal in the study area. To evaluate the daily requirement of ungulates in this study, we adopted a "ruminant daily dry matter intake of at least 3-3.5% of the body weight" (Stuth and Sheffield, 1986; National Research Council, 1987). The available dry matter for foraging was calculated based on the dry weight of twigs sample's, using data from the foraging preference data (the total dry weight of all foraged species at the site). Moreover, a comparison of the available

forage, between DDF and MDF, was done by using the Student's t - test.

RESULTS AND DISCUSSIONS

A total of 4,466 twigs of the understory trees were counted in the study area (MDF and DDF). In addition, 132 species in 83 genera and 51 families were identified. *Helicteres angustifolia* had the highest frequency (0.73) followed by *Desmodium* sp. (0.46), *Ellipeiopsis cherrevensis* (0.46), and *Eupatorium odoratum* (0.40), respectively. The dominant families (based on number of species) were Fabaceae (13 species), Euphorbiaceae (5 species), Rubiaceae (5 species), Caesalpiniaceae (4 species), and Verbenaceae (4 species), respectively.

Food and foraging preferences of banteng

The results suggested that banteng consumed several different plant species in DDF and MDF. In particular, it selected 34 forage plants in DDFs (of a total 84 species found in the study area). We found that the top five species, most frequently consumed by banteng, were *Desmodium* sp., *Shorea obtusa*, *Ellipeiopsis cherrevensis, Helicteres angustifolia,* and Poaceae sp.2, with a consumption quantity of 37.4, 12.7, 10.9, 10.3, and 10.0 kg-dry weight/sq. km, respectively.

The foraging preference analysis indicated that 22 species were eaten at higher frequency relative to their abundance in the DDF. The top 5 preferred plants were *Phyllanthus emblica, Meliantha suavis, Flacourtia rukam, Sindora siamensis,* and Poaceae sp.1, with a preference index of 7.2, 5.2, 4.8, 4.8, and 3.6, respectively (Figure 1). While these top 5 preferred species were heavily consumed by banteng, their availability at the site was very low (0.09%, 0.03%, 0.12%, 0.10%, and 0.13%) (Figure 1).

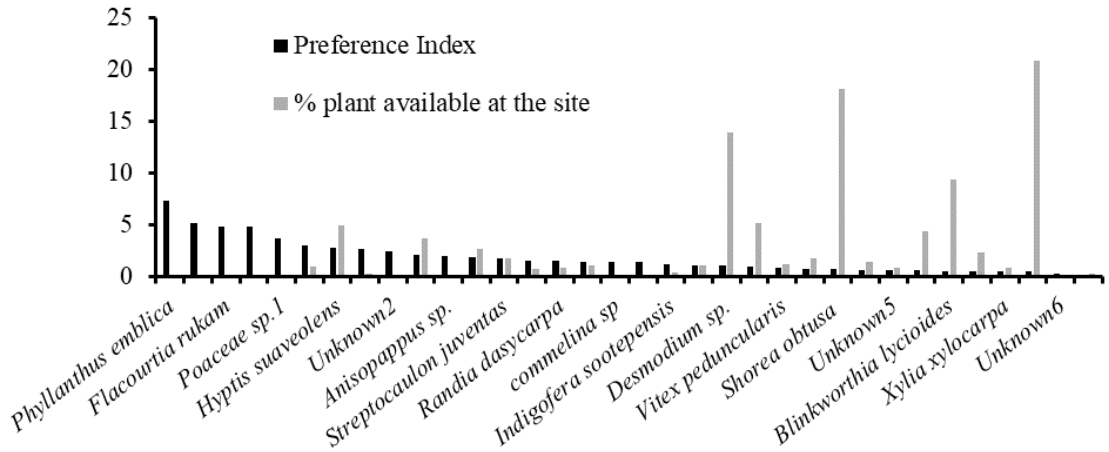

Figure 1 Preference index and percentage plant availability for banteng at the sites in the DDF.

This suggests that the banteng actively selected these species. With a low availability in the surroundings, these species became relatively unimportant in the banteng's diet grazing in the DDF. In addition, our data indicated that the top 5 species, present in high percentage in both the diet and in the environment, were *Desmodium* sp., *H. angustifolia, Hyptis*

suaveolens, Poaceae sp.2, and *Pterocarpus macrocarpus*. Thus, these five species were considered as the most important for a banteng's diet in this habitat.

Based on a total of 68 of plant species in the study area, the banteng fed on at least 33 species of plants in the MDF and 3 of them were also found in the banteng diet in DDF. The top 4 species consumed by banteng consisted of *H. angustifolia, Tiliacora triandra, H. isora,* and *Millettia leucantha* with a quantity of approximately 78.3, 40.0, 14.0 and 13.7 kg-dry weight/sq. km, respectively.

The foraging preference analysis demonstrated that 19 species were consumed at a higher proportion than their availability in the environment. The top 5 plants having the highest preference indices were 3.9 (*Dalbergia foliacea, H. Isora* and *Ventilago denticulata*), followed by 3.7 (Unknown7), 3.0 (*Aganonerion polymorphum)*, 2.7 (*M. leucantha*), and 2.6 (*Desmodium* sp.), respectively (Figure 2).

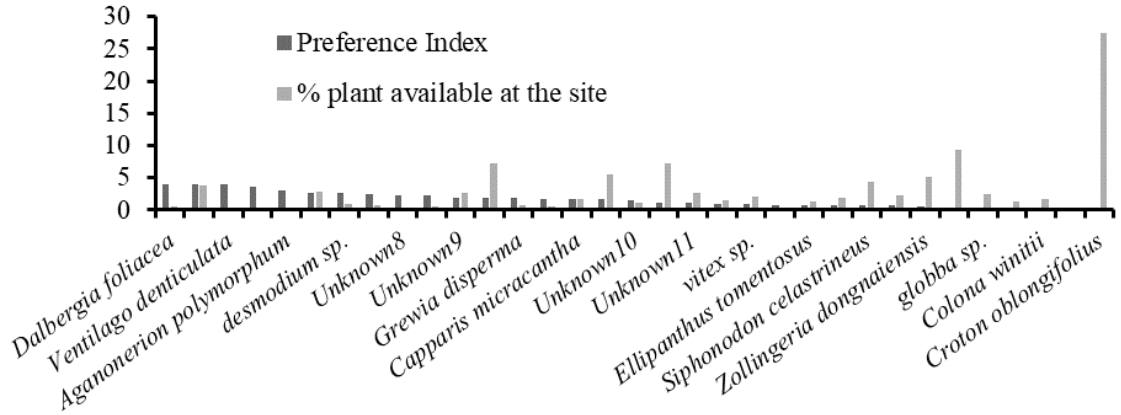

Figure 2 Preference index and percentage plant availability at the site for banteng in the MDF.

It was observed that *D. foliacea, V. denticulate,* Unknown7, and *A. polymorphum,* were preferred by banteng with preference indices of 3.9, 3.9, 3.7, and 3.0 respectively, while their abundance in nature was relatively low (0.53%, 0.09%, 0.43%, and 0.05%, respectively). The variation in the consumption of forage species by an ungulate may be due to the amount of nutrients in the forage species. Earlier, Dostaler *et al*. (2011) had reported that level of crude protein, in a forage species, was positively related with the feeding preferences, particularly as summer progressed. Feeding preferences were also negatively related to fiber content, especially during the early summer and further investigations are needed.

The results also illustrated that 5 preferred species with a high availability in both the environment and banteng diet were *H. isora, M. leucantha, H. angustifolia, Caesalpinia enneaphylla,* and *T. triandra.* Therefore, these five species were the most important food sources for banteng in this MDF.

Although our results reported a total of 64 plant food species consumed by banteng in the HKK, 34 species were found in DDF and 33 species in MDF, while 3 species were

found in both the forest types. This result was consistent with Prayurasiddhi (1988), who reported more than 59 food species consumed by banteng in HKK, but the species composition observed in the two studies are different. This was due to the differences in season when the study was conducted and the microhabitat of sampling areas.

Food and foraging preference of the sambar deer

This study investigated the food and foraging preferences of the sambar deer only in the DDF as the tracks and also the pellets left by the sambar deer did were not found in the sampling plots of MDF. Based on the field data, it was observed that the sambar deer consumed 18 plant species out of 84 species recorded at the site. Our estimation suggests that the sambar deer ate 10.0 kg –dry weigh / sq. km of *H. Angustifolia*, 8.4 kg-dry weight/ sq. km of *Bauhinia* sp., 6.2 kg dry-weigh/sq. km of *Streptocaulon juventas* sp., 5.3 kg-dry weigh/sq. km of *Jasminum and* 4.2 kg-dry weigh/sq. km of *Xylia xylocarpa*.

Among these 18 forage species, we found that 11 species were eaten at a higher proportion than their availability in the environment. The top 5 most favorable plants were Unknown6*, Bauhinia* sp.*, D. cana, Vitex peduncularis,* and *Jasminum* sp. with a preference index of 4.7, 4.3, 3.1, 2.3, and 2.0, respectively (Figure 3).

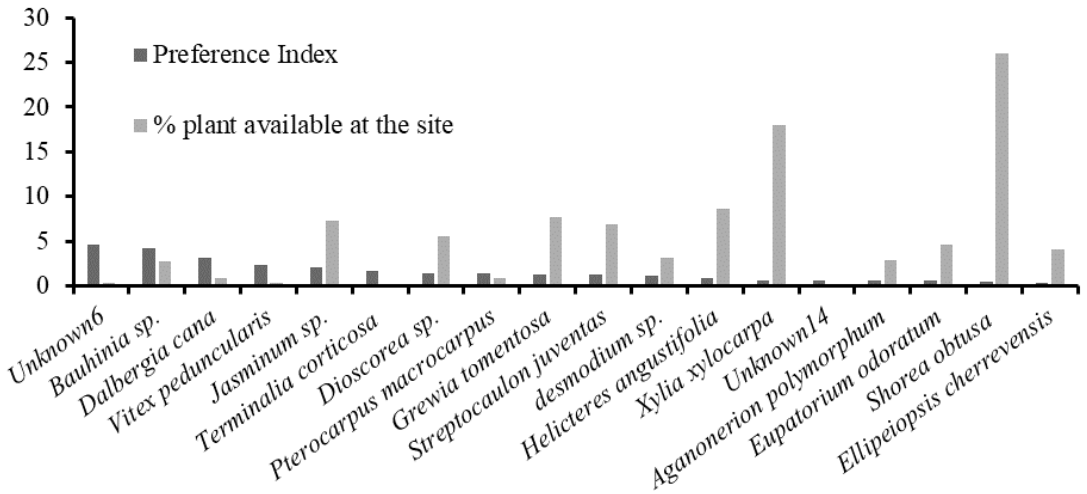

Figure 3 Preference index and percentage plant availability, for the sambar deer, in at the DDF site.

While these 5 foraging species were heavily consumed by the sambar deer, their availability in the site was very low (0.35 %, 0.92 %, 0.29 %, 0.13%, and 0.88%) (Figure 3). This suggested that the sambar deer preferred to feed these species, and as a result, the plants were scarce in DDF and became relatively unimportant for the diet of the sambar deer.

Moreover, the data suggested that the top 5 species available in a high percentage in the environment and in the diet were *Bauhinia* sp., *Jasminum* sp.*, Dioscorea* sp.*, Grewia*

tomentosa, and *S. juventas.* Thus, these five species were the most important food for the sambar deer in this DDF.

Our study suggested that at least 18 forage species, consumed by the sambar deer, had a similar species composition as reported by Sukmasuang (2004), who listed 13 food species consumed by the sambar deer in HKK. However, a different number of species between both the studies may be due to seasonal and spatial differences when the studies were conducted.

Carrying capacity

A total of 4,466 twig samples from 132 plant species were collected. Among these, only 64 species (3,234 twigs) were forage plants and only the forage species were used to estimate the carrying capacity. The results suggested that the DDF provided 5,288.5 (3,157.5 – 7,419.5) kg of dry matter from forage plants/sq.km/month, while the MDF provided 4,375.6 (3,582.4 – 5,168.7) kg of dry matter from forage plants/sq.km/month. However, a Student's *t* - test showed no significant difference between the average dry matter from the forage plant in the DDF and MDF (t = 0.7869, *p-value* = 0.4391, df = 23.67).

For carrying capacity analysis, we used 700 kg and 220 kg average weights for banteng and sambar deer, according to Lekagul and McNeely (1977), respectively. Additionally, an assumption that herbivores generally consume between 3-3.5% of their live weight of dry matter , daily (Stuth and Sheffield, 1986; National Research Council, 1987). The results were calculated in three scenarios: 1) only banteng present in the environment, DDF could support 5.0 to 11.8 animals/sq. km while MDF could support 5.7 to 8.2 animals/sq. km; 2) only sambar deer present in the environment, DDF could support 13.7 to 32.1 sambar deers/sq. km, and MDF could support 15.5 to 22.4 sambar deers/sq. km; 3) both banteng and sambar deer present in the environment and they share equal resources in the area, DDF could support 2.5 to 5.9 bantengs and 6.8 to 16.0 sambars/sq. km, while MDF could support 2.8 to 4.1 bantengs and 7.8 to 11.2 sambars/sq. km. (Table1).

Table 1 Carrying capacity of DDF and MDF in the three different scenarios.

Scenario	forest type	DM available/ month	banteng intake/month[a]	sambar intake/ month[b]	available/ intake	95% CI	No of animals/sq. km
only banteng	DDF	5288.48	630		8.39	3.38	5.01 - 11.78
	MDF	4375.56			6.95	1.26	5.69 - 8.20
only sambar	DDF	5288.48		231	22.89	9.23	13.67 - 32.12
	MDF	4375.56			18.94	3.43	15.51 - 22.38
banteng with sambar	DDF	2644.24	630		4.20	1.69	2.51 - 5.89
	MDF	2187.78			3.47	0.63	2.84 - 4.10
	DDF	2644.24		231	11.45	4.61	6.83 - 16.06
	MDF	2187.78			9.47	1.72	7.75 - 11.19

Note: a,b = Ruminant wildlife factors for estimating the daily forage demand, 3.0% daily for banteng and 3.5% daily for sambar, adapted from Stuth and Sheffield (1986)

These results were consistent with Sukmasuang *et al.* (2000), who reported a banteng and sambar deer population density of 2.01 and 4.03 animals/sq. km, respectively. In addition Srikosamatara and Suteethorn (1995) suggested that the banteng density was well below 50% of the carrying capacity in HKK. Simcharoen *et al.* (2007) reported that the tiger population in the area was 3.98 (0.51) tigers per 100 sq. km. One tiger requires an average of 3,000 kg/year of prey meat (Karanth, 2003). Thus, within an area of 100 sq. km, 12,000 kg of prey mass should have supported approximately 4 tigers/year in this area. On an average, only 2.5 % of minimum body mass was gained by the two ungulate species, within a 100 sq. km, based on scenario 3. The results of this study indicated that the area showed a very high potential to support the tiger and other large carnivore species population, if a habitat improvement is promoted. Jotikapukkana *et al*. (2010) reported that in general, the HKK buffer zone was a suitable habitat for several wildlife species. The sambar is the most widespread and common large deer in this region (Trisurat, 2004) and also in HKK. The banteng is rare in most areas (Francis, 2001), with the largest population in Thailand found in this sanctuary (Gardner *et al*., 2016) and with regular occurrence in the HKK buffer zone. When the sambar deer and banteng were included in the statistical analysis of factor s influencing the occurrence of different wildlife species, the results suggested that the occurrence of three species, sambar deer, banteng, and elephant, was negatively associated with the occurrence of domestic animals in the buffer zone area studied in HKK (Jotikapukkana *et al*., 2010). So, a habitat improvement through improving the water sources, saltlick sites, forest gap, or grassland improvement by man-made cutting or prescribe burning in the

MDF and DDF should be undertaken inside the area far from the sanctuary boundary or buffer zone.

CONCLUSION

1. Banteng in HKK preferred to consume the following forage species: *P. emblica, M. suavis, F. rukam, S. siamensis,* and *Poaceae* sp. in DDF; and *D. foliacea, H. isora, V. denticulate,* and *A. polymorphum* in MDF. However, these preferred species were found in low quantity in the environment. On the other hand, some species which were also preferred by banteng and abundant in the environment became important forage species for it. These species consisted of *Desmodium* sp. *H. angustifolia, Hyptis suaveolens, Poaceae sp.,* and *P. macrocarpus* in the DDF and *H. isora, M. leucantha, H. angustifolia, C. enneaphylla,* and *T. triandra* in the MDF.

2. Sambar deer in the HKK preferred to feed on *Bauhinia* sp*., D. cana, V. peduncularis,* and *Jasminum* sp. The species which were quantitatively important in the diet of sambar and present in large quantity in the environment were *Bauhinia* sp., *Jasminum* sp*., Dioscorea* sp*., G. tomentosa,* and *S. juventas*.

3. DDF and MDF could support 5.01 to 11.78 animals/sq. km and 5.69 to 8.20 animals/sq. km, respectively, if only banteng was present in the surroundings. DDF could support 13.67 to 32.12 sambars/sq. km and MDF can support 15.51 to 22.38 sambars/sq. km if only sambar deer was present in the surroundings.

4. Based on the results of this study, the carrying capacity analysis of the DDF could support 2.51 to 5.89 bantengs/sq. km and 6.83 to 16.06 sambars/sq. km; whereas the MDF could support 2.84 to 4.10 bantengs/sq. km and 7.75 to 11.19 sambars/sq. km. We also determined that on an overall basis, the area can support higher numbers of banteng and sambar than currently found in the area.

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