Temporal overlap of carnivorous mammal community and their prey in Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao Province, Thailand

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Abstract. *Sukmasuang R, Charaspet K, Reontik J, Pla-ard M. 2020. Temporal overlap of carnivorous mammal community and their prey in Khao Ang Rue Nai Wildlife sanctuary, Chachoengsao Province, Thailand. Biodiversitas 21: 922-932.* This study on the temporal overlap of the carnivorous community and their prey in Khao Ang Rue Nai Wildlife Sanctuary was conducted from March 2017 to February 2018. Camera traps were deployed systematically with a total of 4,463 trap nights. Fourteen carnivorous mammals were recorded, which were mainly present at night, with the exception of the dhole, small Indian mongoose, crab-eating mongoose, and yellow-throated marten. The clouded leopard's presence overlapped between day and night. Using the average coefficient overlap(Δ) between a carnivore, and the other carnivorous species, the leopard cat was found to have the highest Δ value, followed by the hog badger, Asiatic jackal, small Indian civet, Asian palm civet, large Indian civet, large spotted civet, Asiatic black bear, dhole, Malayan sun bear, yellow-throated marten, small Indian mongoose, crab-eating mongoose, and clouded leopard. The potential prey species that had the highest Δ with the carnivorous species, was the Siamese hare. This study shows the importance of preserving the carnivorous community within the area. An important threat is a likelihood that carnivorous species in the area may be exposed to external diseases from infected domestic animals when coming out to hunt in the communities surrounding the protected area.

Keywords: Camera trap, eastern forest complex, predator and prey, overlap package

INTRODUCTION

The rainforests are home to a complex diversity of animals, which include many carnivorous species located at the top of the trophic networks (Ridout and Linkie 2009). Carnivores are a particularly difficult species to study due to their ability to evade (Van Schaik and Grifthths 1996), with very few studies conducted on the interaction between carnivores and their prey in tropical areas. These studies are important to conduct, as they provide ecological data to help understand the components and mechanisms of the interactions within a dynamic and changing ecosystem (Hongliang et al. 2016). Previous studies have examined the activity and temporal overlap of wild species using the time recorded on photographs taken by camera traps (Laidlaw and Shaharuddin 1998; Kawanishi and Sunquist 2004; Di Bitetti et al. 2009; Di Bitetti et al. 2010; Monterroso et al. 2013; Sunarto et al. 2015) and via determining the temporal overlap of carnivorous species in tropical forests (Karanth and Sunquist 1995; Ray and Sunquist 2001; Scognamillo et al. 2003; Lynam et al. 2013). Nevertheless, studies are still lacking in the eastern forests of Thailand, including Khao Ang Rue Nai Wildlife Sanctuary (KARN), where the interaction of the temporal overlap of carnivores, and the time presence relationship with their prey species, have yet to be established. The information obtained, is essential to carry out conservation plans for both the animal species studied and the natural environments (Frey et al. 2017). Accordingly, the aims of this study were to (i) study the overall time presence of

carnivorous mammals in the KARN area, (ii) study the activity cycle of each carnivorous species, and (iii) study the temporal overlap of carnivorous species, including their relationship with their prey by camera trapping in the area.

MATERIALS AND METHODS

Study area

Khao Ang Rue Nai (KARN) Wildlife Sanctuary, Chachoengsao Province, Thailand is located between longitude 101° 35' and 102° 05' E, and between latitude 13° and 13° 30' N, with a total area of approximately 1,030 km². It is a large dry evergreen forest, which was once connected to Cambodia, and is one of the world's important protected areas for both wild species and their habitats. It is now connected to 7 protected areas, adding to a total of 1,705 km². KARN is the largest most important protected area in the east of Thailand. It is home to at least 531 species of vertebrates including 290 species of birds, 122 species of mammals, 90 species of reptiles, 29 species of amphibians and at least 47 species of fish. The terrain of the sanctuary is moderately sloping and was once encroached before the evacuation of humans out of the area due to Thai government recognizes the importance of preserving this forest area for conservation rather than changing it to agricultural land and human settlement. The southwestern, northeastern and southeastern parts have high mountains, and the elevation of the area varies from 30-802 meters above sea level. The highest peak is in the

southeast, called Khao Sib Ha Chan, which reaches 802 meters above sea level. The plant communities are mainly dry evergreen forest with only little areas of mixed deciduous, dry dipterocarp and grassland (Department of National Parks Wildlife and Plant Conservation: DNP 2018). The study was conducted in the upper and middle parts of KARN, covering an area of 88.12 km^2 when drawing a line connecting the outer camera trap locations, or when adding the buffer area with a radius of 1 km from the border (e.g. Kelly and Holub 2008) because of the movement of wildlife around the area.

Procedures

Camera traps were placed in 58 locations in Khao Ang Rue Nai Wildlife Sanctuary, in the Chachoengsao Province. The cameras were deployed from March 2017 to February 2018, adding up to a total of 4,463 trap nights; the details are as follows. (i) The 1: 50,000 topographic map was divided into 1 km^2 grid. One camera trap was placed per one grid (Gupta et al. 2009; Jenks et al. 2011; Siripattaranukul et al. 2015a, b). Cameras were set up in 15-20 grids and left for 60 days in each location before moving to a new location (Figure 1). Each camera location was at least 500 m apart to enable independence of the photographs in each grid, and to reduce the possibility of recording the same animal across several cameras (Jenks et al. 2012). (ii) Camera trap location selection was considered from the suitability of the area, e.g., animal trails or signs of carnivorous species. Information around the location was collected including the plant community, roads, patrol routes, permanent water sources, salt licks, ponds and ranger stations (Prayoon et al. 2012; Lynam et al. 2013; Wongchoo et al. 2013; Siripattaranukul et al. 2015a,b). (iii) Camera traps were set up approximately 30-40 cm from the ground, 3-4 m away from the target point (Chutiponget al.2014a,b) or following the suitability of the area. The cameras were set to work 24 hours and take 3 consecutive photographs, 10 seconds apart, after the sensor was triggered (Network 2008). The cameras were placed for 60 days and then moved to new locations, which were recorded with a GPS tracker. (iv) The photographs taken by the camera traps were imported into a computer and classified in the Camera Trap Manager Program (Zaragozí et al. 2015) and added to Microsoft Excel for data analysis.
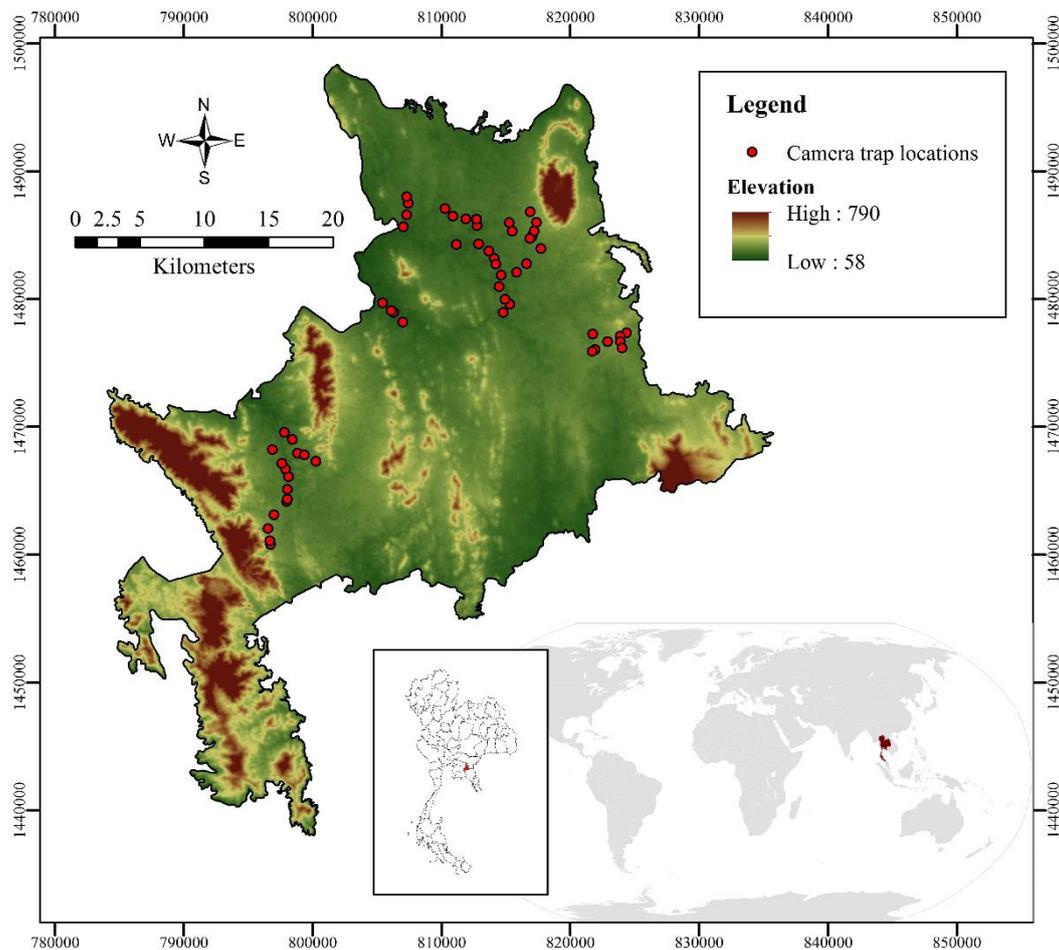

Figure 1. Map of Khao Ang Rue Nai Wildlife Sanctuary and the camera trap locations (n=58 with 4,463 trap nights in total)

Data analysis

(i) The carnivores were classified using their common and scientific names, following Lekagul and McNeely (1988). Only photographs that could be clearly identified with the date and time on the photograph were used. Photographs with more than one carnivore were counted as 1 incidence of each (Jenks et al. 2011), and were considered to be photos or incidences that were independent of each other. The criterion for independence of animal photographs used, included (1) consecutive photographs of different animals, which could be the same or different species, (2) consecutive photographs of the same animal of the same species that were taken more than 30 minutes apart, and (3) nonconsecutive photographs of the same animal of the same species (O'Brien et al. 2003). (ii) The time data from the photographs were summarised by compiling the data and classifying by species. The time period was divided into morning from 06:01-17:59 hrs and night between 18:00-06:00 hrs (Azlan et al. 2009). The data were then used to produce activity cycle graphs for carnivorous species and prey species, respectively. (iii) Time was divided into 24 hours. The activity periods of each species were classified from the photographs and divided into 2 periods, morning from 06:01-17:59 hrs and night between 18:00-06:00 hrs (Azlan and Sharma 2006; Azlan et al. 2009). The percentage of each time period for each species was calculated and the animals were divided into 5 groups following the method by Van Schaik and Griffiths (1996): if the number of photographs at night was more than 85%, the species was classified as strongly nocturnal, if the number of photographs at night was between 61-84%, the species was classified as mostly nocturnal, animals photographed at night and day time in between 40-60%, were classified as cathemeral, species photographed during the day between 61-84%, were classified as mostly diurnal, and animals with a number of day time photographs of more than 85%, were classified as strongly diurnal. (iv) Calculating the style of the temporal overlap on the photographs between carnivorous species and prey species was performed using the method developed by Ridout and Linkie (2009), who used kernel density estimation (Fernandez-Duran 2004) to test the degree of the temporal overlap of the 2 species studied; called the coefficient of overlap (Δ). This is related to the area under the graph, or curve that shows the time of presence of both species together. For the function of the minimum density in each area of the 2 species compared, Δ =1 means that the activity overlaps, while Δ = 0 means no activity overlap was found. Calculating the confidence of Δ was performed using 500 bootstraps with R program version 2.11.1 (R Development Core Team 2009) following Linkie and Ridout (2011).

RESULTS AND DISCUSSION

Diel activity patterns

From studying the activity cycle of the 14 species of carnivores, from 782 photographs, it was found that the carnivores that were in the strongly nocturnal group were Asiatic black bears, Malayan sun bears, large Indian civets, large-spotted civets, and Asian palm civets. The group that was mostly nocturnal included Asiatic jackals, hog badgers, small Indian civets, and leopard cats. The cathemeral group included the clouded leopard. The mostly diurnal group included the dhole, and the strongly diurnal group included the yellow-throated marten, small Indian mongoose, and crab-eating mongoose, as shown in Table 1.

Temporal overlap of carnivorous species

In studying the activity cycles, from the overlapping areas of the two carnivorous species, the carnivore that had the highest temporal overlap with the Asiatic jackal was the small Indian civet, with a coefficient of overlap (Δ) value of 0.83, followed by the leopard cat (0.81), hog badger (0.76), large-spotted civet (0.74), Asian palm civet (0.73), large Indian civet (0.72), Asiatic black bear (0.63), dhole (0.51), Malayan sun bear (0.37), yellow-throated marten (0.36), crab-eating mongoose (0.33), small Indian mongoose (0.26) and clouded leopard (0.13).

The carnivore with the highest temporal overlap with the dhole was the yellow-throated marten, with a Δ value of 0.74, followed by the crab-eating mongoose (0.70), small Indian mongoose (0.62), Asiatic jackal (0.51), leopard cat (0.44), small Indian civet (0.41), yellow-throated marten (0.35), hog badger (0.33), large-spotted civet (0.27), large Indian civet (0.26), clouded leopard (0.23) and Asiatic black bear (0.14).

The carnivore with the highest temporal overlap with the Asiatic black bear was the large Indian civet, with a Δ value of 0.82, followed by hog badger (0.78), large-spotted civet (0.74), small Indian civet (0.70), leopard cat (0.62), and yellow-throated marten (0.46).

The carnivore with the highest temporal overlap with the Malayan sun bear, was the large-spotted civet and hog badger, with Δ values of 0.51 for both species, followed by the small Indian civet (0.50), leopard cat (0.48), large Indian civet (0.46), large-spotted civet (0.39), and clouded leopard (0.34). The carnivore with the highest temporal overlap with the clouded leopard was the Malayan sun bear, with a Δ value of 0.34, followed by dhole, large-spotted civet, small Indian mongoose, and leopard cat, all having the same Δ value of 0.23. The details are shown in Table 2.

Temporal overlap between carnivorous mammals and prey species

In studying the coefficient of overlap between the time recorded from photographs taken between carnivores and their prey, it was found that when comparing important species, the species which had the highest activity overlap with the Asiatic jackals, was the Siamese hare, with a Δ value of 0.72. This was followed by the murid rodent (0.70), Sambar deer (0.65), common muntjac (0.64), gaur (0.63), banteng (0.63), lesser mouse-deer (0.62), wild boar (0.58) and pig-tailed macaque (0.36), respectively. The species with the highest activity overlap with dholes was the wild boar, with a Δ value of 0.88, followed by the common muntjac (0.80), lesser mouse-deer (0.80), pig-tailed macaque (0.75), gaur (0.42), banteng (0.41), Sambar

deer (0.39), Siamese hare (0.40) and murid rodent (0.24). The species with the highest activity overlap with Asiatic black bear was the murid rodent, with aΔ value of 0.87, followed by Sambar deer (0.73), Siamese hare (0.66), gaur and banteng (equal values of 0.47), common muntjac (0.29), lesser mouse-deer (0.28), wild boar (0.22) and pig-tailed macaque (0.04). The species with the highest activity overlap with the Malayan sun bear was the Sambar deer, with a Δ value of 0.64, followed by Siamese hare (0.56), gaur (0.49), lesser mouse-deer (0.48), murid rodent (0.46), banteng (0.46), wild boar (0.36), common muntjac (0.37) and pig-tailed macaque (0.17). The species with the highest activity overlap with clouded leopard was the gaur, with aΔ value of 0.47, followed by banteng (0.45), Sambar deer (0.32), Siamese hare (0.31), lesser mouse-deer (0.30), pig-tailed macaque (0.17), common muntjac (0.17), wild boar (0.16) and murid rodent (0.11); (Table 3).

The relationship between the presence of carnivorous species and prey species showed that the average Δ of all species from the camera traps was 0.50 (see Table 3). The carnivore that had the highest Δ when compared to all species of prey was the Asiatic jackal and leopard cat, which both had Δ values of 0.61, followed by the small Indian civet (0.59), Asian palm civet (0.58), dhole (0.57), and large Indian civet (0.56). An example of the Δs in carnivorous and prey species are shown in Figure 2.

In examining the relationship between the time of presence of temporal overlap of each prey species with carnivores, it was found that that the highest Δ value of the prey species was the Siamese hare (0.58), followed by the Sambar deer (0.56), murid rodent (0.53), gaur (0.52),

banteng (0.51), lesser mouse-deer (0.50), common muntjac (0.48), wild boar (0.46) and pig-tailed macaque (0.36).

Discussion

The results of this study confirm the presence of 14 species of carnivorous mammals in the study area, which were mostly present at night (9 out of the 14 species). The strongly nocturnal species included the Asiatic black bear, Malayan sun bear, small Indian civet, large Indian civet, large-spotted civet, and Asian palm civet. The majority of nocturnal species included the Asiatic jackal, hog badger, and leopard cat. Four species were found to be diurnal, the yellow-throated marten, small Indian mongoose, and crab-eating mongoose were all strongly diurnal, the dhole was mostly diurnal, and only one species, the clouded leopard, was cathemeral (see Table 1). The number of carnivorous species found in the area was lower than previously reported in Chhep Wildlife Sanctuary, which found 16 species, including leopards and jungle cats (Suzuki et al. 2017). Similarly, we observed a lower number of species compared with a study undertaken in the Cardamom Mountains, which included wetlands and hill forest areas (Holden and Neang 2009). The authors identified 15 carnivorous species, with the additional species in their study being the hairy-nosed otter, smooth-coated otter, and oriental small-clawed otter, respectively. Nevertheless, a greater number of carnivorous species were identified compared to a study conducted in Phnom Prich Wildlife Sanctuary, which only found 13 species (Gray and Phan 2011).
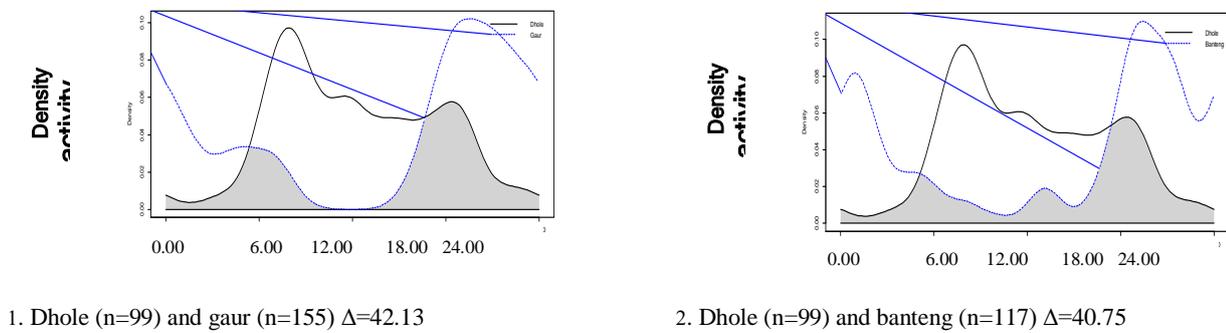

1. Dhole (n=99) and gaur (n=155) Δ=42.13

2. Dhole (n=99) and banteng (n=117) Δ=40.75

Figure 2. Example of diel activity patterns from camera-trap data. Kernel density functions were used to depict dhole and some prey species activity, which was sampled via camera trapping during March 2017 and February 2018, in Khao Ang Rue Nai Wildlife Sanctuary. The overlap coefficient (Δ) is the area under the minimum of the two density estimates (denoted in grey)

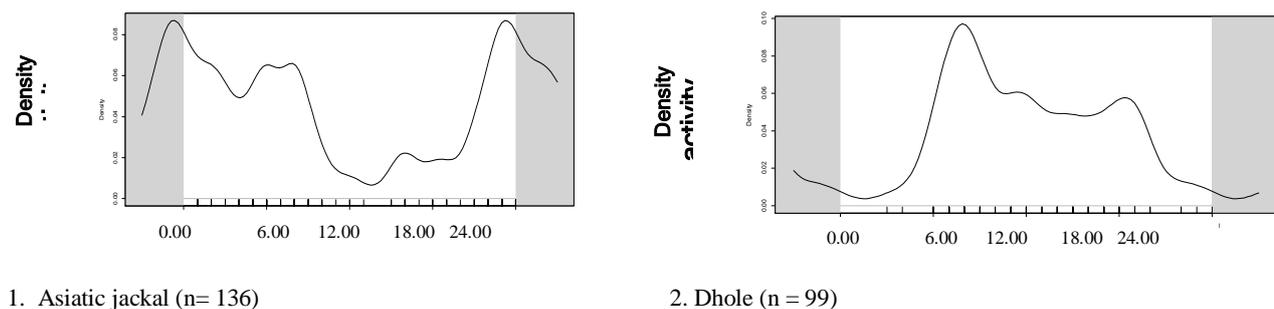1. Asiatic jackal (n= 136)

2. Dhole (n = 99)

Figure 3. Kernel-density estimates of daily activity patterns of example carnivorous mammal species using camera trap data during March 2017 and February 2018, in Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao Province, Thailand

Table 1. Number of detections in day time and night time for categorizing the cathemeral, nocturnal and diurnal periods, shown by their availability, of the carnivores in Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao Province, Thailand

Family, scientific name	Common name	Pictures in day time	%	Pictures in night time	%	N [1]	Periods [2]
Canidae							
Canis aureus	Asiatic Jackal	28	20.59	108	79.41	136	Mn
Cuon alpinus	Dhole	76	76.77	23	23.23	99	Md
Ursidae							
Ursus thibetanus	Asiatic black bear	0	0	2	100.00	2	Sn
Helarctos malayanus	Malayan sun bear	0	0	3	100.00	3	Sn
Mustelidae							
Martes flavigula	Yellow-throated marten	12	100.00	0	0	12	Sd
Arctonyx collaris	Hog badger	2	15.38	11	84.62	13	Mn
Herpestidae							
Herpestes javanicus	Small Indian mongoose	5	100.00	0	0	5	Sd
Herpestes urva	Crab-eating mongoose	13	100.00	0	0	13	Sd
Viverridae							
Viverricula indica	Small Indian Civet	7	17.07	34	82.93	41	Mn
Viverra zibetha	Large Indian Civet	0	0	14	100.00	14	Sn
Viverra megaspila	Large-spotted civet	7	4.38	153	95.63	160	Sn
Paradoxurus hermaphroditus	Asian palm civet	10	5.99	157	94.01	167	Sn
Felidae							
Prionailurus bengalensis	Leopard cat	21	18.26	94	81.74	115	Mn
Neofelis nebulosa	Clouded leopard	1	50.00	1	50.00	2	C
Summary		182		600		782	

Note**:** 1N = Number of photos2, Sn = strongly nocturnal,   Mn = mostly nocturnal,   C = Cathemeral,   Md = mostly diurnal,   Sd = strongly diurnal

Table 2. The overlap coefficient (Δ) calculated using Kernel density functions of large carnivorous mammal species activity sampled via camera trapping during March 2017 to February 2018, in Khao Ang Rue Nai Wildlife Sanctuary, (1=identical activity), with approximate 95% bootstrap confidence intervals in parentheses

Species [1]	DH	ABB	MSB	YTM	HB	SIC	LIC	LSC	APC	SIM	CEM	LC	CL	Average
AJ	0.51	0.63	0.37	0.36	0.76	0.83	0.72	0.74	0.73	0.26	0.33	0.81	0.13	0.55
	(0.51-0.44)	(0.65-0.46)	(0.42-0.36)	(0.36-0.29)	(0.82-0.75)	(0.83-0.86)	(0.83-0.71)	(0.75-0.74)	(0.73-0.73)	(0.29-0.26)	(0.33-0.27)	(0.82-0.79)	(0.21-0.12)	
DH		0.14	0.35	0.74	0.33	0.41	0.26	0.27	0.31	0.62	0.70	0.44	0.23	0.40
		(0.19-0.13)	(0.37-0.37)	(0.74-0.73)	(0.34-0.28)	(0.41-0.32)	(0.28-.008)	(0.27-0.22)	(0.31-0.29)	(0.63-0.60)	(0.70-0.69)	(0.44-0.41)	(0.29-0.23)	
ABB			0.46	0.02	0.78	0.70	0.82	0.74	0.75	0.01	0.02	0.62	0.02	0.46
			(0.50-0.45)	(0.07-0.00)	(0.80-0.76)	(0.70-0.61)	(1.07-0.82)	(0.75-0.74)	(1.24-0.74)	(0.05-0.00)	(0.07-0.00)	(0.63-0.55)	(0.05-0.00)	
MSB				0.13	0.51	0.50	0.46	0.39	0.51	0.20	0.14	0.48	0.34	0.36
				(0.18-0.08)	(0.53-0.51)	(0.53-0.48)	(0.49-0.42)	(0.43-0.28)	(0.52-0.37)	(0.23-0.20)	(0.19-0.14)	(0.51-0.44)	(0.34-0.33)	
YTM					0.17	0.22	0.07	0.09	0.11	0.70	0.91	0.24	0.11	0.31
					(0.20-0.07)	(0.24-0.12)	(0.12-0.00)	(0.12-0.04)	(0.14-0.05)	(0.70-0.58)	(0.93-0.90)	(0.26-0.18)	(0.15-0.11)	
HB						0.83	0.81	0.81	0.85	0.17	0.16	0.82	0.13	0.58
						(0.84-0.83)	(0.84-0.80)	(0.82-0.78)	(0.95-0.83)	(0.19-0.07)	(0.20-0.07)	(0.90-0.82)	(0.20-0.12)	
SIC							0.80	0.78	0.81	0.20	0.21	0.84	0.13	0.54
							(0.80-0.79)	(0.78-0.74)	(0.81-0.80)	(0.24-0.12)	(0.24-0.12)	(0.84-0.83)	(0.20-0.13)	
LIC								0.93	0.89	0.15	0.07	0.81	0.20	0.52
								(1.05-0.92)	(0.98-0.89)	(0.20-0.15)	(0.13-0.00)	(0.86-0.79)	(0.21-0.20)	
LSC									0.86	0.10	0.09	0.80	0.16	0.49
									(0.86-0.85)	(0.13-0.05)	(0.13-0.05)	(0.81-0.79)	(0.17-0.16)	
APC										0.18	0.12	0.83	0.23	0.53
										(0.25-0.18)	(0.15-0.05)	(0.83-0.82)	(0.25-0.23)	
SIM											0.71	0.26	0.23	0.30
											(0.73-0.70)	(0.34-0.26)	(0.25-0.23)	
CEM												0.24	0.18	0.26
												(0.24-0.14)	(0.23-0.18)	
LC													0.23	0.63
													(0.23-0.23)	
CL														0.46

Note**:** AJ: Asiatic Jackal, DH: Dhole, ABB: Asiatic black bear, MSB: Malayan sun bear, LC: Leopard cat, LIC: Large Indian Civet, LSC: Large-spotted civet, APC: Asian palm civet, SIM: Small Indian mongoose, CL: Clouded leopard, YTM: Yellow-throated marten, HB: Hog badger, SIC: Small Indian Civet, CEM: Crab-eating mongoose

Table 3. The overlap coefficient (Δ) calculated using Kernel density functions of large carnivorous mammal species and their prey activity sampled via camera trapping during March, 2017 and February, 2018, in Khao Ang Rue Nai Wildlife Sanctuary, (1=identical activity), with approximate 95% bootstrap confidence intervals in parentheses.

Species	GA	BT	SB	RM	WB	PM	SH	LD	MR	Average
AJ	0.63	0.63	0.65	0.64	0.58	0.36	0.72	0.62	0.70	0.61
	(0.65-0.63)	(0.72-0.63)	(0.67-0.65)	(0.65-0.64)	(0.58-0.57)	(0.36-0.35)	(0.81-0.72)	(0.63-0.58)	(0.70-0.69)	
DH	0.42	0.41	0.39	0.80	0.88	0.75	0.40	0.80	0.24	0.57
	(0.43-0.42)	(0.43-0.41)	(0.40-0.34)	(0.80-0.78)	(0.92-0.77)	(0.74-0.71)	(0.39-0.34)	(0.84-0.79)	(0.25-0.16)	
ABB	0.47	0.47	0.73	0.29	0.22	0.04	0.66	0.28	0.87	0.45
	(0.49-0.32)	(0.50-0.39)	(0.81-0.96)	(0.33-0.22)	(0.26-0.18)	(0.08-0.02)	(0.64-0.67)	(0.32-0.26)	(1.06-0.87)	
MSB	0.49	0.46	0.64	0.37	0.36	0.17	0.56	0.48	0.46	0.44
	(0.53-0.48)	(0.47-0.45)	(0.65-0.63)	(0.42-0.34)	(0.40-0.35)	(0.20-0.13)	(0.57-0.50)	(0.61-0.48)	(0.47-0.33)	
YTM	0.22	0.22	0.18	0.65	0.75	0.94	0.17	0.57	0.08	0.42
	(0.24-0.18)	(0.24-0.21)	(0.20-0.16)	(0.68-0.65)	(0.80-0.74)	(1.05-0.93)	(0.20-0.05)	(0.57-0.43)	(0.12-0.03)	
HB	0.62	0.56	0.73	0.43	0.38	0.19	0.76	0.48	0.83	0.55
	(0.61-0.71)	(0.77-0.55)	(0.91-0.72)	(0.47-0.42)	(0.39-0.37)	(0.20-0.13)	(0.89-0.75)	(0.53-0.44)	(0.88-0.82)	
SIC	0.60	0.64	0.73	0.53	0.46	0.24	0.81	0.56	0.78	0.59
	(0.60-0.57)	(0.68-0.63)	(0.73-0.72)	(0.54-0.49)	(0.47-0.41)	(0.25-0.17)	(0.82-0.80)	(0.56-0.55)	(0.78-0.78)	
LIC	0.67	0.68	0.78	0.37	0.29	0.10	0.83	0.43	0.85	0.56
	(0.68-0.66)	(0.75-0.67)	(0.88-0.77)	(0.39-0.25)	(0.31-0.18)	(0.13-0.06)	(0.83-0.71)	(0.43-0.26)	(0.91-0.84)	
LSC	0.66	0.66	0.72	0.38	0.31	0.12	0.81	0.40	0.83	0.54
	(0.66-0.68)	(0.66-0.65)	(0.72-0.70)	(0.39-0.38)	(0.32-0.31)	(0.13-0.11)	(0.81-0.80)	(0.41-0.31)	(0.84-0.81)	
APC	0.73	0.73	0.80	0.39	0.32	0.14	0.85	0.44	0.80	0.58
	(0.75-0.73)	(0.73-0.72)	(0.83-0.79)	(0.40-0.35)	(0.33-0.29)	(0.15-0.12)	(0.89-0.84)	(0.44-0.37)	(0.82-0.80)	
SIM	0.25	0.29	0.25	0.54	0.55	0.69	0.27	0.51	0.08	0.38
	(0.29-0.24)	(0.31-0.28)	(0.27-0.24)	(0.55-0.11)	(0.57-0.48)	(0.70-0.58)	(0.28-0.25)	(0.53-0.49)	(0.11-0.03)	
CEM	0.26	0.26	0.20	0.59	0.72	0.89	0.18	0.57	0.08	0.42
	(0.27-0.25)	(0.27-0.23)	(0.22-0.15)	(0.59-0.58)	(0.71-0.76)	(0.88-1.06)	(0.22-0.05)	(0.57-0.50)	(0.12-0.03)	
LC	0.72	0.68	0.72	0.55	0.47	0.27	0.80	0.58	0.69	0.61
	(0.71-0.73)	(0.68-0.58)	(0.72-0.71)	(0.55-0.52)	(0.47-0.46)	(0.27-0.25)	(0.80-0.79)	(0.58-0.49)	(0.69-0.68)	
CL	0.47	0.45	0.32	0.17	0.16	0.17	0.31	0.30	0.11	0.27
	(0.46-0.50)	(0.44-0.47)	(0.31-0.34)	(0.15-0.23)	(0.14-0.22)	(0.15-0.25)	(0.30-0.33)	(0.29-0.32)	(0.09-0.15)	
Average	0.52	0.51	0.56	0.48	0.46	0.36	0.58	0.50	0.53	0.50

Note: GA: Gaur, BT: Banteng, SB: Sambar deer, RM: Red muntjac, B: Wild boar, PM: Pig-tailed macaques, SH: Siamese hare, LD: Lesser mouse deer, MR: Murid rodent , AJ: Asiatic Jackal, DH: Dhole, ABB: Asiatic black bear, MSB: Malayan sun bear, YYTM: Yellow-throated marten, HB: Hog badger, SIC: Small Indian Civet, LIC: Large Indian Civet, LSC: Large-spotted civet, APC: Asian palm civet, SIM: Small Indian mongoose, CEM: Crab-eating mongoose, LC: Leopard cat, CL: Clouded leopard

In agreement with past studies, we found carnivores in KARN to be mostly active at night (Simchareon 1990; Van Schaik and Griffiths 1996; Sribuarod 1999; Kanchanasaka 2001; Gonzalez-Maya et al. 2009; Wongchoo et al. 2013; Siripattaranugul et al. 2015a, b), generally observing the carnivores to have the highest activity cycle during 00:00-06:00 hrs, and 06:00-08:00 hrs, respectively. The activity of the carnivores was subsequently observed to decrease and reach the lowest values from 12:00-13:00 hrs, with only the dholes, found to have additional activities during the day. Wongchoo et al. (2013) found that the behaviors of the viverrids were nocturnal, with activity observed between 18:00-06:00 hrs, and peaking at dusk from 19:00-22:00 hrs, and before dawn, between 04:00-06:00 hrs, respectively. An example Δ of carnivorous species' daily activities are shown in Figure 3.

In determining the Δ between carnivorous species in the study area, the Δs for nocturnal animals were greater than for the diurnal species (large Indian civet, large-spotted civet, Asian palm civet, and the leopard cat), and had a higher degree of overlap than other carnivorous species. However, the small Indian civet had a lower overlap compared with other carnivores, while the clouded leopard had the lowest overlap due to the very low number of detections. Across carnivorous species, the leopard cat was observed to have the highest Δ value (0.63), followed by the hog badger (0.58), Asiatic jackal (0.55), small Indian civet (0.54), Asian palm civet (0.53), large Indian civet (0.52), large spotted civet (0.49), Asiatic black bear (0.46), dhole (0.40), Malayan sun bear (0.36), yellow-throated marten (0.31), small Indian mongoose (0.30), crab-eating mongoose (0.26), and clouded leopard (0.17).

In studying the Δacross all carnivorous and prey species, the carnivore that is the most important hunter in the area was the dhole, with aΔ value of 0.57, higher than the average Δ(0.46) of all 14 species of carnivores. Despite some other carnivores having high Δ values, they are not direct hunters, therefore their presence in the same area may only be associated with using the same habitat at night; as prey species also forage at night, e.g., gaur, Sambar deer, banteng. This is in contrast to species like the common muntjac and wild boar that are active and present during the daytime. The calculation of the temporal overlap coefficient value of prey species, showed that the prey species, which had the highest Δ with carnivorous species was the Siamese hare (0.58), followed by the Sambar deer (0.56), murid rodent (0.53), gaur (0.52), banteng (0.51), mouse deer (0.50), common muntjac (0.48), wild boar (0.46) and pig-tailed macaque (0.36), respectively. This demonstrates the importance of prey species in maintaining the society of carnivorous species in the area (see Table 3).

A previous study by Lynam et al. (2013), found that the Δin clouded leopards and leopard cats were 0.90 (0.77-0.91), however, in this study, the Δ value for these species was only 0.23, with the greatest overlap observed in the Malayan sun bear 0.34 (0.34-0.33). Our contrasting findings, are likely related to Lynam et al. (2013) analyzing the combined data from 15 protected areas, while we only

considered the area within KARN, identifying leopard cats 115 times and clouded leopards only twice.

In this study, four species of nocturnal viverrids were found, namely the small Indian civet, large Indian civet, large-spotted civet, and Asian palm civet. These species accounted for the highest number of photographs in this study (382 photographs), equating to 48.84 % of the carnivore photographs recorded. These results are similar to Gray and Phan (2011) and Suzuki et al. (2017), who studied camera trap photographs from the Phnom Prich Wildlife Sanctuary and the Chhep Wildlife Sanctuary, Cambodia, respectively. We presently observed the large-spotted civet, which is categorized as an endangered species (Timmins et al. 2016), to be the most common out of the 4 species in the KARN area. This species has also been reported in Myanmar, however, they were reported to be very few in number (Zaw et al. 2008), with their presence also recorded in the South-Western part of Cambodia (Holden and Neang 2009) and also in Malaysia (Hamirul et al. 2015). In Thailand, reports show that they are present in both Khao Yai National Park and Thap Lan National Park, but appear uncommon and are near communities (Sukmasuang et al. 2018). Therefore, this study confirms, that alongside Chhep Wildlife Sanctuary in Cambodia, KARN is an important habitat for the large-spotted civet, one of the world's endangered species.

The Canid species, including the Asiatic jackal and dhole, was the second most frequent carnivore family found in this study. A total of 235 photographs were captured, accounting for 30.05% of all the carnivore photographs recorded, with 136 photographs attributed to the jackal, and 99 to the dhole. The dhole is the apex predator in the area (Jenks et al. 2015) as they can hunt large species (Kamler et al. 2015). Reports from Chhep Wildlife Sanctuary suggest that the villagers go into protected areas to harvest forest products and take their pet dogs with them. Dholes have been found dead in traps several times, and there has been an outbreak of canine distemper virus (CDV) in the area, causing dholes to become scarce. However, the presence of dholes in human settlement areas is reportedly less than jackals (Jenks et al. 2015), which is a concern for the management of the protected areas in Thailand, which have found jackals and dholes living near the communities that surround the forest (Jenks et al. 2015).

Four species from the Mustelidae family were found in this study, including the small Indian mongoose, crab-eating mongoose, hog badger, and yellow-throated marten. A total of 43 photographs of these species were recorded, which were mainly found during the day, except for the hog badger, which was found at night. The results are in line with previous observations (Grassman et al. 2005; Johnson et al. 2009), which found that hog badgers were mostly nocturnal. In regards to the yellow-throated marten, a camera trap study in the long-term dry evergreen forest in Huai Kha Khaeng Wildlife Sanctuary (Sukmasuang et al. 2018) observed yellow-throated martens to be as active during the day as they were at night.

In the present study, only two species of bears were found, the Asiatic black bear and the Malaya sun bear, both of which were present during the night. Similar to a report by Suzuki et al. (2017) in Chhep Wildlife Sanctuary, the bears were observed to be few in number compared to other species. In regards to the wild felids, only two species were detected, the clouded leopard and the leopard cat. The clouded leopard was found in only 2 photographs in 1 location; demonstrating the rarity of the clouded leopard in the study area. In comparison, 4 species of wild felids were found in the Chhep Wildlife Sanctuary, Cambodia, including the leopard, clouded leopard, jungle cat and leopard cat (Suzuki et al. 2017). A previous study in the KARN (Sribuarod1999) recorded 23 carnivorous species, including the leopard, tiger and fishing cat, using camera traps and detection of animal signs. However, the previous report (Jenks et al.2012) of the presence of the golden cat in the area, was not confirmed in this study.

In conclusion, this study on the temporal overlap of the wild carnivorous community and their prey in KARN revealed 14 carnivorous species. The majority of the species were nocturnal, except for the dhole, small Indian mongoose, crab-eating mongoose, and yellow-throated marten, whereas the clouded leopard was found to be cathemeral but only 2 pictures were recorded. In studying the Δ between carnivorous species, it was found that the species with the highest value was the Asian palm civet (0.64) and the lowest was clouded leopard (0.17), with an average Δ of 0.40 for all of the 14 carnivorous species.

While the carnivorous species and all the prey species had an average Δof 0.57, the species with the highest Δin the prey species was the Siamese hare (0.58), and the lowest was pig-tailed macaque (0.36). This shows the importance of the prey species in conserving the carnivore community in the area. Furthermore, the results also show that KARN is an important habitat for the large-spotted civet and dhole, which are on the world's endangered species list. An important threat to the wild species is exposure to diseases from outside of the protected area, via contact with sick domestic animals when coming out to hunt in the community areas. Recommendations for management include strict area protection, especially concerning wildlife poaching in the area, restricting domestic pets into the area, and prohibiting the use of the highway that passes through KARN. In addition, education and publicity about the importance of the wildlife sanctuary as an important habitat for wild carnivores in the eastern forests of Thailand, should be provided. Further studies include the installation of camera traps in this wildlife sanctuary especially in the southern part of the area. Which still cannot be operated due to limitations in accessing the inner area. Studies are also suggested to be undertaken on both the population ecology of important wildlife in the area, with any epidemic of disease in pets and wildlife monitored, in order to prevent disease outbreaks from domestic animals to wildlife.

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