Ranging, habitat use and activity patterns of binturong Arctictis binturong and yellow-throated marten Martes flavigula in north-central Thailand

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Ranging, habitat use and activity patterns of binturong *Arctictis binturong* and yellow-throated marten *Martes flavigula* in north-central Thailand

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The binturong *Arctictis binturong* and yellow-throated marten *Martes flavigula* are widely distributed through much of Southeast Asia, yet their natural history remains poorly understood. We radio collared and tracked five male binturongs, and five yellow-throated martens (four males and one female) for 4-23 months in Phu Khieo Wildlife Sanctuary, Thailand. For binturongs, mean annual range size (± SD; 95% minimum convex polygon) was 6.2 km^2 (± 1.0), and mean range overlap was 35%. Wet season ranges were larger for most binturongs. Binturong mean daily distance was 688 m (± 667). A cumulative activity pattern of 47% indicated that binturongs were arrhythmic and crepuscular. Yellow-throated martens showed an annual range of 7.2 km^2 (± 4.3) and exhibited overlapping ranges of 34%. Yellow-throated martens traveled an average of 966 m/day (± 834) and activity (58%) was characterized as diurnal, but increases in nocturnal activity increased during lunar nights (± 7 days from full moon).

Key words: activity patterns, Arctictis binturong, binturong, habitat use, Martes flavigula, range size, Thailand, yellow-throated marten

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There is little information on the natural history of many Southeast Asian carnivores. Wildlife biologists have largely ignored the Mustelidae and Viverridae in this region, and information on the ecology and status of these large families is poorly represented in the literature. The binturong *Arctictis binturong*, a viverrid, and the yellow-throated marten *Martes flavigula*, a mustelid, have wide distributions in Southeast Asia yet their ecology remains largely unknown.

The binturong is the largest civet in the world occurring within intact forest remnants in Southeast Asia (Lekagul & McNeely 1977, Kanchanasakha et al. 1998). Adult binturongs average 15 kg body weight and are covered in dense, shaggy dark hair (Lekagul & McNeely

1977). Binturongs are unique in being the only civet with a semi-arboreal tail (Lekagul & McNeely 1977, Payne et al. 1985). There has been just one other field study of binturongs. Austin (2002) tracked two adults for six and 18 months in Khao Yai National Park, Thailand.

The yellow-throated marten is distributed through western Asia and Siberia down through Southeast Asia in a wide range of habitats (Lekagul & McNeely 1977, Roberts 1997, Sathyakumar 1999). It is the only marten in mainland Southeast Asia (Kanchanasakha et al. 1998). Yellow-throated martens average 3 kg body weight and are covered in light to dark brown hair with conspicuous yellow pelage along the chest and throat (Lekagul & McNeely 1977, Roberts 1997). Yellow-throated marten diet is diverse consisting of rodents, birds, fruit and small ungulates (Lekagul & McNeely 1977, Roberts 1997, Sathyakumar 1999). Martens in North America and Europe have been studied extensively (Cowan & MacKay 1950, Powell 1979, Buskirk et al. 1989, Buskirk & McDonald 1989, Balharry 1993, Bull et al. 1996, Zalewski 2000), but there have been no field studies of the yellow-throated marten.

Most information on binturong and yellow-throated marten consists primarily of captive species accounts, distribution lists and taxonomic descriptions (Lekagul & McNeely 1977, Rozhnov 1994, 1995, Roberts 1997, Duckworth et al. 1999, Sathyakumar 1999, Choudhury 2000). We report on the first field study of co-occurring binturong and yellow-throated marten. Research objectives included determining annual and seasonal range sizes, intraspecific overlap, and daily movements of binturong and yellow-throated marten in Phu Khieo Wildlife Sanctuary (Phu Khieo), Thailand. We attempt to explain the factors that influenced range size, and also quantify the activity patterns of these species.

Material and methods

Phu Khieo is located in north central Thailand (16°5'-16°35' N, 101°20'-101°55'E; Fig. 1), encompasses 1,560 km^2 of forests within the larger 4,550 km^2 Western Issan Forest Complex (Kumsuk et al. 1999) and represents the largest protected area within the northcentral region. Phu Khieo is one of three protected areas in Thailand that contain no permanent human settlement (Kekule 1999).

Phu Khieo is dominated by a mixed evergreen for-

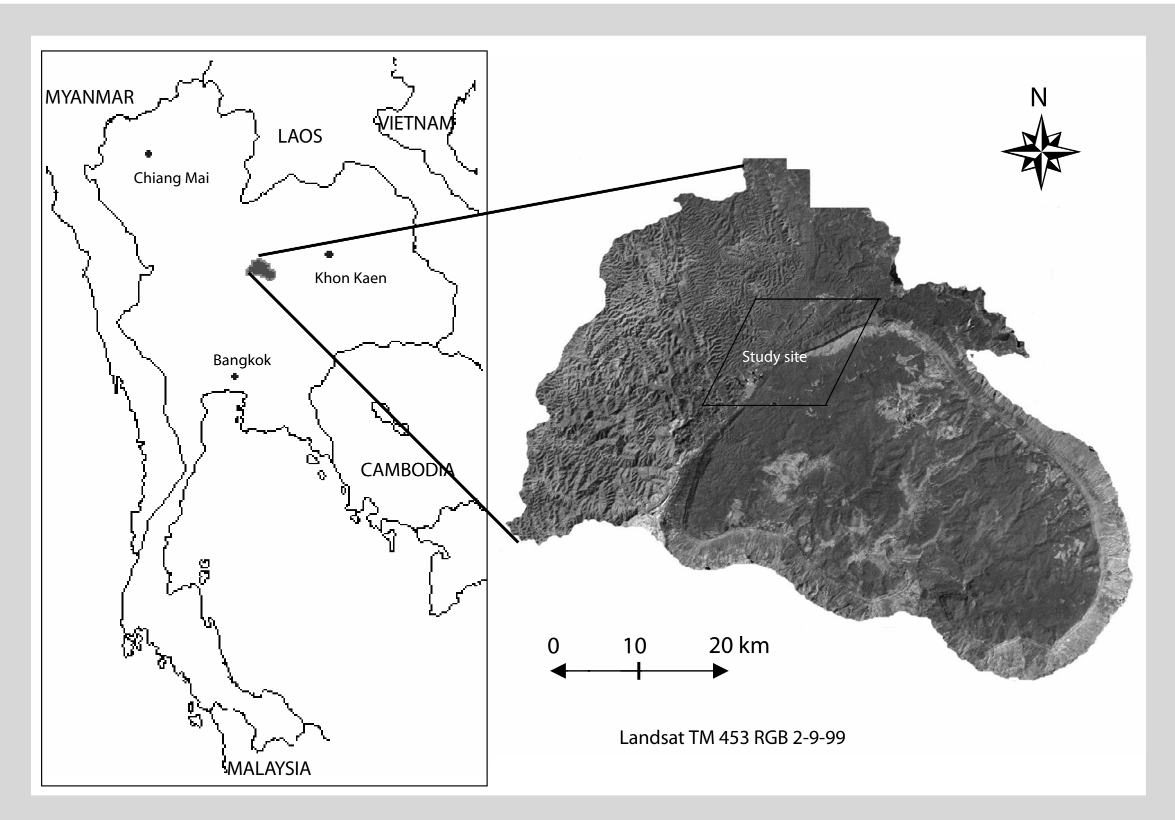

Figure 1. Phu Khieo Wildlife Sanctuary and location of study site in north-central Thailand.

est on an 800-1,100 m elevation plateau. The topography consists primarily of forested hills rising into mountains westward. The vegetation is composed of dry and hill evergreen forest (75%), mixed deciduous forest (13%), dry dipterocarp forest (4%), bamboo (4%), grassland (3%), and a forest plantation (1%; Anon. 2000). Dominant trees include evergreen oaks *Quercus auricoma*, *Castanopsis* spp., malut *Hopia ferrea*, figs *Ficus* spp., white merantis *Shorea* spp., Asian pine *Pinus keysia* and dipterocarps *Dipterocarpus* spp. (Kumsuk et al. 1999). Grassland communities are patchy and dominated by the Thung Kha Mang grassland (3.0 km^2) near the sanctuary headquarters.

The climate of Phu Khieo is strongly influenced by the seasonal monsoons. There are two distinct seasons: wet season (April-October) and dry season (November-March). Mean annual precipitation was 140 cm with 90% occurring during June-October (Kumsuk et al. 1999). Annual mean temperature is 21°C (range: -3 - 37°C).

The study area, which covers ca 200 km^2, was located in the north-central portion of the sanctuary. This area includes the main park road, Thung Kha Mang Headquarters, smaller trails, the Phrom River and several perennial streams. Site selection was based on its central location within the sanctuary, abundant carnivore sign and low tourism. Illegal hunting and aloewood *Aquilaria crassna* extraction occurred intermittently throughout the study site.

Trapping occurred intermittently for binturongs and yellow-throated martens during September 1998 - November 2002. We used 45 steel mesh box traps (150 × 40 × 50 cm) to capture the animals with live domestic chickens used as bait in a separate compartment attached to the end of the trap. Chickens were chosen as bait because other carnivore species also were targeted during a concurrent study. Traps were set along the main road, trails and riverbanks where marten and binturong sign occurred. Traps were spaced 300-1,000 m apart in closed and open forest habitat. Traps were visited daily to feed and water the bait chickens and check for captures.

Captured binturongs and yellow-throated martens were anesthetized with an intramuscular injection of Zoletil® (Virbac, Ltd., Carros, France; tiletamine hydrochloride) at 10 mg/kg, or Calypso® (Gideon Richter, Ltd., Budhapest, Hungary; ketamine hydrochloride) and Tranquivid® (Ben Venue Laboratory, Inc., Bedford, Ohio; xylazine hydrochloride) at 10 mg/kg and 2 mg/kg, respectively. Sedated animals were aged, measured, weighed, radio collared and photographed. Ectoparasites and genetic samples (hair, blood) were also collected for another study.

Animals were aged using tooth eruption and wear, body size, sexual development and overall body condition. Four age classifications were assigned: juvenile, subadult, adult and old adult. After data collection and collaring, animals were returned to the trap for recovery and released when reflexes and natural behaviour returned after 2-4 hours.

Binturongs were fitted with a 120 g radio collar and yellow-throated martens were fitted with a 55 g radio collar at 148-149 MHz frequency (Advanced Telemetry Systems, Inc., Isanti, Minnesota) with an activity switch activated by animal movements. An internal lithium battery provided a constant pulse signal for 9-18 months. Due to equipment limits, only five radio collars were allotted per species. Radio tracking was primarily done on the ground with either a hand-held 3-element antenna on trails, or a large, vehicle-mounted null antenna on the main road (Kenward 2001). Animals were located intermittently throughout the duration of the study during diurnal and nocturnal periods. Locations were derived from triangulations of ≥ 3 signal bearings. Signal range was 1-15 km depending upon the obstruction of the terrain such as dense forest and hills, and the elevation at which the signal was received.

Radio-telemetry error was assessed with a global positioning system (GPS) by identifying the location of 20 radio transmitters placed by another person within the forest (Blankenship 2000, Kenward 2001). Distances between the hidden transmitter and the receiver were > 1 km. Mean distance between triangulated locations and GPS locations indicated a mean triangulation error of 68 m (± SD 62, range: 213 m; N = 20).

Independence of locations was assumed by using only one location per 24-hour period during diurnal and nocturnal periods. Animal locations were determined using the LOAS® (Ecological Software Solutions, Inc., Sacramento, California) software program. Cumulative ranges were analyzed using the 95% and 100% minimum convex polygon (MCP) methods (Mohr 1947), and the 95% fixed kernel estimator (FK) with the Animal Movement Extension (Hooge & Eichenlaub 2000) of Arc View® (version 3.2, Environmental Systems Research Institute, Inc., Redlands, California). Using several range estimators enabled comparisons with other studies. Core areas were generated using 50% of locations after outlier removal (Hooge & Eichenlaub 2000). Overlap comparisons were calculated using the 95% MCP estimator for annual ranges. Daily movements were calculated by measuring the linear distance between consecutive daily locations (Rabinowitz 1989, Bailey 1993). Because of varying topography and a non-linear route followed by these carnivores the distances covered

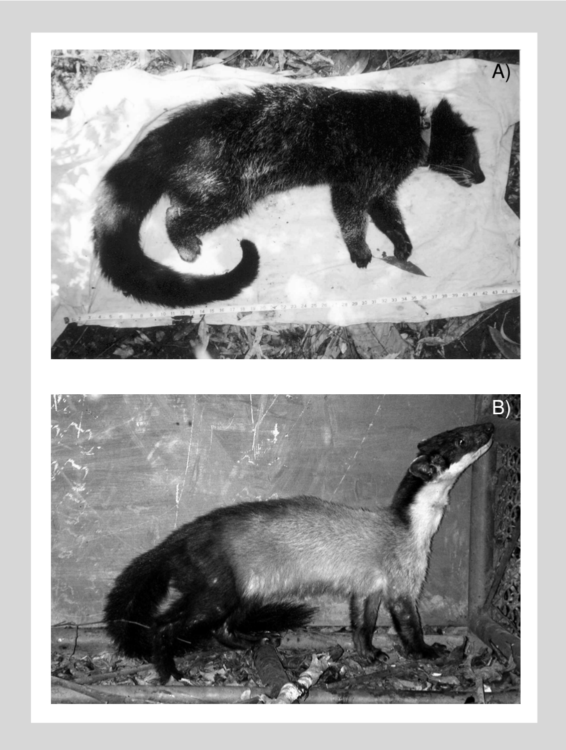

Figure 2. Binturong (A) and yellow-throated marten (B) captured in this study.

between consecutive days were greater than expressed (Bailey 1974).

Vegetation types were delineated on a 1:50,000 scale topographic map (Royal Thai Survey Department) developed from SPOT satellite imagery obtained in March 1992. Three vegetation types were delineated within the study site: closed forest, open forest-grassland and abandoned orchard. Vegetation use compared to availability was assessed with a Chi-square goodness-of-fit test and Bonferroni Z-test 95% confidence interval (Byers et al. 1984). This method has been used to determine habitat use by jaguars *Panthera onca* (Crawshaw & Quigley 1991) and felids in Thailand (Austin 2002).

Activity levels for each radio collared animal were recorded intermittently during the diel. We assumed that 15 minutes satisfied independence of observation between each activity reading during diels. Activity also was recorded during radio tracking for spatial locations (≤ 5 minutes/reading). Significance between seasonal activity proportions was assessed with a Chi-Square test.

Temporal segregation among animals was examined by vegetation type and climatic season. Spatial and temporal patterns were partitioned by gender and season. We included ± 1 SD and minimum and maximum values with the means. Statistical significance was determined at ≤ 0.05. Statistical analyses were undertaken with the software program SPSS® (version 11.0, Chicago, Illinois).

Results

We captured 31 binturongs and radio collared five males (one subadult, four adults) that were tracked 12-23 months (Fig. 2). We used 554 radio locations to calculate cumulative range sizes. Cumulative range size (95% MCP estimator) of males BM1, BM2, BM3, BM4, and BM5 was 6.0 km^2 (N = 80), 7.7 km^2 (N = 90), 4.7 km^2 (N = 169), 6.5 km^2 (N = 99), and 6.1 km^2 (N = 116), respectively (Table 1). BM1 and BM2 showed larger ranges during the dry season ($\bar{x}$, increase = 24% ± 25, range: 6-41), whereas BM3, BM4, and BM5 had larger wet season ranges ($\bar{x}$, increase = 236% ± 238, range: 90-511; Table 2). Five of six binturong range pairings overlapped an average of 46% (± 16, range: 32-70; Fig. 3). BM3 occupied a range independent from the other binturongs.

Of five binturongs, two used habitat in disproportion to availability. BM2 used open forest-grassland proportionally more than closed forest (χ^2 = 14.6, df = 1, P < 0.05; Bonferroni Z-test 95% confidence interval $0.625 \leq p_2 \leq 0.837$, expected: 0.529), whereas BM5 used closed forest proportionally more than expected (χ^2 = 23.1, df = 1, P < 0.05; Bonferroni Z-test 95% confidence interval $0.861 \leq p_1 \leq 0.977$, expected: 0.714).

Mean one-day movement of binturongs was 688 m (± 667, range: 25-4,143; N = 266). Mean daily movement of individuals was 350 m (range: 25-1,389; N = 34), 662 m (range: 25-4,144; N = 42), 645 m (range: 35-

Table 1. Mean range sizes (± SD; in km^2) of binturongs and yellow-throated martens using the 100% (MCP 100) and 95% (MCP 95) minimum convex polygon, and 95% (FK 95) and 50% (FK 50) fixed kernel estimators in Phu Khieo Wildlife Sanctuary, Thailand, during October 1998 - August 2001.

Species	Sex	N	Locations	MCP 100	MCP 95	FK 95	FK 50
Binturong	♂	5	107.4 ± 32.2	8.4 ± 1.3	6.2 ± 1.0	5.2 ± 1.8	0.6 ± 0.2
Yellow-throated marten	♂	4	45.2 ± 15.3	8.1 ± 6.3	6.8 ± 4.9	8.1 ± 4.8	0.8 ± 0.2
	♀	1	116.0	13.3	8.8	14.1	3.0

Table 2. Seasonal range sizes (in km^2; MCP 95) of binturongs and yellow-throated martens in Phu Khieo Wildlife Sanctuary, Thailand, during October 1998 - August 2001. n/a indicates that no data were available.

Species	Sex	ID	Wet	Dry	Annual
Binturong	♂	BM1	3.3	3.5	6.0
	♂	BM2	4.1	5.8	7.7
	♂	BM3	5.7	0.9	4.7
	♂	BM4	5.8	2.8	6.5
	♂	BM5	6.1	3.2	6.1
Yellow-throated marten	♂	YM1	n/a	10.1	10.1
	♂	YM2	9.0	10.5	11.8
	♂	YM3	n/a	1.7	1.7
	♂	YM4	3.3	0.7	3.5
	♀	YF1	9.6	3.8	8.8

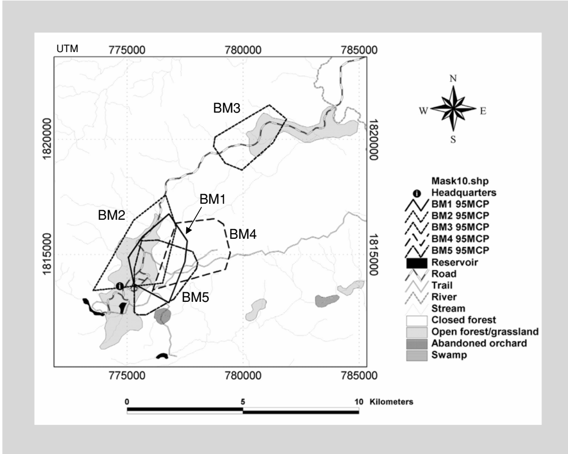

Figure 3. Binturong annual ranges (MCP 95 estimator) depicted in Phu Khieo Wildlife Sanctuary during November 1998 - August 2001.

2,821; N = 92), 898 m (range: 25-2,698; N = 40), and 736 m (range: 25-2,487; N = 58), respectively (Table 3).

Binturongs were active during 1,127 of 2,422 observations (47%). Binturongs exhibited arrhythmic activity dominated by crepuscular and nocturnal tendencies with peaks between 04:01-06:00 hours and 20:01-22:00 hours (cumulative $\bar{x}$ = 68%; Fig. 4). Reduced activity periods occurred from midday to late afternoon (11:01-18:01 hours, $\bar{x}$ = 38%). We recorded two diurnal observations of individual binturongs in the canopy of fig trees. Binturong activity decreased during illuminated lunar nights (± 7 days from full moon) between 19:00 hours and 06:00 hours (52%) and increased the other nights (63%). Highest average monthly activity (61%) was recorded during August, whereas the lowest (39%) was recorded during November. Seasonal activity patterns were not significantly different (χ^2 = 0.10, df = 1, P > 0.05).

We captured 40 yellow-throated martens and radio collared five (three adult males, one old adult male, one adult female) that were tracked for 4-16 months (see Fig. 2). We used 297 radio locations to calculate cumulative ranges. Cumulative range size of males YM1, YM2, YM3, YM4, and female YF1 was 10.1 km^2 (N = 48), 11.8 km^2 (N = 64), 1.7 km^2 (N = 27), and 3.5 km^2 (N = 42), respectively, whereas female YF1 showed a range of 8.8 km^2 (N = 116; see Table 1). Yellow-throated marten ranges generally increased during the wet season ($\bar{x}$, increase = 262% ± 155, range: 152-371), however, the range of YM2 increased marginally (17%) during the dry season (see Table 2). Mean range overlap of yellow-throated martens was 34% (± 37, range: 0.2-97; Fig. 5). Male YM4 and female YF1 occupied ranges independent from other martens.

Yellow-throated martens generally used habitat in proportion to availability. However, YM1 was observed to use open forest-grassland less than it was available (χ^2 = 15.69, df = 2, P < 0.05; Bonferroni Z-test 95% confidence interval 0.061 ≤ p_3 ≤ 0.321, expected: 0.340).

Yellow-throated martens were located on consecutive days 95 times for a mean one-day movement of 966 m (± 834, range: 25-4,127). Mean daily movement of the male martens was 770 m (± 642, range: 25-3,380; N = 63), whereas female marten YF1 showed a mean daily movement of 1,349 m (± 1,028, range:160-4,127; N = 32; see Table 3).

Yellow-throated martens were active during 656 of 1,127 observations (58%) and were primarily diurnal with arrhythmic tendencies. Diurnal activity peaks occurred during the morning (06:01-08:00 hours, 83%) and late afternoon (16:01-18:00 hours, 71%; see Fig. 5). We recorded five diurnal observations of adult pairs of yellow-throated martens traveling along the main road and trails. Reduced activity periods were scattered during the night (20:01-04:00 hours, = 14%). Marten activ-

Table 3. Mean daily distances (± SD; in m), seasonal range and annual movements of binturongs and yellow-throated martens in Phu Khieo Wildlife Sanctuary, Thailand.

			Dry season		Wet season		Annual movements	
Species	Sex	N	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Binturong	♂	5	499 ± 556	25-2,698	754 ± 715	25-4,143	688 ± 667	25-4,143
Yellow-throated marten	♂	4	744 ± 647	25-3,380	871 ± 636	150-2,524	770 ± 642	25-3,380
	♀	1	704 ± 491	160-1,439	1,563 ± 1,076	201-4,127	1,349 ± 1,028	160-4,127

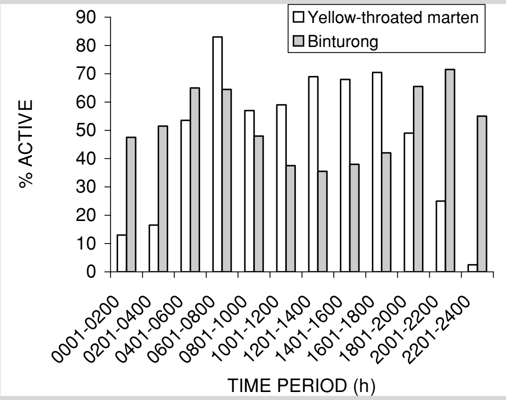

Figure 4. Binturong and yellow-throated marten activity patterns depicted in Phu Khieo Wildlife Sanctuary, Thailand during October 1998 - August 2001.

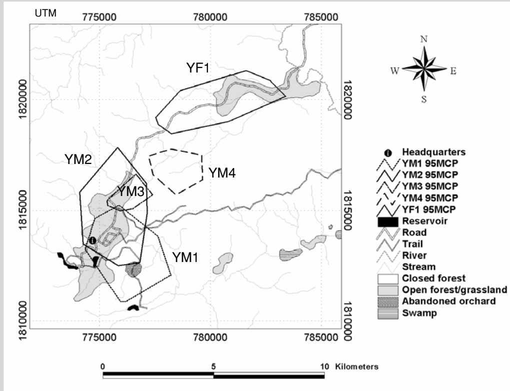

Figure 5. Yellow-throated marten annual ranges (MCP 95 estimator) depicted in Phu Khieo Wildlife Sanctuary, Thailand during October 1998 - May 2001.

ity was greater during lunar nights (33%) than the other nights (20%). Highest average monthly activity (85%) was recorded during October, whereas the lowest (48%) was recorded during March. Wet season activity (63%) was significantly greater ($\chi^2 = 8.04$, df = 1, $P < 0.05$) than dry season activity (55%).

Discussion

Radio-collared binturongs were similar in size and occupied similarly-sized ranges. Conversely, Austin (2002) reported one female and one male binturong ranged 4.0 km^2 and 20.5 km^2 (FK 95 estimator), respectively. Also, Austin (2002) reported two core areas with a combined area of 3.5 km^2 for the male binturong. This mature adult weighed 12.5 kg, similar to the binturongs in Phu Khieo and was about the same age, yet the cumulative range was nearly four times the size of the mean cumulative range (FK 95) of binturongs in Phu Khieo ($\bar{x}$ = 5.2 km^2 ± 1.8).

Cumulative ranges of other Asian viverrids have been reported for large Indian civets *Viverra zibetha* (Rabinowitz 1991), small Indian civets *Viverricula indica* (Simchareon 1990), Malay civets *Viverra tangalunga* (Macdonald & Wise 1979, Colon 2002), common palm civets *Paradoxurus hermaphroditus* (Joshi et al. 1995, Grassman 1998), and masked palm civets *Paguma larvata* (Grassman 1998). In most of these studies viverrids did not exhibit territoriality. Intraspecific variation in range size is common with civets and probably reflects varying habitat and resources (Joshi et al. 1995, Colon 2002).

Seasonal effects on range size revealed greater increases during the wet season for three binturongs, whereas two binturongs increased their range size during the dry season. In addition, increases in daily movements during the wet season also were observed. Binturong movements during the wet season were probably related to exploiting fig trees outside of the dry season range.

Binturong overlap was substantial between five of six pairings. Although avoidance between binturongs was observed, range overlap indicated lack of territories. Colon (2002) reported significant overlap between Malay civets in logged and unlogged forests, and Joshi et al. (1995) noted extensive overlapping ranges of common palm civets in Nepal attributed to the lack of territoriality related to the temporal and spatial variation in food resources. These same resource-based influences likely applied to binturong spatial patterns.

Binturongs in our study were primarily nocturnal and crepuscular. Similar activity patterns for binturongs were noted by van Schaik & Griffiths (1996), Lambert (1990) and Austin (2002), whereas diurnal observations were made by Nettelbeck (1998). Conversely, Rozhnov (1994) noted strictly nocturnal activity in a captive binturong. As a predominantly frugivorous carnivore, binturongs do not have to adjust their activity to prey activity (Zielinski 1988). A consequence of arrhythmic activity was greater exposure to large predators (i.e. tiger *Panthera tigris* and dhole *Cuon alpinus*). However, as the largest civet with formidable teeth and claws, binturongs were probably rarely preyed upon. A concurrent study of dhole within the same study area failed to identify binturong remains in 172 dhole scats (L.I. Grassman, Jr., unpubl. data).

Powell (1979) maintains that mustelids commonly show intrasexual territoriality, however, yellow-throated marten ranges in this study were large with significant intraspecific overlap. No range information existed for yellow-throated martens or the similarly-sized Nilgiri marten *Martes gwatkinsi* of southern India (Wirth & Van Rompaey 1991, Kurup & Joseph 2001). Comparisons between yellow-throated marten and the smaller Tsushima marten *Martes melampus tsuensis* of Japan revealed extreme differences. Tsushima marten ranges were smaller (N =11, $\bar{x}$ = 0.67 km^2 ± 0.20) and exhibited territoriality with little intrasexual overlap (Tatara 1994). Female YF1 exhibited the largest range size and greatest daily movements compared to similarly aged males. This female's movements were contrary to what was expected. Sandell (1989) and Kruuk & Macdonald (1985) stated that female ranges were determined by the distribution of food, whereas male ranges were determined by the distribution of females, thus male ranges were expected to be larger.

Lekagul & McNeely (1977) stated that yellow-throated martens may hunt together in pairs and that some pairings may be life-long. Similarly, Sathyakumar (1999) reported seven yellow-throated marten pair sightings in the western Himalayas. One camera trap photo (Royal Forest Department of Thailand, unpubl. data) and five visual observations were of adult yellow-throated marten pairs traveling together. It is unknown if these were siblings, parent-offspring or male-female pairs, but the sightings were contrary to the belief that martens were solitary (Powell 1979). Research is needed on the social structure of yellow-throated martens.

Yellow-throated martens were primarily diurnal, although some nocturnal activity was observed during moonlight nights. Camera trapping in Indonesia indicated that yellow-throated martens were crepuscular (van Schaik & Griffiths 1996). Kurup & Joseph (2001) observed Nilgiri martens several times during the day, and hunters in Taiwan have observed the yellow-throated marten during the day (Lin 2000). Conversely, Tatara (1994) reported the Tsushima marten as primarily nocturnal. Activity duration of martens in temperate forests is affected by winter thermal stress and summer mating (Zalewski 2000). Yellow-throated martens in our study experienced no climatic stress, thus marten activity was probably related to the activity of potential prey (Zielinski 1988).

Kavanau & Ramos (1975) regard dusk as an optimal period for small carnivores to hunt because prey are more active, visibility is better than at night, and because dim light provides adequate cover for small carnivores from large predators. Moonlight has been shown to influence the activity of European badgers *Meles meles* (Cresswell & Harris 1988), woolly opossums *Caluromys philander* (Julien-Laferriere 1997), and temperate rodents (Wolfe & Summerlin 1989). In these studies activity decreased during maximum moonlight, probably because of the conspicuousness perceived by these nocturnal animals. In contrast, activity increases by yellow-throated martens during moonlight may have been hunting related to increased prey activity, or conspicuousness.

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