NAT. HIST. BULL. SIAM SOC. 47: 77–93, 1999

ECOLOGY AND BEHAVIOR OF THE INDOCHINESE LEOPARD IN KAENG KRACHAN NATIONAL PARK, THAILAND

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ABSTRACT

As part of a larger investigation of sympatric carnivore ecology, three adult Indochinese leopards *Panthera pardus delacouri* (2 males, 1 female) were captured and radio-collared in Kaeng Krachan National Park, Petchaburi Province, Thailand, from February, 1996 through February, 1997. Movement data indicate that leopards occupied overall home range sizes of 8.8 to 18.0 km^2, showed a mean daily movement of 1.95 km, and exhibited arrhythmic activity dominated by nocturnal and crepuscular tendencies. Range overlap of > 40 % was recorded between two males and between a male and a female. Identification of scat (n=41) contents revealed that leopard feces was dominated by hog badger *Arctonyx collaris* (44%), barking deer *Muntiacus muntjak* (19.5%) and wild pig *Sus scrofa* (7.3%). Comparisons between this study and a previous study in Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province, suggest that fluctuations in seasonal home range size, activity pattern and diet were less marked in Kaeng Krachan National Park leopards. Seasonal change and environmental stress es (fire and floods) were less severe in Kaeng Krachan than in Huai Kha Khaeng, and these factors in addition to differences in forest type may be responsible for the ecological differences.

INTRODUCTION

Of the large cats, perhaps the leopard (*Panthera pardus*) has been the most studied. Previous leopard research has focused on ecology (SCHALLER, 1972; SMITH, 1978; ILANY, 1986; SEIDENSTICKER *ET AL.*, 1990; MUCKENHIRN & EISENBERG, 1973; BAILEY, 1993), movements (NORTON & HENLEY, 1987; BERTRAM, 1982; MITZUTANI, 1993), prey selection (BOESCH, 1991; HOPPE-DOMINK, 1984; SEIDENSTICKER, 1983; KARANTH & SUNQUIST, 1995; JOHNSINGH, 1992; NORTON *ET AL.*, 1986; SATHYAKUMAR, 1992), dispersal (SUNQUIST, 1983), early maternal behavior (SEIDENSTICKER, 1977) and conservation status (SANTIAPILLAI *ET AL.*, 1982).

The majority of research on leopards has been carried out in Sub-Saharan Africa, India, Sri Lanka, Nepal, and Israel, while in Southeast Asia only one previous study exists: RABINOWITZ's (1989) study in a dry forest mosaic in western Thailand. This study, as part of a larger investigation of sympatric carnivore ecology (GRASSMAN JR., 1997), was initiated to investigate the natural history of leopards in a tropical evergreen forest.

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Received 10 February 1998; accepted 5 January 1999.

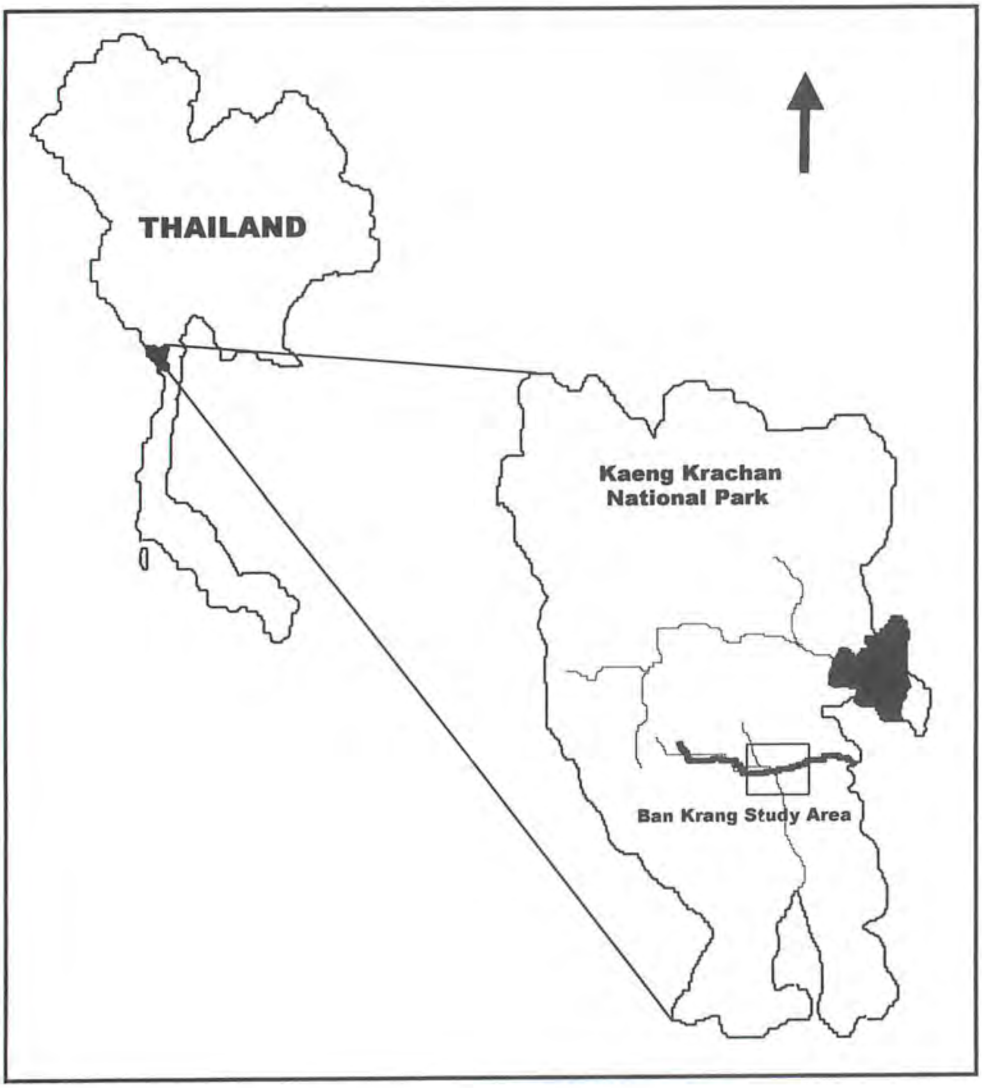

Figure 1. Map of location of study site in Kaeng Krachan National Park.

STUDY AREA

Kaeng Krachan National Park (KKNP) is Thailand's largest national park with 2,915 km^2. Located in south-central Thailand, KKNP occupies approximately half of Petchaburi and part of Prachuab Khiri Khan Provinces, with its western boarder adjacent to Myanmar on the Tenassarim mountain range (Figure 1). The general topography consists primarily of forested hills rising westward into mountains (Figure 2). Khao Panoem Thung is the highest peak within the park at 1,200 m. The subtropical forest is composed of dry and wet evergreen (85%), mixed deciduous (10%) and dry dipterocarp (5%) forest species (TISTR, 1989). Wet evergreen forest generally occupies elevations above 500 m, while dry evergreen can be found below 500 m. Mixed deciduous occurs is mainly in the eastern, more level terrain, and dry dipterocarp is found intermittently on steep grades of approximately 300–400 m. Dominant evergreen species included *Tetrameles nudiflora, Acrocarpus fraxinifolius, Aphanamixis polystachya, Elaeocarpus grandiflorus, Stereospermum fimbriatum, Barringtonia macrostachya and Crateva magna* (TISTR, 1989).

The climate of KKNP is influenced by seasonal monsoons. There are two distinct seasons: typically, June through October is the wet season, and November through May is the dry season (CUMMINGS, 1992). Average yearly precipitation in Petchaburi Province was 1,000 mm, with June through September accounting for over 90% of precipitation (GRAY *ET AL.*, 1986). Temperatures ranged from lows of 25°C in December to highs of 30°C in May, with an overall average of 28°C.

The region contains a mix of Sundaic and Indochinese fauna due to the convergence of these two zoogeographic subregions. Some larger mammalian species present in KKNP included: elephant *Elephas maximus,* gaur *Bos gaurus,* sambar *Cervus unicolor,* barking deer *Muntiacus muntjak,* tapir *Tapirus indicus,* tiger *Panthera tigris,* and leopard *P. pardus* (personal observations).

The study area was restricted to the south-central portion of the park at the Ban Krang Camping Area. Encompassing 60 km^2, the area consisted of hilly/mountainous terrain at 500–800 m elevation, primarily with seasonal evergreen forest. The main park road running east and west, some smaller trails, and the Pranburi River were included within the study area. The site was chosen due to its central location, abundant carnivore sign, and low number of visiting tourists in the area. In addition, steeper terrain to the west would have rendered the logistics of a telemetric study very difficult, while the lower elevations within the study site were more suitable for radio-telemetry.

METHODS

Trapping Procedure

Three large wooden-log (200x90x100 cm) and six medium steel mesh (150x40x50 cm) box traps were used to capture the leopards used in this study (Figure 3). All traps had single door openings which were tripped by a foot treadle. Domestic chickens were used as live bait in the rear of the traps.

Traps were set along the main road, trails and riverbanks where leopard sign occurred in the form of spoor, feces or scrapes. Carnivore scent concentrate was periodically applied to increase the attractiveness of the set. Traps were visited daily to feed and water the bait chickens, and check for captures. If, after three weeks, there were no captures, a trap was considered unsuccessful and moved to a new location.

Capture Protocol

Captured leopards were anesthetized via intramuscular injection with a hand-held syringe at 10 mg/kg Calypso (ketamine hydrochloride; Gedeon Richter, Hungary). All animals were injected in the hindquarters through side openings in the traps. Recumbancy time and attempted versus actual drug dosage rates were recorded (Table 1).

Table 1. Immobilization parameters of study leopards injected with ketamine hydrochloride.

ID	Sex	Weight (kg)	Attenpted dosage (mg/kg)	Actual dosage	Time to recumbancy	Time to "head up"
L350	Male	37	10	10.8	4.0	72.0
L600	Male	40	10	10	7.5	104.0
L700	Female	25	10	15	6.0	40.0

During the first 30 minutes of sedation each animal was fitted with a radio-collar and biological data were collected. Leopards were sexed, aged, weighed and measured. Head-and-body length, tail length, ear length, front foot spoor, and hind foot length were recorded to the nearest cm. Upper canine length was measured to the nearest mm and overall dentition was checked for possible injuries obtained while in the trap. If abrasive injuries were present, we applied a topical antiseptic and gave a multi-vitamin booster shot (Biocatalin, Italy).

Individuals were aged using tooth wear, eruption (i.e. presence or absence of deciduous teeth), body size, sexual development and overall body condition (QUIGLEY, 1987; BAILEY, 1993). Four age classes were assigned: juvenile (J), young adult (YA), prime adult (PA), and old adult (OA). After collecting data and collaring a leopard, we placed it back into the trap to recover. When all reflexes and natural behavior returned (2–4 hours) we opened the trap door and released the animal.

Radio-tracking

Adult leopards were fitted with a butyl, collar-mounted radio transmitter (Wildlife Materials, Inc., Carbondale, IL.) at 142 MHz to obtain movement and activity data. Each transmitter contained an activity switch activated by head movements. Signal range varied from 1 to 15 km depending upon obstructions of the terrain and the elevation at which the signal was received. All tracking was done on the ground with hilltop stations used

Figure 2. General topography and habitat of KKNP.

Figure 3. Wooden-log box trap used to capture study leopards.

Figure 4. Leopard L600

Figure 5. Leopard L700

frequently for establishing first bearings when the signal could not be received at lower elevations.

The convex polygon method (MOHR, 1947) was used for annual and seasonal home range size (HRS) and home range overlap estimates. All plotted points were considered part of a home range, even those where only a small amount of time was spent (LOPEZ, 1985). Leopards were radio-tracked intermittently during 24–hour periods, but once a month continuous 24–hour tracking was done on each animal. Animals were considered active or non-active based on signal integrity and pulse frequency. Daily movements were calculated by measuring the linear distances between consecutive 24–hour radio locations (BAILEY, 1993; RABINOWITZ, 1989).

Food Habits

We analyzed prey selection by leopards from examination of fecal contents and a regurgitation sample. On one occasion prey taken by a leopard was discovered by walking in on its radio signal location when it remained feeding in one area for an extended period of time.

Leopard feces in the field was identified by the presence of spoor and scrapes in conjunction with feces 2–3 cm in diameter (RABINOWITZ, 1989). The only other cat with similar fecal characteristics was the clouded leopard *Neofelis nebulosa,* but its presence in the study area was unconfirmed.

Leopard fecal samples were washed over 1–mm wire mesh with tap water, and hair, bone and other contents separated and dried. Hair samples were mounted on microscopic slides for examination of the cuticular and medullar characteristics for comparison with known specimens in a reference collection (BAKER, 1991; CHENGVANICHSAWAD, 1977; PUTMAN, 1984; PALMER & FAIRALL, 1988). The number of each prey species found in a fecal sample was recorded based upon particular body parts or hairs consistent with that species. Prey selectivity was compared to the wet and dry seasons and focused on frequency of occurrence and live weight (RABINOWITZ, 1989; EMMONS, 1988; SAKAGUCHI, 1994).

RESULTS

Between February and September, 1996 two adult male leopards and one adult female were captured and radio-collared. Leopards exhibited no signs of physical stress during sedation, and all animals were released in good physical condition (Table 2). Male leopards L350 and L600 were of the yellow pelage phase, while female L700 was of the black phase (Figures 4 and 5).

Home Range Size and Overlap

Movement data on leopards were derived from a total of 202 radio locations gathered from February, 1996, through February, 1997. The overall HRS for male leopards L350 and L600 was 17.3 km^2 (n=42) and 18.0 km^2 (n=68), respectively, while female L700 exhibited an overall HRS of 8.8 km^2 (n=92) (Table 3). On average, L350's radio

Table 2. Physical parameters of study leopards.

ID #	Sex	Age	Body measurements					
			Weight (kg)	HB (cm)	TL (cm)	HF (cm)	E (cm)	URC (mm)
L350	M	YA	37	112	76	23	7.2	25
L600	M	PA	40	132	79	24	5.5	24
L700	F	PA	25	106	75	21	6	11

Note: YA= young adult, PA= prime adult
HB head and body length
TL tail length
HF hind foot length
E ear length
URC upper right canine length

Table 3. Overall home range size, seasonal size and mean daily movements of study leopards in KKNP.

ID	Overall home range size (km^2)	Wet season (km^2)	Dry season (km^2)	Mean daily movements (km)
L350	17.3	17.3	16.5	2.8
L600	18.0	18.0	14.6	1.6
L700	8.8	*	8.8	1.8

* Data not available

signal could not be received 30% of attempted times, and L600, 10% of attempted times. This suggests that L350 and L600 possibly had larger home ranges than reported. Female L700's signal was always received when attempted.

Males L350 and L600 had a range overlap of 8.1 km^2, although at no time during this study were these two males recorded within one kilometer of each other within the overlap area. Female L700's range overlapped with L350 by 8.0 km^2 and with L600 by 2.9 km^2. There were marginal shifts in HRS during the wet and dry seasons with the largest sizes occurring during the wet season (mean increase: 12%).

All three leopard home ranges encompassed the Pranburi River and the main road (Figure 6). Leopards utilized river and valley corridors and the main road proportionately more than forested terrain. Lower elevations within the study site (500–600 m) were utilized more frequently than higher elevations (700–900 m).

Movements

Radio-collared leopards were located on consecutive days 86 times, nine of which showed no movement from the previous day's location. The remaining 77 times when movement occurred, the mean one-day movement was 1.95 km (range: 0.3–8.5 km). The

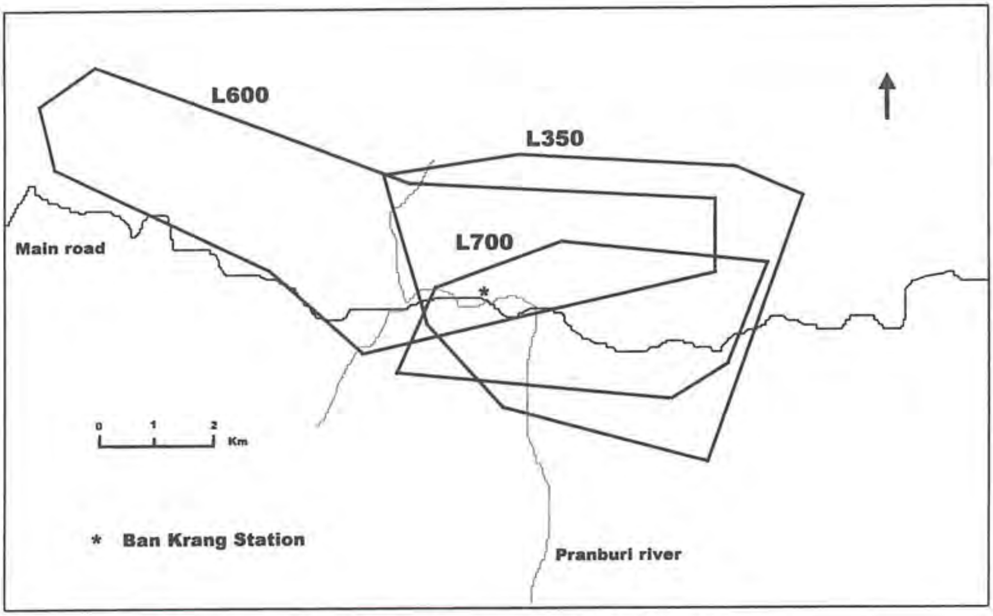

Figure 6. Overall home ranges of study leopards at Ban Krang Study Area, KKNP.

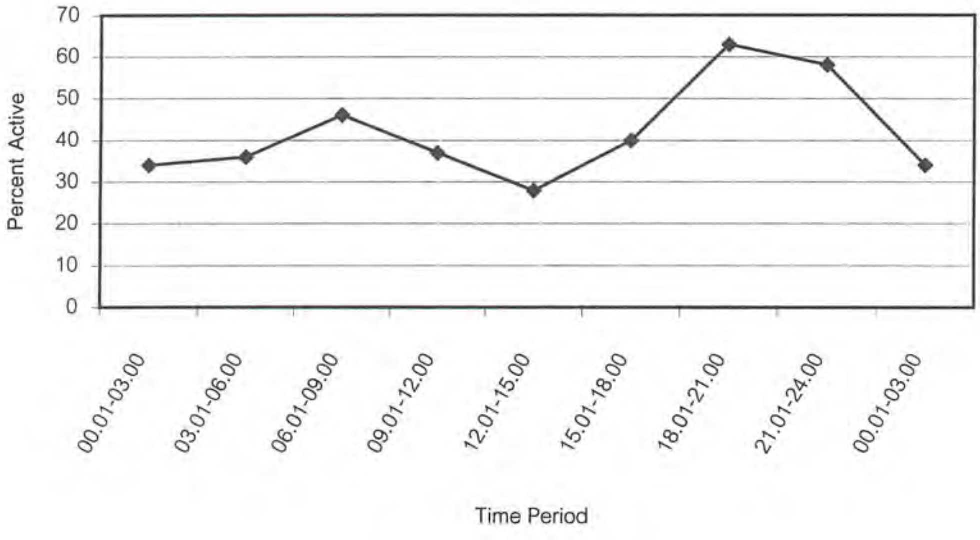

Figure 7. Mean activity pattern of study leopards in KKNP (n=1,120 activity readings).

mean daily movement of L350 was 2.8 km (range: 0.9–6.0 km; n=18), while for L600 the mean was 1.6 km (range: 2.3–8.5 km; n=30) and for female leopard L700 a mean daily movement of 1.8 km (range: 0.3–4.5 km; n=29) was recorded (Table 3).

Activity

Leopards were active during 546 (49%) of 1,120 activity readings. Daily activity levels indicated that leopards exhibit arrhythmic activity dominated by crepuscular and nocturnal tendencies with peak activity occurring between 0601 to 0900, and 1801 to 21:00 h (mean: 55%) (Figure 7). Diurnal activity was clustered towards early morning and late afternoon, while the greatest concentration of inactive period readings was during mid-day (1201–1500 h; 28% active) and late night (2401–0300 h; 33% active). Activity varied little between months (range: 48–50%).

Food Habits

A total of 41 leopard feces, one regurgitation sample and one carcass discovery showed that leopards utilized at least nine prey species (Table 4). Hog badger *Arctonyx collaris* accounted for 41% of total feces collected while other important prey species included barking deer *Muntiacus muntjak* (20%) and wild pig *Sus scrofa* (7%).

All scat samples contained only one prey item. Four of five unidentified scat samples were produced from meaty meals which lacked guard hairs for comparison, which probably were of large ungulates RABINOWITZ (1989).

DISCUSSION

Home Range Dynamics

The overall HRS of male leopards of 17.3 and 18.0 km^2, and the female of 8.8 km^2, were smaller than those reported for leopards in Huai Kha Khaeng, Thailand, by RABINOWITZ (1989). However, the overall HRS of L350 should be viewed as a minimum estimate due to the frequent number of times he could not be located. Rabinowitz reported two adult males as having a HRS of 27 and 37 km^2 and a female of 11.4 km^2. Other HRS estimates for forest leopards include 30 km^2 (n=1) in the Ivory Coast (JENNY, 1993) and 8 to 30 km^2 in Sri Lanka (EISENBERG & LOCKHART, 1972). However, it should be noted that the Ivory Coast study included only five days of radio-telemetry and the Sri Lanka study is a crude estimate based upon cursory observations. RABINOWITZ's (1989) study utilized radio-telemetry intensively and as such is the only reliable tropical leopard HRS estimate.

Home range dynamics for any carnivore are dependent upon a variety of factors: prey biomass and availability (NORTON & HENLEY, 1987), metabolic requirements (GITTLEMAN & HARVEY, 1982), habitat composition (MACDONALD, 1983), intra-and interspecific carnivore densities (KNOWLES, 1985; LITVAITIS *ET AL.*, 1986), seasonal trends (CRAWSHAW JR. & QUIGLEY, 1991; WOLDA, 1983), age and sex (BAILEY, 1993).

Table 4. Frequency of occurrence of prey items identified from leopard feces (n=41) from Ban Krang Study Area.

Prey species	Live weight (kg)[c]	(n)	Frequency of occurrence
Mustelidae			
Arctonyx collaris	10.5	17	41%
Felidae			
Prionailurus bengalensis	4.0	1	3%
Viverridae			
Viverricula indica	3.0	1	3%
Cervidae			
Muntiacus muntjak	24.0	8[a]	20%
Cervus unicolor	222.5	1	3%
Suidae			
Sus scrofa	137.5	3	7%
Cercopithecidae			
Semnopithecus obscura	7.5	2	5%
Rhizomyidae			
Rhizomys sumatrensis	3.9	1	3%
Hystricidae			
Atherurus macrourus	1.0	2[b]	5%
Unidentified mammal		5	12%
Total		41	

[a] includes one carcass
[b] includes one regurgitation sample
[c] averaged from Lekagul & McNeely (1977)

Tiger sign was never encountered within the study area, hence leopards were considered to be the dominant terrestrial carnivore. As all leopards were healthy adults with established, stable home ranges, the dominant environmental influence on leopard behavior appeared to be prey availability. While barking deer *Muntiacus muntjak* was the dominant leopard prey item in Huai Kha Khaeng (43%) (RABINOWITZ, 1989) their representation in the feces of KKNP leopards was much lower (20%) (Table 4). This was likely due to the lower deer densities in KKNP than in Huai Kha Khaeng (Saksit Simchareon, pers. comm.). Barking deer sign in KKNP were infrequent during the wet season, a period of some seven months. A consequence of lower deer densities in KKNP appears to be increased predation on alternative species.

The opportunistic hunting strategy of leopards (SCHALLER, 1972; BAILEY, 1993; HOPPE-DOMINIK, 1984; RABINOWITZ, 1989; MUCKENHIRN & EISENBERG, 1973) accounts for a greater prey base and variety when preferred prey are not available. In KKNP leopards maintained a relatively small HRS while satisfying their dietary requirements. This was likely a reflection of opportunistic hunting behavior combined with adequate prey densities of species such as hog badger *Arctonyx collaris*. Hog badger were heavily utilized by leopards possibly due to their greater densities than barking deer.

The homogenous habitat of KKNP provided a relatively consistent, year-round environment for leopards. The rivers, while swelling during the wet season and shrinking during the dry season, remained running year-round and provided a constant source of free water for leopards and potential prey species. This stable environment may have been conducive for maintaining stable prey populations and, as a result, stable leopard home ranges. The Pranburi River and its smaller tributaries made up the majority of radio locations for males L350 and L600. While travel was likely easier along river valleys, waterways also offered potential hunting opportunities due to the accumulation of prey species as suggested for other felids by EMMONS (1988) and RABINOWITZ & NOTTINGHAM JR. (1986).

Increases in HRS during the wet season (mean increase: 12%), although slight, are consistant with Rabinowitz's data for Huai Kha Khaeng leopards, and may have been due to dispersion of prey species and the subsequent expansion of leopard home ranges to encompass them.

The high degree of home range overlap (40%) between males L350 and L600 was unexpected because both leopards were sexually mature adults expected to be intolerant of one another. However, at no time during this study were these two leopards recorded within one kilometer of each other, thus possibly indicating temporal spacing and avoidance. In addition, because the HRS of male L350 was likely larger than reported, the percentage of overlap between the two males may have been overestimated.

The nearly completely encompassed HRS of female L700 by male L350 (91%) and partial overlap of L600 (34%) accords with previous reports that home range sharing is tolerated between opposite sexes. BAILEY (1993) recorded female leopard home ranges overlapping with at least two male ranges on five separate occasions in Kruger National Park, South Africa. RABINOWITZ (1989) also documented the overlap of home ranges between female and male leopards in Huai Kha Khaeng. Presumably, the negative influence of hunting competition is outweighed by the positive influence of increased mating encounters through the sharing of home ranges.

Movements

The mean daily movements of leopards in KKNP (1.95 km, n=3) were similar to those for Huai Kha Khaeng (mean: 1.7 km, n=2) (RABINOWITZ, 1989), Kruger National Park (mean: 1.7 km, n=24) (BAILEY, 1993) and Cape Province, South Africa (mean: 2.5 km, n=3) (NORTON & HENLEY, 1987). The smaller HRS of KKNP leopards did not result in shorter daily movements as expected.

QUIGLEY (1987) argued that while jaguars of the Pantanal, Brazil, showed similar mean daily movements with other jaguars in Brazil (SCHALLER & CRAWSHAW JR., 1980) and tigers in Chitwan, Nepal (SUNQUIST, 1981), "the much smaller home ranges of Chitwan tigers . . . may represent a more intensive use of living area than jaguars in the Pantanal". This same argument may apply to KKNP leopards where similar mean daily movements combined with small HRS may represent a more intensive use of home range than leopards in Huai Kha Khaeng and South Africa. However, it should be noted that KKNP male leopard HRS were likely to have been larger than reported.

Activity

The overall activity pattern of leopards in KKNP (48%) (n=1,120 activity readings) was lower than that shown for leopards in Huai Kha Khaeng (57%) (n=1,358 activity readings) (RABINOWITZ, 1989). In addition, while Rabinowitz observed an arrhythmic activity pattern, KKNP leopards exhibited greater crepuscular and nocturnal activity.

RABINOWITZ (1989) stated that the overall activity level of Huai Kha Khaeng leopards was lower than the 75% activity level observed for an overlapping tiger and leopard by SEIDENSTICKER (1976) in Nepal. Although the Huai Kha Khaeng study area included at least one resident tiger, Rabinowitz argued that resident leopards in the area did not show some of the subordinate behavior patterns documented for leopards occurring sympatrically with tigers in Chitwan, due to the low use of the study area by tigers and thus possibly the lower activity levels. This argument appears to substantiate the data on KKNP leopards where an even lower activity level than Huai Kha Khaeng may have been due to the absence of tigers in the study area. In the Ban Krang Study Area, leopards did not have to avoid or otherwise adjust their movements around tigers.

ZIELINSKI (1988) maintained that "the daily activity of some predators is correlated with the activity pattern of their prey. If capture efficiency varies as a function of prey activity, a predator that synchronizes its foraging activity with the time of day that prey are most vulnerable should capture more prey, and at a lower cost, than a predator that initiates foraging at random." Peak temperatures of mid-day appear to have influenced leopard activity, as the lowest activity rates (28%) were recorded during this time period. It follows that many other animals, both predator and prey species alike, were likely to be inactive during this period. However, high temperatures were not strictly prohibitive as activity was recorded several times during this study when the temperature was above 30°C. BAILEY (1993) also observed an active leopard in Kruger when the temperature was 32.4°C.

Leopards maintained relatively constant monthly mean activity. Seasonal variation in activity was negligible with monthly mean activity (52%) during the colder, dry month of January slightly exceeding the lowest monthly average (48%) in October at the end of the wet season. Rainfall, both light and heavy, did not appear to influence leopard activity.

Food Habits

Previous studies have shown that leopards tend to select prey smaller than themselves (JOHNSINGH, 1983; HESS, 1991; KARANTH & SUNQUIST, 1995; RABINOWITZ, 1991; SCHALLER, 1972; SUNQUIST, 1981). The diet of KKNP leopards is consistent with this.

Small carnivores were an important prey group, comprising nearly one-half of total leopard feces examined. However, because smaller prey have a greater surface-to-mass ratio, their hairs should show up more frequently in scats than those of larger prey (Alan Rabinowitz, pers. comm.; MERIWETHER & JOHNSON, 1980) which will bias the estimates of number of prey of different size classes consumed (WEAVER & HOFFMAN, 1979). Thus, the importance of large prey will be undervalued when examining only fecal contents. The large "unidentified mammal" category in this study (12%) likely contained ungulate or other large, meaty prey remains.

The high frequency of occurrence of hog badger (41%) in leopard feces was likely due to their relative abundance and behavior. Hog badger sign were common throughout the year, and they were observed on two occasions on the main road during late afternoon. These conspicuous, slow moving carnivores seemed undisturbed by human presence and when finally alerted, they retreated slowly. Such behavior would likely result in relatively easy captures for leopards. Two other carnivores, leopard cat *Prionailurus bengalensis,* and small Indian civet *Viverricula indica,* were also identified from fecal remains. Leopards will take other carnivores provided they are not too large, and can be caught without risk of injury (BAILEY, 1993; HESS, 1991; RABINOWITZ, 1991). Leopard cat and small Indian civet, which weigh 3–6 kg, likely offer little effective resistance to a leopard attack.

The hunting and killing method of a leopard was documented on one occasion (February 14, 1996) when, after walking in on L350's signal, a barking deer carcass was discovered draped over a log 5 m from the Pranburi River. Inspection of the carcass revealed that death was caused by dual canine punctures through the dorsal braincase. The carcass remains, after three days of feeding, consisted of the head, forelimbs, miscellaneous bones, and the entire hide. Closer inspection of the main road revealed deer blood and hair near the edge of dense vegetation, being consistent with an ambush type kill. The ambush may have followed a stalking sequence as observed by BAILEY (1993) and SCHALLER (1972) for African leopards, but the method of killing differed. African leopards were observed to kill predominantly by neck and throat bites, while RABINOWITZ (1991) recorded a bait pig killed by canine punctures through the skull, similar to this instance. In addition, while leopards commonly cache prey in trees in Africa, the absence of tiger and other large scavengers in the study area makes cacheing unnecessary.

The low incidence of primate remains recovered from leopard feces (5%) may have been due to the dense evergreen habitat, which permits primates to travel easily through the canopy without having to descend to the ground. RABINOWITZ (1991) stated that the dry mosaic forest of Huai Kha Khaeng may have often forced primates to use the ground, thus exposing them to greater risk of predation from big cats. Rabinowitz identified primate hairs in 11% of leopard feces with the highest percentage being from macaques *Macaca* spp. (8.0%), monkeys known to move on the ground frequently (Kim Bauers, pers. comm.) while the more arboreal langurs *Semnopithecus* spp. were encountered less often in leopard feces (3%). The occurrence of langurs but not macaques in feces may imply that predation took place in trees. POCOCK (1939), however, described how leopards can imploy a feigning move to climb a tree in order to scare langurs to the ground where they are more vulnerable to attack.

SEIDENSTICKER (1983) stated that the intensity of predation on macaques and langurs by big cats is directly correlated with the availability and abundance of alternative prey. In this study the availability and abundance of non-primate prey appeared to have been adequate with the exception of ungulates. Low densities of barking deer, sambar and other ungulates may have influenced leopards to prey upon primates. However, as primates constituted only a small percentage of leopard feces, the relevance of this argument may be questioned.

The only seasonal variation noted in leopard feces was a greater occurrence of barking deer during the dry season (75%) than during the wet season (25%). All other major prey items were equally represented across seasons. This correlates with the low frequency of barking deer sign observed during the wet season, and increased deer movement during the dry season (Alan Rabinowitz, pers. comm.).

CONSERVATION OF THE LEOPARD IN THAILAND

Leopards, like all big cats, require adequate living space, water and prey to sustain viable populations (RABINOWITZ, 1989; BAILEY, 1993; SCHALLER, 1972, NOWELL & JACKSON, 1996). In KKNP, although habitat and water sources appeared adequate, low densities of barking deer and sambar were probably the direct result of illegal hunting. Further decline of deer populations will force leopards to prey upon less preferable, smaller species, and ultimately lead to the extinction of the tiger in KKNP, which must have these prey in order to survive.

Throughout Thailand the greatest threats to leopard survival remain habitat loss and reduction of prey through illegal hunting. Of these, loss of habitat represents the most serious and immediate threat to leopards. Thailand must continue to vigorously protect its established parks and wildlife sanctuaries from illegal logging and encroachment, in addition to establishing new protected areas where leopards now range but are afforded little legal protection. Protected areas must be patrolled diligently against poaching, with arrests leading to strong penalties.

Conservation of large cats requires a firm commitment from the Thai government, but ultimately the support of the Thai people must be obtained to drive the decision processes of the government. Continuing education at all levels, emphasizing the importance of wildlife conservation should be in place to insure a conservationist mindset for the upcoming generation of Thai leaders.

ACKNOWLEDGMENTS

Approval for this study was granted by the Royal Forest Department, National Park Division, and the National Research Council of Thailand. I thank Samart Moungmaitong, Chief of Kaeng Krachan National Park, for arranging my living quarters within the park and otherwise assisting when needed. I am greatly indebted to Umaporn Grassman, Sean Austin and Kwanchai Sukgao for their field assistance throughout the duration of this study. This research was funded by Societa Zoologica La Torbiera. I thank Society President Francesco Rocca for his support and valuable comments.

REFERENCES

BAILEY, T. 1993. *The African Leopard: Ecology and Behavior of a Solitary Felid.* Columbia Univetrsity Press, New York. 429 pp.

BAKER, L. 1991. Feeding ecology of reintroduced bobcats on Cumberland Island, Georgia. M.S. thesis, University of Georgia, Athens.

BERTRAM, B.C.R. 1982. Leopard ecology as studied by radio tracking. *Symp. Zool. Soc. Lond.* (49): 341–352.

BOESCH, C. 1991. The effects of leopard predation on grouping patterns in forest chimpanzees. *Behaviour* 117: 34.

CHENGVANICHSAWAD, S. 1977. Morphological features of hair from some Artiodactyla in Thailand. M.Sc. thesis, Kasetsart University, Bangkok.

CRAWSHAW JR., P. AND H.B. QUIGLEY. 1991. Jaguar spacing, activity and habitat use in a seasonally flooded environment in Brazil. *J. Zool. Lond.* (223): 357–370.

CUMMINGS, J. 1992. Thailand: *A Travel Survival Kit.* Lonely Planet Pub., Hawthorn, Australia. 626 p.

EISENBERG, J. AND M. LOCKHART. 1972. An ecological reconnaissance of Wilpattu National Park, Ceylon. *Smithson. Contrib. Zool.* 101: 1–118.

EMMONS, L. 1988. A field study of ocelots *Felis pardalis* in Peru. *Rev. Ecol. (Terre vie).* 43: 133–157.

GITTLEMAN, J. AND P.H. HARVEY. 1982. Carnivore home range size, metabolic needs and ecology. *Behav. Ecol. Sociobiol.* (10): 57–63.

GRASSMAN, L. I. JR. 1997. Ecology and behavior of four sympatric carnivore species (Mammalia: Carnivora) in Kaeng Krachan National Park, Thailand. M.Sc. thesis, Kasetsart University. 94 p.

GRAY, D., C. PIPRELL AND M. GRAHAM. 1986. *National Parks of Thailand.* Industrial Finance Corporation of Thailand. 238 pp.

HESS, L. 1991. *The Leopards of Londolozi.* New Holland Pub., Ltd., London. 164 p.

HOPPE-DOMINIK, B. 1984. Etude du spectre des proies de la panthere, *Panthera pardus,* dans le Parc National de Tai en Cote d'Ivoire. *Mammalia.* 48 (4): 477–487.

ILANY, G. 1986. Preliminary observations on the ecology of the leopard *Panthera pardus jarvisi* in the Judean Desert. Page 199 (abstract), *in* S.D Miller and D.D. Everett (eds.). *Cats of the World: Biology, Conservation, and Management.* National Wildlife Federation, Washington, D.C.

JENNY, D. 1993. Leopard research in Ivory Coast rain forest. *Cat News* 18: 12–13. IUCN Cat Specialist Group.

JOHNSINGH, A.J.T. 1992. Prey selection in three large sympatric carnivores in Bandipur. *Mammalia* 56(4): 517–526.

KARANTH, K.U. AND M.E. SUNQUIST. 1995. Prey selection by tiger, leopard and dhole in tropical forests. *J. Anim. Ecol.* (64): 439–450.

KNOWLES, P.R. 1985. Home range size and habitat selection of bobcats, Lynx rufus, in north-central Montana. *Canadian. Field Natural.* (99): 6–12.

LEKAGUL, B. AND J. A. MCNEELY. 1977. *Mammals of Thailand.* Assoc. for Conservation of Wildlife. Saha Karn Bhaet Co., Bangkok, Thailand. 758 pp.

LITVAITUS. J.A., J.A. SHERBURNE AND J.A. BISSONETTE. 1986. Bobcat habitat use and home range size in relation to prey density. *J. Wildl. Manag.* 50 (1): 110–117.

LOPEZ, D.N. 1985. Status and distribution of the ocelot *Felis pardalis* in south Texas. M.S. thesis, Texas A & I University, Texas.

MACDONALD, D.W. 1983. The ecology of carnivore social behavior. *Nature* 301 (3): 379–384.

MERIWETHER, D. AND M.K. JOHNSON. 1980. Mammalian prey digestibility by coyotes. *J. Mammal.* 61 (4): 774–775.

MITZUTANI, F. 1993. Home range of leopards and their impact on livestock on Kenyan ranches. Pages 64-69. *In* N. Dunstone and M.L. Gorman (eds.). *Mammals as Predators.* Proc. Symp. Zool. Soc. Lond. 65. Clarendon, Oxford.

MOHR, C.O. 1947. Table of equivelant populations of North American small mammals. Amer. Midl. Nat. 37: 223–249.

MUCKENHIRN, N.A. AND J.F. EISENBERG. 1973. Home ranges and predation of the Ceylon leopard *Panthera pardus fusca.* Pages 142–175 in R.L. Eaton (ed.), *The World's Cats.* 1 (1). World Wildlife Safari, Winston, Oregon.

NORTON, P.M., A.B. LAWSON, S.R. HENLEY AND G. AVERY. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *S. Afr. J. Wildl. Res.* 16 (2): 47–52.

NORTON, P.M. AND S.R. HENLEY. 1987. Home range and movements of male leopard in the Cedarberg Wilderness Area, Cape Province. *S. Afr. J. Wildl. Res.* 17 (2): 41–48.

NOWELL, K. AND P. JACKSON. 1996. *Wild Cats: Status Survey and Conservation Action Plan.* IUCN, Gland, Switzerland. 382 pp.

PALMER, R. AND N. FAIRALL. 1988. Caracal and African wild cat diet in the Karoo National park and the implications thereof for hyrax. *Sawat. Sararuch. Afr. Tydskr. Natuurnav.* 18 (1): 30–34.

POCOCK, R.I. 1939. *The Fauna of British India, Mammals, I. Primates and Carnivores.* 2d ed., Taylor and Francis, London.

PUTMAN, R.J. 1984. Facts from faeces. *Mammal Rev.* 14 (2): 17–25.

QUIGLEY, H. 1987. Ecology and conservation of the jaguar in the Pantanal region, Mato Grosso Do Sul, Brazil. Ph.D. dissertation, University of Idaho, Moscow, Idaho.

RABINOWITZ, A. 1989. The density and behavior of large cats in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Nat. Hist. Bull. Siam Soc.* 37 (2): 235–251.

RABINOWITZ, A. 1991. *Chasing the Dragon's Tail: The Struggle to Save Thailands Wild Cats.* Doubleday, New York. 241 pp.

RABINOWITZ, A. AND B.G. NOTTINGHAM JR. 1986. Ecology and behavior of the jaguar *Panthera onca* in Belize, Central America. *J. Zool. Lond.* (210): 149–159.

SAKAGUCHI, N. 1994. Ecological aspects and social system of the Iriomote cat(Felis iriomotensis) (Carnivora; Felidae). Ph.D. dissertation, Kyushu University, Fukuoka, Japan.

SANTIAPILLAI, C., M.R. CHAMBERS AND N. ISHWARAN. 1982. The leopard *Panthera pardus fusca* (Meyer 1794) in the Ruhuna National Park, Sri Lanka, and observations relevant to its conservation. *Biol. Cons.* 23: 5–14.

SATHYAKUMAR, S. 1992. Food habits of leopard *Panthera pardus* on Mundanthurai Plateau, Tamil Nadu India. *Tigerpaper* 19 (2): 8–9.

SCHALLER, G.B. 1972. *The Serengeti Lion.* Chicago University Press, Chicago. 480 p.

SCHALLER, G.B. AND P.G. CRAWSHAW JR. 1980. Movement patterns of jaguar. *Biotropica* 12 (3): 161–168.

SEIDENSTICKER, J. 1976. On the ecological separation between tigers and leopards. *Biotropica.* 8 (4): 225–234.

SEIDENSTICKER, J. 1977. Notes on early maternal behavior of the leopard. *Mammalia* 41 (1): 111–113.

SEIDENSTICKER, J. 1983. Predation by *Panthera* cats and measures of human influences in habitats of South Asian monkeys. *Inter. J. of Prim.* 4 (3): 323–326.

SEIDENSTICKER, J., M. E . SUNQUIST AND C. MCDOUGAL. 1990. Leopards living at the edge of the Royal Chitwan National Park, Nepal. Pages 415-423, *in* J.C. Daniel and J.S. Serrao (eds.), *Conservation in Developing Countries: Problems and Prospects.* Bombay Nat. Hist. Soc., Bombay.

SMITH, R.M. 1978. Movement patterns and feeding behavior of the leopard in the Rhodes Matopos National Park, Rhodesia. *Carnivore* (1): 58–69.

SUNQUIST, M. 1981. The social organization of tigers *Panthera tigris* in Royal Chitwan National Park, Nepal. *Smithsonian Contr. Zool.* (336): 1–99 p.

SUNQUIST, M. 1983. Dispersal of three radiotagged leopards. J. Mamm. 64 (2): 337–341.

TISTR. 1989. Master plan for Kaeng Krachan National Park. Thailand Institute of Scientific and Tecnological Reasearch, Bangkok. 105 p. (In Thai).

WEAVER, J.L. AND S.W. HOFFMAN. 1979. Differential detectability of rodents in coyote scats. J. Wildl. Manage. 43 (3): 783–786.

WOLDA, H. 1983. Spatial and temporal variation in abundance in tropical animals. Pages 93–105, *in* S.L. Sutton, T.C. Whitmore and A.C. Chadwick (eds.), *Tropical Rainforests: Ecology and Management.* Blackwell Science Publ., London.

ZIELINSKI, W.J. 1988. The influence of daily variation in foraging cost on the activity of small carnivores. Anim. Behav. 36: 239–249.