Original article

Monitoring of the Leopard Population at Khao Nang Rum In Huai Kha Khaeng Wildlife Sanctuary

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Received: November 20, 2007 Accepted: June 18, 2008

ABSTRACT

Leopard population was monitered using capture-recapture technique. Camera traps were set up for 3 years (1996-1999) over a 115.88 km^2 area (A) around Khao Nang Rum Wildlife Research Station, Huai Kha Khaeng Wildlife Sanctuary. Eighteen leopards were photographed including 4 adult females, 3 sub-adult females, 3 adult males, 3 sub-adult males and 5 males that could not be identified by age class. Four black leopards were individually identified: one leopard was collared and 3 leopards were identified by their size, sex, photograph time and locations. Closure test indicated that the leopard population was closed ($p>0.05$). The estimation of population size of leopard using model M_h are 10, 10 and 11 leopards for three sessions respectively. Log-normal-based 95% confidence interval ranged from 10 to 29 leopards for the first session, from 9 to 17 leopards for the second session and from 11 to 26 leopards for the third session. Estimated leopard densities were decreased from 7.88 ± 5.82 to 5.21 ± 3.12 and 4.86 ± 2.29 leopards/ 100 km^2 respectively. The average leopard density in this study was 5.98 leopards/ 100 km^2. This highly leopard density indicated that the Western Forest Complex is an important area for leopard conservation. Moreover, data on the abundance and density of leopard will help us to understand their present status in the study area and evaluate habitat quality and success of the management.

Keywords: Leopard, Panthera pardus, Population, Huai Kha Khaeng Wildlife Sanctuary

INTRODUCTION

The leopard is an important predator in the tropical rainforest ecosystem. It plays an important role in predator-prey interactions. It regulates prey populations and maintains natural selection by influencing prey behavior and directly affects the vigor of prey populations and indirectly, the health of the whole ecosystem. However, leopard is an endangered large felid which shows a declining trend due to habitat loss, depletion of prey and direct hunting. It has been listed on Appendix I of the Convention of International Trade of Endangered Species of Wild Fauna and Flora (CITES) since 1983. Monitoring of leopard population is important to the planning and management to maintain them.

Leopard is secretive and usually nocturnal animals. Thus, methods for estimating abundance of wild cats such as tiger and leopard in the past used counting tracks of individual animal identified by measurement of their tracks (Riordan, 1998) and track shape (Panwar, 1979). However, this method has serious problems associated with field surveys and some assumptions are erroneous (Karanth 1987, 1988, 1995).

Capture-recapture is a common approach to investigating the abundance of marked animals; capture histories of animals can be used for determining the number of undetected animals present. There are statistical models to be employed for estimating the both of open and closed populations. In a closed population, it is assumed that there are no births/deaths/ immigration/emigration during the time of the survey.

Camera trapping is probably the best possible available technique to build up capture histories that can be analyzed in readily available capture-recapture software such as CAPTURE (Otis *et al*., 1978; White *et al*., 1982) and MARK (White and Burnham, 1999). This approach already has been used for leopards in many area (Jenny, 1996; Stander *et al*., 1997; Khorozyan, 2003; Kostyria *et al*., 2003; Spalton *et al*., 2006) and also has been applied to other cryptic felids such as tiger (*Panthera tigris*) (Karanth, 1995; Karanth and Nichols, 1998; Kawanishi and Sunquist, 2004), jaguar (*Panthera onca*) (Silveira *et al*., 2003; Wallace *et al*., 2003; Maffei *et al*., 2004; Silver, 2004), snow leopard (*Uncia uncia*) (Spearing, 2002) and ocelot (Trolle and Kerv, 2003). Moreover, they are linked with movement, distribution, activity patterns, habitat use and reproductive information that are important for wildlife conservation (Spalton *et al*., 2006; Silveira *et al*., 2003).

The majority of past research has taken place in sub-Saharan Africa, India, Sri Lanka and Nepal. In Thailand, there has been little research concerning the abundance, behavior and some aspects of leopard ecology. However, the detailed knowledge of leopard abundance has not been fully studied and is necessary to manage and conserve the leopard in the wild. Data on the abundance and density of leopard will help us to understand their present status in the study area and evaluate habitat quality and success of the management. These factors are the principal objectives of this study.

MATERIALS AND METHODS

Study Area

The study was carried out in the forests around Khao Nang Rum Wildlife Research Station (N. Lat. 15º25´-15º31´ and E. Long. 99º15´-99º20´) within Huai Kha Khaeng Wildlife Sanctuary (Figure 1), which forms part of an 18,727 km^2 protected area network known as the Western Forest Complex. The area has rugged, hilly topography, mean annual temperature in 20 years from 1986 to 2005 was 24.64ºc and annual rainfall of 1447 mm. The area supports four vegetation type dry evergreen forest, hill evergreen forest, mixed deciduous forest and dry dipterocarp forest depending on rainfall patterns and edaphic factors (Srikosamatara, 1993; Tunhikorn *et al*., 2004).

Camera Trapping

This study was begun to document the presence of leopards and other mammals. Consequently camera trapping was done on an ad hoc basis, without strictly following optimal survey protocols (Nichols and Karanth, 2002). However, The following field protocols were helpful for analyzing the data within a formal capture-recapture framework.

Camera trapping was carried out for 3 years (1996-1999) over a 115.88 km^2 area (A) around Khao Nang Rum Wildlife Research Station (Figure 2), Huai Kha Khaeng Wildlife Sanctuary. The area (A) was determined by a minimum convex polygon around all camera locations. Camera traps were deployed for 3-4 months a year.

Trailmaster® (Goodson Associates, Inc., Kansas, USA) camera traps were set on the trails and roads where leopard tracks or other secondary signs were frequently found.

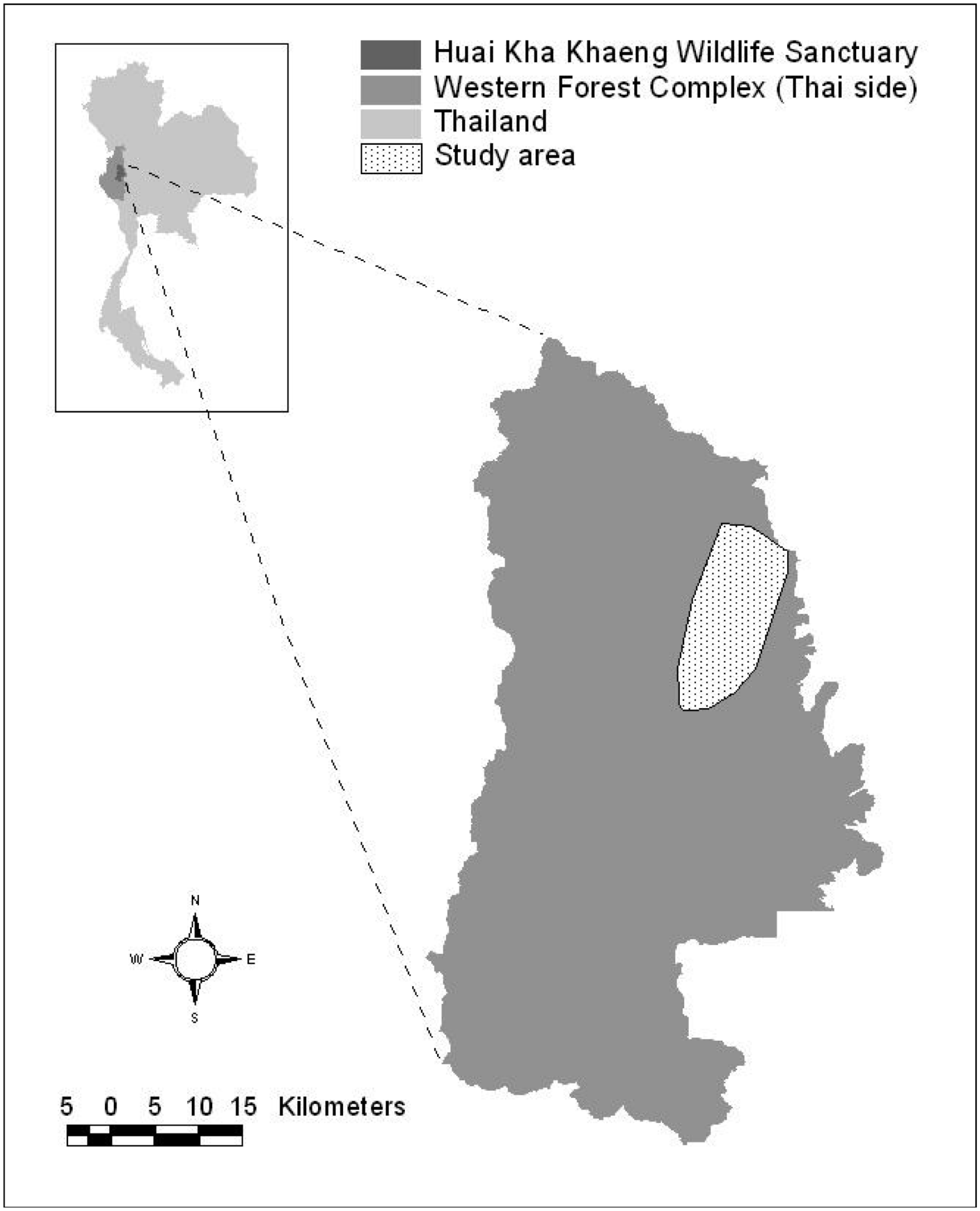

Figure 1. Map of Huai Kha Khaeng Wildlife Sanctuary and the study area.

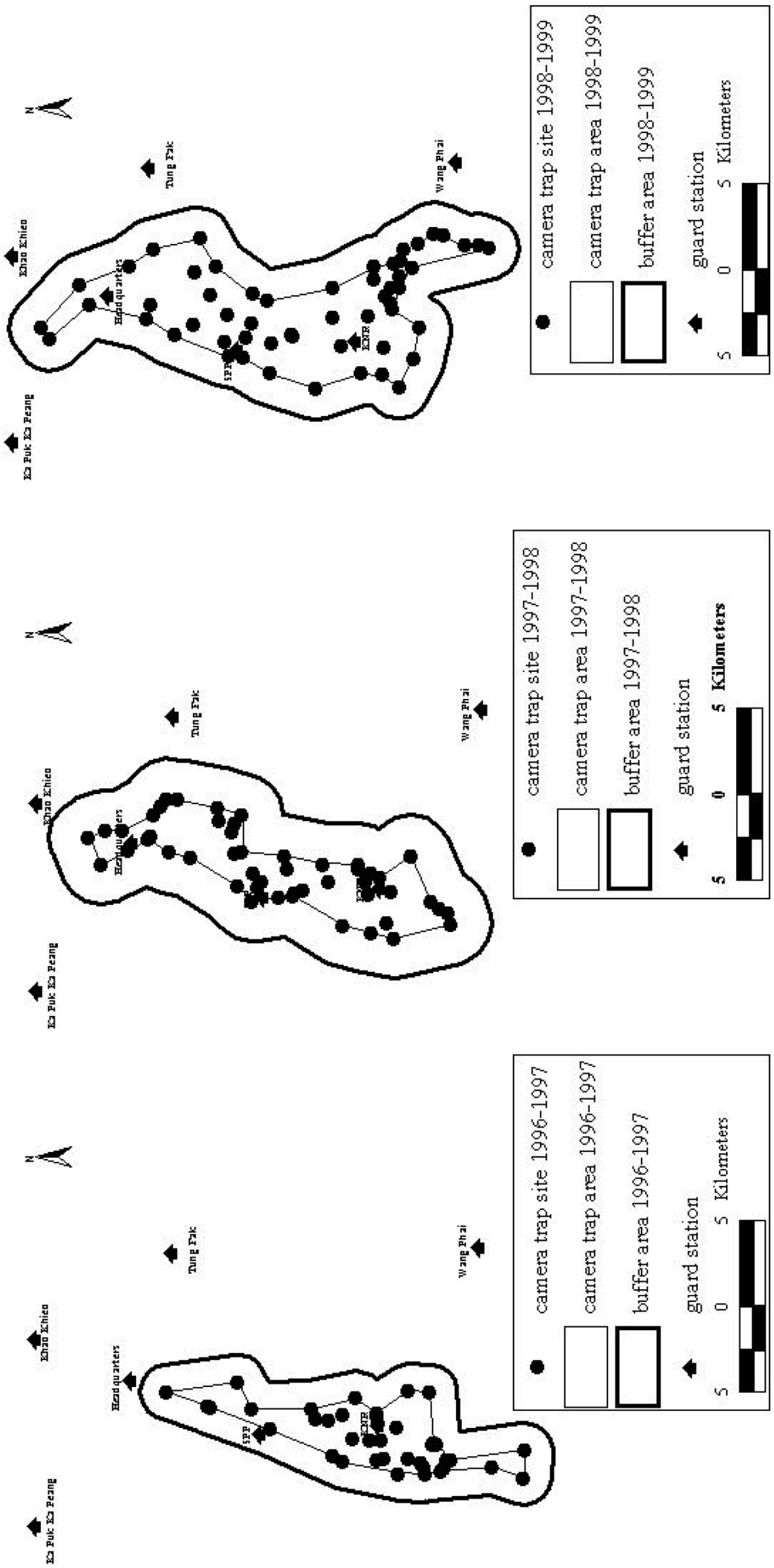

Figure 2. Camera trap sites, camera trap areas, and buffer areas.

Camera traps were mounted on trees 3-4 m from the path, with the infrared beam set 45 cm above the ground (Karanth, 1995; Karanth and Nichols, 1998; Kostyria, 2003). Camera traps were set out in pairs to capture the opposing, asymmetrical spot patterns of the passing leopards (Karanth, 1995). The distance between unit pairs was 1.0-3.0 km, with GPS locations taken for all sites. Cameras were checked every 2-3 days to change batteries and film and to document the presence of animal tracks.

Leopard Identification

Leopards are patterned animals that we can individually identify from their natural markings. Rosettes and spot patterns of individual leopard are asymmetrical on the two flanks. Both sides of each animal had to be photographed simultaneously. The photographs are needed for clear identification. However the obtained, photographs viewed only on one side, can be linked to the left or right profile from camera trapping and radio collared leopard to identify individual leopards. Unclear animal photographs on one side were not used for analysis. Black leopards could not be identified clearly by their spot pattern. However, they were identified by their size, sex and photograph locations which relate to photograph time.

Animal photographs were organized separately for each individual leopard and the date, time, photograph location, age class and sex were recorded. Leopards were given all ID from their collar number or new ID was created for non-collared animal.

Estimating Abundance

The capture history was used to describe capture frequencies. Data were recorded in an X matrix consisting of *i* animals in rows and *t* trapping occasions in columns, assuming a value of either "0" if the animal was not photographed or a "1" if it was photographed. We used five trapping occasions for all sites with each occasion containing 3 day. The capture histories of individual leopards were used in the framework of capture-recapture theory to estimate capture probabilities and population size using the computer program CAPTURE (Otis *et al*., 1978; White *et al*., 1982; Rexstad and Burnham, 1991). The program estimates abundance of closed population under seven models (M_h, M_b, M_t, M_{bh}, M_{th}, M_{tb}, M_{tbh} that vary by h-heterogeneity, b-behavior, t-time) using M_0, in which probabilities are constant is null the hypothesis (White *et al*., 1982). In CAPTURE, the closure test for the number of individual is constant during the overall study period and is computed for the subset of the data defined by the capture frequencies. However, the validity test can not be devised because of problems in behavioral responses and time trends (White *et al*., 1982). However, we assumed that the population closed because the short period. The study would end before significant immigration could occur. In this study, we used model M_h in which capture histories vary by individual heterogeneity because the estimator for model M_h (the jackknife, $\hat{N}_h$) is the most robust of the five estimators ($\hat{N}_{bh}, \hat{N}_b, \hat{N}_t, \hat{N}_0$) (White *et al*., 1982). In addition, this model was widely used for estimate abundance for large cats (Karanth and Nichols, 1998; Kostyria *et al*., 2003) that are territorial animals in which home range size and trapping depend on social position and spatial location of the animal (Karanth, 1995).

Estimating Density

Animal density can be estimated using abundance estimates from CAPTURE. Density is defined as:

$$\hat{D} = \hat{N} / \hat{A}(W) \qquad (1)$$

$\hat{D}$ is the estimated animal density, $\hat{N}$ is the estimated abundance and $\hat{A}(W)$ is the estimated effective area in which photographed animals live; W is the boundary strip of width that is added around the perimeter of the area in which the camera traps were set.

Variance in animal density is calculated from variance in estimated abundance and effective area:

$$\hat{\text{var}}(\hat{D}) = \hat{D}^2 \left[\frac{\hat{\text{var}}\left(\hat{A}(W)\right)}{\left[\hat{A}(W)\right]^2} + \frac{\hat{\text{var}}(N)}{\hat{N}^2} \right] \quad (2)$$

Variance in estimated abundance was computed by program CAPTURE. The effective area includes the area where camera trap sites were plotted and connected on the edge to form the perimeter and the buffer area. The buffer width ($\hat{W}$) was calculated using the mean maximum distance moved by leopards ($\hat{\bar{d}}$) between camera trap sites divided by two (Karanth and Nichols, 1998).

$$\hat{W} = \hat{\bar{d}} / 2 \quad (3)$$

Variance in buffer width was calculated using variance in mean maximum distance moved by leopards. Let d_i denote the maximum distance moved between camera trap sites for animal *i* and *m* denote the number of animals that cameras trapped at least twice:

$$\hat{\text{var}}\left(\hat{W}\right) = 0.25 \times \hat{\text{var}}\left(\hat{\bar{d}}\right) \quad (4)$$

$$\hat{\text{var}}\left(\hat{\bar{d}}\right) = \frac{\sum_{i=1}^{m}\left(d_i - \hat{\bar{d}}\right)^2}{m(m-1)} \quad (5)$$

Variance in estimated effective area was calculated following Karanth and Nichols (1998):

$$\hat{\text{var}}\left(\hat{A}(W)\right) = 4\pi^2\left(c + \hat{W}\right)^2 \hat{\text{var}}\left(\hat{W}\right) \quad (6)$$

This estimation approximates each of the sampled areas as a circle in which *c* is a constant that is calculated from $\hat{A}(W) = \pi\left(c + \hat{W}\right)^2$; $\hat{A}(W)$ is the estimated effective area that includes the camera trap area and the buffer area and $\hat{W}$ is the buffer width.

RESULTS AND DISCUSSION

Camera Trap Effort

Camera traps were set up around Khao Nang Ram WRS ranging from 39 to 56 locations per session and covered an area of 115.88 km^2. The research activition for each session were carried out for 3-4 months during the dry season. A total of 2,094 trap nights included 650 trap nights between December 1996 and March 1997, 620 trap nights between December 1997 and February 1998 and 824 trap nights between December 98 and March 99. This traps sampled each location, on an average for about 15 days. Leopards were detected 106 times during 2,094 trap-nights; 43, 39 and 24 times for the three sessions respectively (Table 1).

Abundance

Eighteen leopards were captured including 4 adult females, 3 sub-adult females, 3 adult males, 3 sub-adult males and 5 males that could not be identified by age class. From a total of 27 black leopard photographs, 15 photographs were separated for 4 individual leopards; one leopard had a collar and 3 leopards were identified by their size, sex, photographed time and locations. L055 and L195 were captured every session. Five leopards were captured for two sessions and eleven leopards were capture during only one session.

Capture frequency between sexes was difference: males were photographed 1.81 times more than females. The mean capture rate of males was 0.77 detections/ 100 trap nights for adults and 0.18 detections/100 trap nights for sub-adults. The mean female capture rate was 0.43 and 0.10 detections/100 trap-nights for adults and sub-adults respectively. The average number of photograph locations for individual leopards were 0.56, 0.28, 0.13 and 0.10 locations/100 trap nights for adult males, adult females, sub-adult males and sub-adult females respectively. Both mean capture rate and number of photograph locations ranked from most to least value as determined by number of detections and photographed locations per 100 trap-nights are: adult male, adult female, sub-adult male and sub-adult female. The highest capture rate male was L055 which was photographed 1.88 detections/100 trap-nights; L390, the highest capture rate female, was photographed 0.61 detections/100 trap-nights.

Table 1. Summary statistics for camera trap data on leopards in HKK

session	sampling period	No. locations	traps sampled (days/location)	Effort (trap-nights)	No. detections	No. photographs	No.individuals caught	No. occasions
1	Dec 1996-Mar 1997	39	16.67	650	43	44	9	5
2	Dec 1997-Feb 1998	49	12.65	620	39	50	8	5
3	Dec 1998-Mar 1999	56	14.71	824	24	32	10	5
		144		2,094	106	126		

Closure tests indicated that leopard population was closed (Table 2). The estimation of population size of leopard using model M_h are 10, 10 and 11 leopards for the three sessions respectively. Log-normal-based 95% confidence interval ranged from 10 to 29 leopards for the first session, from 9 to 17 leopards for the second session and from 11 to 26 leopards for the third session. Estimated capture probability over all sampling occasions varied between 0.80 and 0.91. Estimated values of average capture probability were varied ranging from 0.33 to 0.44 (Table 2).

Density

For the three sessions, the camera trap areas were 42.05, 57.86 and 96.93 km^2 respectively. The number of animals which the camera trapped at least twice was six for all three sessions. Average maximum distances moved by photographed leopards ranged from 3.19 to 4.65 km. The estimated boundary strip widths were 1.59(SD=0.30), 2.33(SD=0.40) and 1.81(SD=0.15) km respectively (Table 3). The estimated effective area from the first to the third sessions, which included the camera trap area and the boundary strip were 126.93, 191.76 and 226.44 km^2 (Figure 2). In these areas, the estimated population sizes were 10, 11 and 11 leopards respectively. We used these estimates in conjunction with Equation 1 to estimate leopard density. We found that the estimated leopard densities decreased from 7.88 ± 5.82 to 5.21 ± 3.12 and 4.86 ± 2.29 leopards/ 100 km^2 respectively (Table 4). The average leopard density in this study was 5.98 leopards/ 100 km^2.

Discussions

Results of the study indicated that, 126 photographs of leopards during 2,094 trap-nights (6.02 photographs/100 trap-nights) which was higher than the ones which were obtained from the study on leopard in Kaeng Khachan National Park (KKNP), Thailand (3.25 photographs/100 trap-nights, Ngoprasert, 2004) and in Southwest Primorski Krai (4.69 photographs/100 trap-nights, Kostyria *et al*., 2003). In addition, the estimated capture probabilities of this study (0.44, 0.42 and 0.33) are higher than the results were obtained from the study in KKNP (0.27, using model M_h) and Southwest Primorski Krai (0.20, using model M_h).

Table 2. Estimated abundance and capture probabilities of leopards in HKK under model M_h of program CAPTURE

Session	Closure test (p)	Estimates based on M_h			
		$\hat{p}$	*M(t+1)/N*	*N(SE(N))*	95% CI
1	0.81	0.44	0.90	10 (3.01)	10-29
2	0.95	0.42	0.80	10 (1.76)	9-17
3	0.37	0.33	0.91	11 (2.48)	11-26

Notes: M(t+1) is the total number of leopards captured in all occasions, M(t+1) is the probability of a leopard present being caught over the whole sample period and is mean probability of each leopard being caught in each occasion; if less than 0.05 indicates that the population was closed. SE(N) was calculated by the jacknife estimator used in CAPTURE.

The average maximum distances between capture sites, was varied from 3.19 to 4.65 km, and with the significance level which was lower than the one obtained form the Southwest Primorski Krai (9.70 km). Southwest Primorski Krai is in the temperate zone with low temperature and snow cover in winter, which are extremal conditions for leopard (Kostyria *et al*., 2003). These conditions probably impacted the distances which were higher than the ones obtained from the other study areas including KKNP and this study.

Table 3. Calculated effective area using half the mean maximum distance moved by leopards caught on more than one occasion

Session	camera trap area (km^2)	*m*	Maximum distance moved (km)		Buffer width (km)		Effective area (km^2)	
			$\overline{d}$ (km)	SE(*d*)	*W* (km)	SE(*W*)	$\hat{A}(W)$ (km^2)	SE($\hat{A}(W)$)
1	42.05	6	3.19	0.59	1.59	0.30	126.93	11.80
2	57.86	6	4.65	0.80	2.33	0.40	191.76	19.56
3	96.93	6	3.62	0.30	1.81	0.15	226.44	8.09

Notes: camera trap area is the area enclosed by the perimeter camera traps, m is the number of tigers caught on more than one occasion.

Table 4. Estimated leopard density and detectable change using program CAPTURE and calculated effective area A(W)

Session	*D* (leopards/100km^2)	SE(*D*)	95% CI
1	7.88	2.97	2.05 to 13.71
2	5.21	1.59	2.09 to 8.34
3	4.86	2.56	2.56 to 7.16

Moreover, the obtained male leopard photographs was 1.81 times which was more than female leopard photographs. In the same way, Ngoprasert (2004) reported that capture frequency between sexes was differenced. Male leopards had recapture more than female leopards (T-test, p=0.01). Santiapillai *et al*. (1982) reported that male leopards were visually observed more frequently (72%) than female leopards in Ruguna National Park parallels the observations of Muckenhirn and Eisenberg (1973) in Wilpattu National Park and Bailey (1993) in Kruger National Park. Bailey (1993) reported that males were captured with less trapping effort than females and were observed more often (63%) than females along tourist roads although, females were observed more often (68%) and more than males along fire-break roads. He suggested that the females avoided contact with human more than the males. The data support the contention that the females were shyer than males (Santiapillai *et al*., 1982).

Estimated density using a framework of capture-recapture averaged 5.98 leopards/ 100 km^2. The densities were 7.88 ± 5.82 to 5.21 ± 3.12 and 4.86 ± 2.29 leopards/ 100 km^2, which were close to densities using radio tracking in the same period (6.3 leopards/100 km^2). The average density using radio tracking method were 10.1, 6.9, 3.7 and 4.5 leopard/100 km^2 from 1996 to 1999 respectively. In the same times and area, both methods gave nearly densities and with a decreasing trend. Furthermore the average leopard densities were greater than in KKNP (4.78 leopards/100 km^2) (Ngoprasert, 2004) and much greater than in Southwest Primorski Krai (1.2 ± 0.2 leopards/ 100 km^2) (Kostryria *et al*., 2003). In Huai Kha Khaeng Wildlife Sanctuary, Rabinowitz (1989) estimated leopard density was lower (4 leopards/ 100 km^2) than the obtainul result from this study. Based on the comparison with the another method, the average leopard density in this study was lower than in Tsavo National Park, Kenya (Hamilton, 1976); Cape Province, South Africa

(Norton and Henley; 1987) and Tai National Park, Ivory Coast (Jenny, 1996) but higher than in Sri Lanka (Clark, 1901); Wilpattu National Park, Sri Lanka (Eisenberg and Lockhart, 1972); Serengeti National Park, Tanzania (Schaller, 1972; Cavallo, 1993); Kalahari Desert, Southern Africa (Bothma and Le Riche, 1984); Stellenbosch, Cape Province (Norton and Lawson, 1985); Kruger National Park, South Africa (Bailey, 1993); and North-eastern Namibia (Stander *et al*., 1997).

The trend of leopard density decreased throughout the study period which during the same period the tiger density increased from 1.71 ± 0.99 to 2.27 ± 1.12 and 2.94 ± 2.26 tigers/ 100 km^2 respectively. Seidensticker (1976) recorded that a tiger may have appropriated a kill from a leopard, and he believed that social dominance is a major factor in tiger-leopard interaction. He found that leopard used areas not which were frequented by tiger in order to minimize their chance of encounter. Moreover, we found a female black leopard was killed in the study area. The animal died as a result of one powerful bite to the chest over the heart which is only one clue and we found female tiger tracks around it. We believed that this leopard was killed by a tiger.

The average estimated density in this study can roughly estimate the leopard population size in Huai Kha Khaeng Wildlife Sanctuary, which covered an area of 2780.14 km^2, as 166 leopards. If the habitat quality in the Western Forest Complex, which covered an area of 18,727 km^2, were the as same as in this study area, estimated leopard population size was 1,120 leopards. The data indicated that The Western Forest Complex was an important area for leopard conservation. Moreover, data on the abundance and density of leopard will helped us to understand their present status in the study area and evaluate habitat quality and success of the management.

CONCLUSION AND RECOMMENDATION

Monitoring of leopard population was covered an area of 115.88 km^2 around Khao Nang Rum Research Station, Huai Kha Khaeng Wildlife Sactuary. Eighteen leopards were photographed included 4 adult females, 3 sub-adult females, 3 adult males, 3 sub-adult males and 5 males that could not be identified by age class. From a total of 27 black leopard photographs, 15 photographs were separated for 4 individual leopards; one leopard had a collar and 3 leopards were identified by their size, sex, photographed time and locations.

Closure tests indicated that leopard population was closed. The estimates of population size of leopard using model M_h are 10, 10 and 11 leopards for the three sessions respectively. Log-normal-based 95% confidence interval ranged from 10 to 29 leopards for the first session, from 9 to 17 leopards for the second session and from 11 to 26 leopards for the third session. Estimated leopard densities decreased from 7.88 ± 5.82 to 5.21 ± 3.12 and 4.86 ± 2.29 leopards/ 100 km^2 respectively. The average leopard density was 6.0 leopards/ 100 km^2.

ACKNOWLEDGEMENTS

We would like to express our great appreciation to the National Park, Wildlife and Plant Conservation Department for giving me the opportunity to work and study at Khao Nang Rum Wildlife Research Station. We gratefully acknowledge the late Mr. Mark Graham and WWF (Thailand) for supporting the camera trap. We are particularly appreciated Prof. Dr.Ullas Karanth, Director Wildlife Conservation Society (India), for explanation and suggestion about the estimation of leopard population. We especially thank Mr. Onsa Norrasan, Mr. Precha Prommakun and Mr. Pakawat Ponak for their help in the field study. We would like to give special thank to Ms. Ardith Eudey who helped editing our English manuscript. Our appreciation also is due to Ms Namkhang Saelee for completing our manuscript. We would like to thank everyone who helped and supported this study.

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