The ecology and conservation of tigers and their prey in Kuiburi National Park, Thailand

WWF–Thailand

and

Kuiburi National Park
Department of National Parks, Wildlife, and Plant Conservation

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SUMMARY

- Kuiburi National Park in Thailand is part of the Tenasserim Tiger Conservation Landscape, a globally significant region for tigers. This project (ongoing since 2006) combines field research, outreach, and adaptive management directed towards the recovery of tigers and their prey in Kuiburi National Park.
- Tigers use about 50% of the park's area, centered on the central portion of the park where abundance and diversity of major prey species (gaur, sambar, pigs, and muntjacs) is highest.
- Low prey abundance is the main threat to tiger conservation in Kuiburi. Three prey recovery zones were established in 2007. Patrolling and village outreach efforts have been focused on these zones. Sambar, gaur, pigs, and muntjacs are each increasing in abundance and distribution in at least 1 zone.
- Estimated tiger abundance in the park is 10 individuals, with a density of 1.0 adult tiger per 100 km^2. Tiger distribution and abundance has been stable since 2006. Tigers are breeding in the park—3 cubs have been photographed since 2006.
- Outreach efforts have reached at least 700 people around in villages and towns around the park. Research results were returned to local villages to promote understanding of the rationale for park management actions and elicit local support for prey recovery efforts.
- An improved patrolling and threat monitoring system was initiated in 2008.

PREFACE

This report documents the progress and findings of the ongoing project "Ecological research for tiger conservation in Kuiburi National Park, Thailand" (hereafter, Kuiburi Tiger Project), from 2006–2009. The Kuiburi Tiger Project is conducted through a long-term partnership between Kuiburi National Park, the Department of National Parks, Wildlife, and Plant Conservation, and WWF Thailand. Local people are also increasingly becoming partners.

The Kuiburi Tiger Project started in January 2006 with funding from Keidanren Nature Conservation Fund (Japan), and by a generous donation from Francois and Sheila Brutsch (through WWF US). The Rhinoceros and Tiger Conservation Fund of the U.S. Fish & Wildlife Service provided funding from May 2006 to April 2007 (Award #6G129). WWF France provided funding in 2008–present.

This report is an update since the previous progress report (Steinmetz et al. 2007), but also evaluates the entire project from 2006 to the present, especially in terms of trends in the status of tigers and their prey. Thus, some information is repeated.

INTRODUCTION

Tigers presently occupy just 7% of their historical range (Figure 1a); this dire situation is the result of habitat loss, direct killing for the wildlife trade, and prey depletion. The Tenasserim region of mainland Southeast Asia is one of the most important landscapes for the future of tigers because its extensive, intact forests retain relatively large populations of tigers and prey (Sanderson et al. 2006; Figure 1a). Kuiburi National Park in Thailand (969 km^2) is a little-explored protected area within the Tenasserim landscape, and part of an important protected area complex that contains 1 of Thailand's 15 remaining tiger populations (Tunhikorn et al. 2004). This complex includes Kaeng Krachan National Park and Mae Nam Pachi Wildlife Sanctuary (Figure 1b).

Tiger density is positively correlated with the abundance of prey, particularly sambar, wild pigs, wild cattle, and muntjacs (Sunquist et al. 1999). Even small tiger populations can recover rapidly from low numbers if sufficient prey populations exist; thus, the status of prey in an area is a critical concern for the persistence and recovery of tiger populations.

Throughout most of their range, tigers coexist with dholes (*Cuon alpinus*) and leopards (*Panthera pardus*), potential competitors that subsist mainly on the same ungulate species as do tigers (Grassman 1999, Grassman et al. 2005). Tigers, leopards and dholes are habitat generalists (Karanth & Sunquist 2000), whose coexistence in an area is facilitated by the abundance and availability of ungulate prey in different size classes (Karanth & Sunquist 1995).

In sum, understanding the conservation status of tigers requires a parallel assessment of prey abundance and availability, and, additionally, is enriched by considering the status of leopards and dholes as well. The goal of this project was to determine the status of tigers, other coexisting large carnivores, and their prey in Kuiburi National Park, and use this information to implement conservation activities with park management and local people.

PROJECT SITE AND BACKGROUND

Kuiburi National Park (969 km^2) was established in 1999 and is located in Prachuap Khirikan Province in southwestern Thailand (Fig. 2). The park is characterized by steep mountainous topography incised with abundant seasonal and perennial streams that lie between 100 and 300 m elevation. Highest elevation is 946 m. Vegetation in the park is predominantly semi-evergreen forest, portions of which were logged in the past. Other forest types are less abundant, however mixed deciduous forest occurs in the western portion of the park (Hup Inthanin).

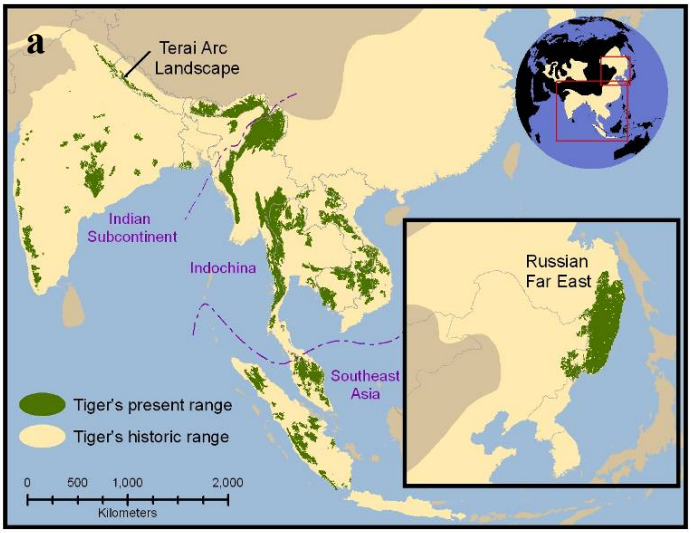
The park is largely surrounded by agricultural land, particularly pineapple plantations, except to the west where it is contiguous with extensive evergreen forest in Myanmar. Adjacent to the park to the east is a 50 km^2 area of regenerating secondary forest that is important for wildlife (Pa Yang). This area is administered as a Royal Initiative to increase forest cover for elephants, and is not officially part of the park.

However, for purposes of wildlife conservation, the area is effectively treated as part of the national park.

The abundance and diversity of major prey species (gaur, banteng, sambar, muntjacs, wild pig) is generally very low throughout the park (Steinmetz et al. 2007). Prey depletion in Kuiburi was already severe prior to park establishment (1999), and is the result of (a) previous logging concessions within the park that facilitated hunting, (b) commercial and subsistence hunting, (c) sport hunting by urban visitors, and (d) the loss of lowland mixed deciduous forest habitat in the past (converted to pineapple plantations before park establishment). Prey recovery is a major focus of the project. Prey species mentioned in this report are listed below.

Prey species of tiger, leopard, and dhole in Kuiburi National Park	
Stump-tailed macaque	*Macaca arctoides*
Hog badger	*Arctonyx collaris*
Wild pig	*Sus scrofa*
Lesser mouse deer	*Tragulus kanchil*
Red muntjac	*Muntiacus muntjak*
Fea's muntjac	*Muntiacus feae*
Gaur	*Bos gaurus*
Sambar	*Cervus unicolor*
Serow	*Capricornis sp.*
Malayan porcupine	*Hystrix brachyura*
Brush-tailed porcupine	*Atherurus macrourus*

Figure 1. Historical and present distribution of tigers (a), and location of Kuiburi National Park within the Tenasserim region of Thailand (b).



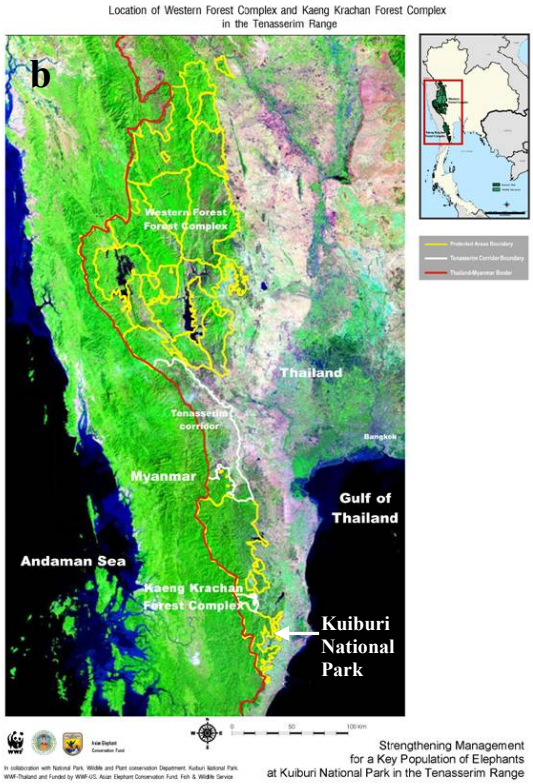
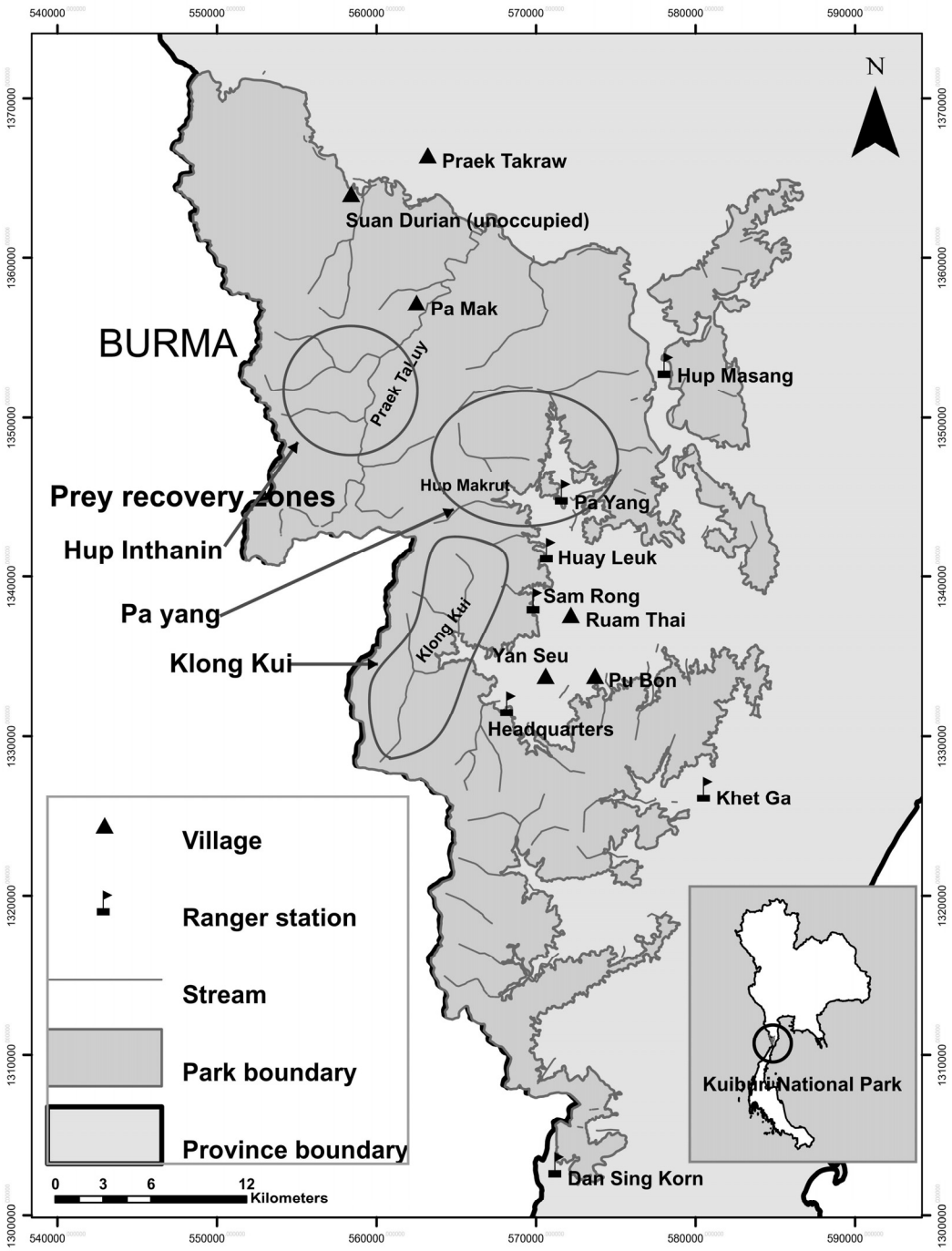


Figure 2. Kuiburi National Park, showing 3 prey recovery zones where project efforts have been focused.



GOALS AND OBJECTIVES

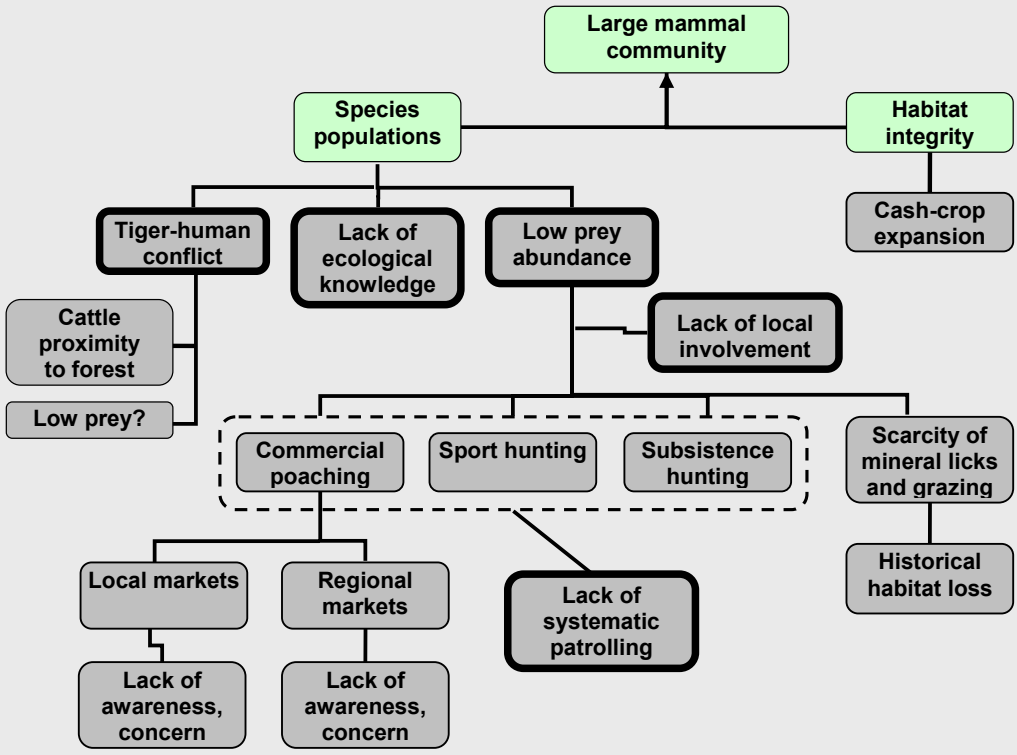
Goal—Increase tiger abundance by 50% in Kuiburi National Park by 2013.

To achieve the goal of increasing tiger numbers in Kuiburi, we need to understand the status of tigers and their prey in the park, address threats to the persistence and recovery of tigers, monitor the results of our efforts, and adapt our approach and activities based on lessons learned along the way (i.e., adaptive management).

To help guide project efforts, we developed and used a conceptual model that outlines what we believe are the main threats and contributing factors that affect tigers (Fig. 3) (Margoluis & Salafsky 1998). This conceptual model, developed with park staff verbally over time, represents the project's working assumptions about the factors that affect tigers and the presumed cause-effect relationships between various factors. This model has helped us identify key areas for intervention and communicate these with local stakeholders. Project objectives are derived from this conceptual model as well: objectives are intended to address or alleviate specific threats identified in this model.

Conceptual models are useful also for evaluation of a project (Margoluis et al. 2009). In this report, we use this model to evaluate the Kuiburi Tiger Project, by assessing progress made towards achieving project objectives. A summary of our evaluation is in Table 1, and details in the remainder of the report.

Figure 3. Conceptual model of assumed relationship between our conservation target—the large mammal community of Kuiburi National Park (in green)—and threats or contributing factors that affect large mammals (in gray). Specific threats being addressed through project activities are outlined in bold black. We evaluated the project based on progress towards addressing these threats (see Table 1).



Model summary

The project seeks to conserve the large mammal community of Kuiburi National Park. The health of this community depends on sufficient high-quality habitat (Habitat integrity), and species populations that are large enough to maintain themselves over time. Habitat integrity has been degraded historically through the loss of lowland deciduous forest, a result of pineapple expansion. There is not much we can do about this, and the project focuses on threats to species populations. Tiger-human conflict such as cattle-killing potentially endangers the small tiger population at Kuiburi, were livestock owners to kill offending tigers. The potential for conflict depends on proximity of cattle to forest edge, and perhaps the scarcity of wild prey. Lack of ecological knowledge impedes the park's capacity to focus its interventions and understand their biological outcomes. Low prey abundance is the most critical short-term threat to tigers: without sufficient prey, the park will support a perpetually small or declining population with high probability of extinction. Low prey is driven by 3 forms of hunting, one of which—commercial poaching—is driven by demand from wildlife markets and lack of concern by consumers. More systematic patrolling that also monitors hunting pressure would help alleviate this threat. Local people presently have limited awareness, concern, or involvement in tiger conservation efforts of the park. Their active support would enhance tiger and prey recovery efforts, by reducing threatening activities like commercial hunting.

Table 1. Summary and evaluation of the Kuiburi Tiger Project, 2006–2009. This table shows progress made towards objectives that are linked to threats and contributing factors affecting the recovery of tigers. Threats and factors were identified in the conceptual model (Fig. 3).

Threat, Contributing factor - from conceptual model	**Objectives -** to address factors/threats	**Activities -** what we did to achieve objectives	**Outcomes -** what was achieved
Lack of ecological knowledge	Determine distribution and abundance of tigers, their competitors (i.e., leopards), and prey	▪ Occupancy study of distribution of tiger, leopard, dhole (reported in Steinmetz et al. 2007) ▪ Capture-recapture study of tigers, leopards (using camera traps) ▪ Sign surveys for tiger prey	▪ First tiger and leopard population estimates for the park ▪ Clear link observed between tiger distribution and prey availability ▪ Inverse distribution between dholes and tigers observed ▪ Compelling wildlife photos obtained that have captured attention of park staff and public ▪ Tiger status between 2006–2009: ○ Tigers use about 50% of park; concentrated in central portion of park ○ Number of tigers approx. 10; Density = 1/100 km^2 ○ Tiger population stable, or slightly increased, from 2006
Low prey abundance	Increase prey abundance by 50% in 3 zones by 2012	▪ Established 3 prey recovery zones ▪ Promoted and publicized prey recovery efforts with communities ▪ Planned with park staff to refocus patrol effort in recovery zones ▪ Monitored prey response annually ▪ Conducted survey of wildlife restaurants around park	▪ 9–19% increases in sign abundance of Gaur, Pigs, and Muntjac in at least 1 zone (statistically significant) ▪ 8% increase of Sambar in 1 zone (non-significant) ▪ Steady 3-year increase of Sambar in 1 zone ▪ Increased spatial distribution of Gaur and Sambar in park
Lack of systematic patrolling	Initiate patrol system and train and equip rangers to implement it	▪ Designed patrol and threat monitoring system with rangers ▪ Held ranger training, and follow-up refresher training ▪ Equipped 9 ranger stations (GPS, data sheets, etc) ▪ Trained 1 park staff in data entry ▪ Regular meetings with park staff to analyze resulting data	▪ Patrol zones and routes mapped ▪ 285 km of patrol effort accumulated in 8 patrol zones between Nov 2008–May 2009 ▪ Patrol effort increased 76% in 2 recovery zones (mean trips/month = 3 in 2007, 17 in 2008) ▪ Clearer picture of distribution of hunting pressure in park

Threat, Contributing factor - from conceptual model	**Objectives -** to address factors/threats	**Activities -** what we did to achieve objectives	**Outcomes -** what was achieved
Tiger-human conflict	Zero tigers killed in retribution for livestock losses	▪ 7 cattle killed in 3 month period! (by a tiger, not us) ▪ Project and park staff visited affected farmers ▪ Analyzed kills with farmers (attack routes, tiger behavior, proximity of cows to forest, husbandry) ▪ Worked out tactical adjustments with farmers regarding cattle placement and husbandry ▪ Explained to farmers that we were working on this problem also by recovering prey within park	▪ Suspected killer camera-trapped ▪ Only 1 more cow killed after farmers responded to problem ▪ Zero tigers killed in retribution
Lack of local awareness, concern, and involvement	Increase community awareness, concern, and action towards tiger conservation	▪ Conducted outreach and education campaign: ▪ Spoke to ~700 people at 33 events around park (villages, county meetings, youth camps, schools) ▪ Returned research results to 5 villages (i.e. showed camera trap photos, discussed trends) ▪ Initiated jointly-managed prey recovery zone with Pa Mak village ▪ Organized youth group trip to build 1 mineral lick in 1 recovery zone ▪ Gave out 400 posters, brochures in villages and towns ▪ Park Superintendent presented camera-trap photo album to Provincial Governor	▪ Public awareness of tiger status and prey recovery efforts has increased, but is localized to 3 villages where effort concentrated ▪ Village leaders now speak, by their own initiative, about wildlife conservation at public meetings (2 leaders) ▪ Youth groups involved directly in prey recovery by going to recovery zones and implementing habitat improvement (making mineral licks) ▪ A network of local school youth groups involved in wildlife recovery is emerging

FIELD RESEARCH METHODS

Study sites and survey design

- A combination of methods was used to study the tigers and their prey at Kuiburi National Park (Table 2). Sign surveys and camera-trapping were used to derive independent indices of relative abundance for focal species. Camera-trapping was used to estimate population abundance of tigers and leopards.
- Signs of tigers and leopards (scats, scrapes, foot prints) were recorded opportunistically. Scats were also collected for future diet analysis.
- All field work was conducted by WWF project staff together with teams of 4–10 rangers.
- Previously (2006–2007), we conducted tiger occupancy surveys and prey sign surveys throughout the park (Steinmetz et al. 2007). These surveys showed that tigers and their prey were scarce in the northern and southern portions of the park, and we focused subsequent project efforts on the central sector, particularly in and around three prey recovery zones that were established in early 2007 (Fig. 2).

Table 2. Methods and data for wildlife research in Kuiburi National Park, 2006–2009.

Method	Variables	What does it tell us?	Used for	
			Large carnivores	Prey species
Sign surveys	▪ Percent of 50 m transect segments with signs of focal species (in 400 m transects)	▪ Relative abundance	No	**Yes**
Camera trapping	▪ Photographs/100 trap nights	▪ Relative abundance	**Yes**	**Yes**
	▪ Number of individual animals + capture probability (capture-recapture sampling)	▪ Population abundance	**Yes**	No
	▪ Number of camera locations at which species was photographed	▪ Spatial distribution	**Yes**	**Yes**

Surveys for tiger prey

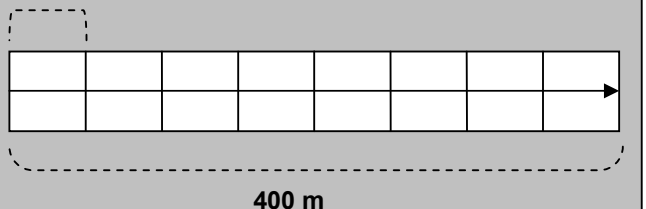
Sign surveys

- Prey species occur at low densities and in dense forest with limited visibility; moreover, they are often nocturnal. Direct sightings are rare under these conditions, so we used incidence of animal signs to monitor prey status.
- We searched for signs of ungulates (tracks and scats) in strip transects. Transects were 400 m long and 2 m wide, divided into 8, 50 m-long segments (Fig. 4). Survey teams walked slowly (~1 km/hr), searching carefully for signs in transects. Using standard data sheets, signs were recorded as present or absent in each 50 m transect segment. Only recent signs (< 2 weeks) were recorded. Animals that walked along the transect route, passing from one segment to the next, were counted in only 1 segment.

- Transects followed linear topographic features such as streams, trails, or ridges. The start and end locations of each transect were determined with a GPS unit. Transect length was measured with a hipchain. Transects were separated from each other by at least 400 m, to promote independence. We generally tried to place 1 transect in each 1 km^2 grid cell of each prey recovery zone.
- Animal signs were used to derive an index of relative abundance, expressed as the proportion of 50 m transect segments with signs (Table 2). Transects were the sample units.
- Herds of wild pigs and gaur were distinguished from signs of individual animals, to reflect social differences in habitat use and abundance. Also, we were interested in knowing the status of herds in particular, as these are reproductive units of the population.
- Survey effort to monitor prey abundance in recovery zones is shown in Table 3. Prey sign surveys were conducted twice (2006, 2008) at Pa Yang and Klong Kui, and thrice at Hup Inthanin (2006, 2008, 2009). We intended to conduct sign surveys in 2009 at Pa Yang and Klong Kui, but the rains arrived before we could begin so surveys were cancelled. Data from the rainy season would not be comparable with previous surveys, which were conducted in dry conditions.

Figure 4. Sign transect design for prey surveys

Signs of tiger prey species were recorded in 400 m × 2 m strip transects. Transects were divided into 8, 50 m segments. Observers recorded presence or absence of signs of each species in each segment. The percent of segments with signs was used as an index of relative abundance.



Estimating prey species distribution and diversity from photos

- Camera trapping was conducted mainly to count tigers, but prey species were often photographed as well, and we used this information to assess prey species distribution and diversity.
- We first determined numbers of independent photographs of each prey species. Following O'Brien et al. (2003), independent photos were defined as (a) consecutive photos of different individuals of the same species, (b) consecutive photos of different species, (c) consecutive photos of individuals of the same species taken > ½ hr. apart, and (d) nonconsecutive photos of individuals of the same species. In the case of animals photographed from both sides, only one photograph was counted.

- Distributions of prey species in 2007 and 2009 were compared by examining the percent of all camera-trap locations (n = 25–26 each year) with independent photos of a species. Results pertain to central Kuiburi where camera-trapping was conducted.
- To characterize diversity and composition of the prey base, we separated prey into large (> 100 kg) and small (< 100 kg) species, and compared the percent of independent photographs in each group. Tigers depend on large prey, which were scarce in 2006 when our project started; improving prey status would be indicated by an increasing proportion of the large prey class over time. At the same time, we would like to maintain a prey base that has high species diversity and abundance in both size classes, to facilitate the coexistence of tigers with smaller competitors, leopards and dholes.

Table 3. Survey effort for monitoring the status of prey species in 3 prey recovery zones, Kuiburi National Park, 2006–2009. na: not applicable, because no survey was conducted.

Year	Recovery zone	Sign surveys		Camera trapping		
		Date	Transects	Date	Camera locations	Trap nights
2006	Pa Yang	26 Feb–10 Mar	28	*no trapping*	*na*	*na*
	Klong Kui	16–29 Jun	30	*no trapping*	*na*	*na*
	Hup Inthanin	16–25 Nov	11	*no trapping*	*na*	*na*
2007	Pa Yang	*no survey*	*na*	8 Apr–14 Jul	9	457
	Klong Kui	*no survey*	*na*	3 Apr–17 Jul	16	598
	Hup Inthanin	*no survey*	*na*	*no trapping*	*na*	*na*
2008	Pa Yang	12–16 Jun	30	*no trapping*	*na*	*na*
	Klong Kui	14–20 Mar	26	*no trapping*	*na*	*na*
	Hup Inthanin	25–28 Apr	12	*no trapping*	*na*	*na*
2009	Pa Yang	*no survey*	*na*	3 Dec 2008–24 Feb 2009	10	576
	Klong Kui	*no survey*	*na*	9 Dec 2008–31 Mar 2009	16	882
	Hup Inthanin	26 Apr–2 May	26	*no trapping*	*na*	*na*

Surveys for tigers and leopards

Estimating abundance of tigers and leopards

- We used a closed model capture-recapture sampling approach to estimate abundance of tigers and leopards, using camera traps to obtain photographs of each species (Karanth & Nichols 2002).
- 48 cameras (Deercam and Stealthcam brands), set in pairs to photograph both sides of passing animals, were deployed along likely tiger travel routes (trails, streams, and ridges) at 25 locations in 2007 (not shown) and 26 locations in 2009 (Figure 5). Total camera-trap effort was 1055 trap nights in 2007 and 1458 in 2009. Many camera locations were the same in both years, though in 2009 we expanded the sampled area slightly. Camera locations were 2–4 km apart: close enough to ensure no gaps where a tiger or leopard could escape the chance of detection.

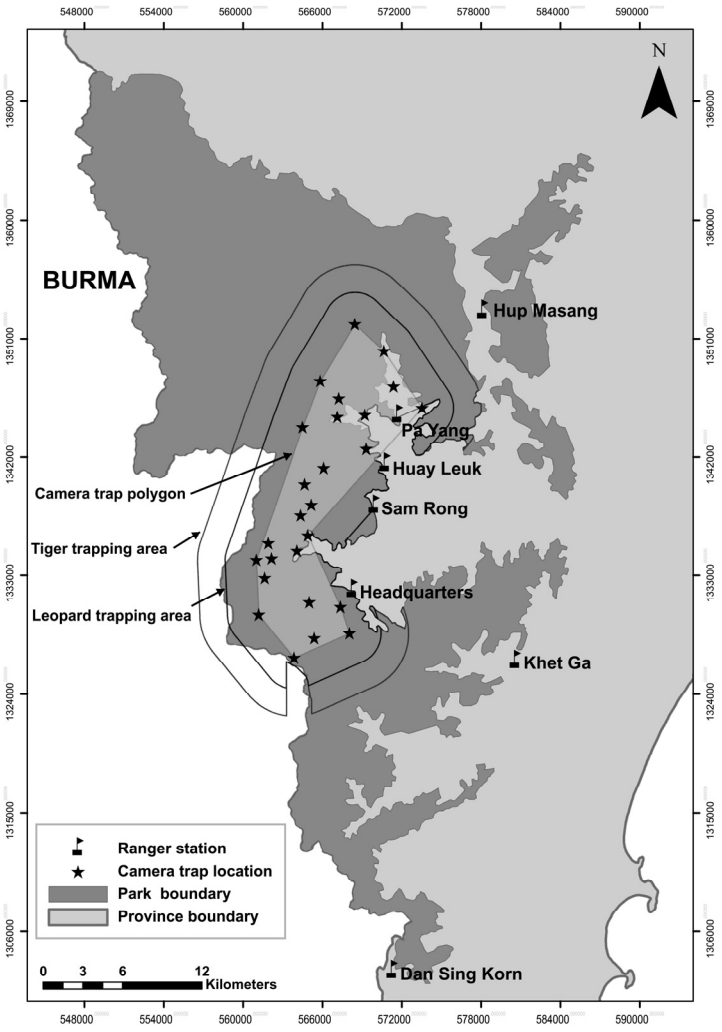
- Camera trapping was conducted for 3 months in 2007 (April–July) and 4 months in 2008/2009 (December 2008–March 2009; referred to as "2009" in this report). We considered this period short enough that populations were closed to changes due to births, deaths, and possible immigration from contiguous forest in Myanmar.
- Tigers were individually identified based on their unique patterns of stripes. Leopards were identified based on spots, or, for black leopards, scars. All but 1 black leopard had scars, usually white in color, which contrasted sharply with the black hair and allowed individual identification. In most cases the sex of animals could be determined.
- We created a capture history matrix of individual tigers and leopards using 1-week sampling occasions (n = 12 in 2007, 16 in 2009), and analyzed these data in program CAPTURE. CAPTURE results indicated the closed population assumption of this method was not violated for tigers or leopards ($P > 0.25$ in all cases).
- Following Karanth & Nichols (2002), we chose CAPTURE model M_h to estimate tiger and leopard abundance. This model permits each individual to have different capture probabilities, and is thus most biologically realistic for tigers. This model gave the best or second-best fit to the data for tigers (model selection criteria = 0.99 out of 1) and leopards (selection criteria = 0.9–1.0) each year.
- Density of tigers and leopards was estimated by dividing estimated abundance (from CAPTURE results) by the effective camera-trapping area. Effective trap area consisted of the polygon enclosed by the outermost camera locations, plus a boundary width equal to half the mean maximum distance moved (half MMDM) by tigers and leopards that were photographed multiple times (at different locations). This method may underestimate actual distances moved, resulting in small effective trapping areas and hence density overestimates (Soisalo & Cavalcanti 2006). However, the method is commonly used in Asia and we follow it so that we can make relative comparisons with tiger and leopard density estimates from other studies.
- No tigers were recaptured in 2007 (i.e., photographed more than once). This precluded an estimate of abundance based on capture-recapture sampling in 2007. For the same reason, we were unable to determine distance moved by tigers with which to calculate effective trapping area. To work around this, we borrowed detection probability from our 2009 data, to estimate abundance in 2007, using the method in Lynam et al. (2009). We also borrowed half MMDM from our 2009 data to calculate boundary width and effective trap area for 2007.
- All recaptured leopards in our study in both years were recaptured at the same locations, so we could not estimate distances moved and effective trap areas. Therefore, we borrowed half MMDM from a leopard camera-trap study by Ngoprasert (2004) in nearby Kaeng Krachan Park.

Sign identification

- We employed tiger signs to help illustrate the general distribution of tigers outside of our camera trapping area. Dedicated tiger sign surveys were not conducted in 2008/2009, but project and park staff consistently documented tiger signs they encountered in the forest during routine work.
- Signs of tigers were differentiated from leopards by hind foot pad width > 7.0 cm, and other dimensions. Scats > 3.5 cm diameter were considered to be from tiger.

Large cat scrapes were not identified to species unless accompanied by measurable footprints.

Figure 5. Camera trap locations and effective trapping areas for tigers and leopards in Kuiburi National Park, Dec 2008–March 2009. The 2007 sample area (not shown) was similar in location and area.

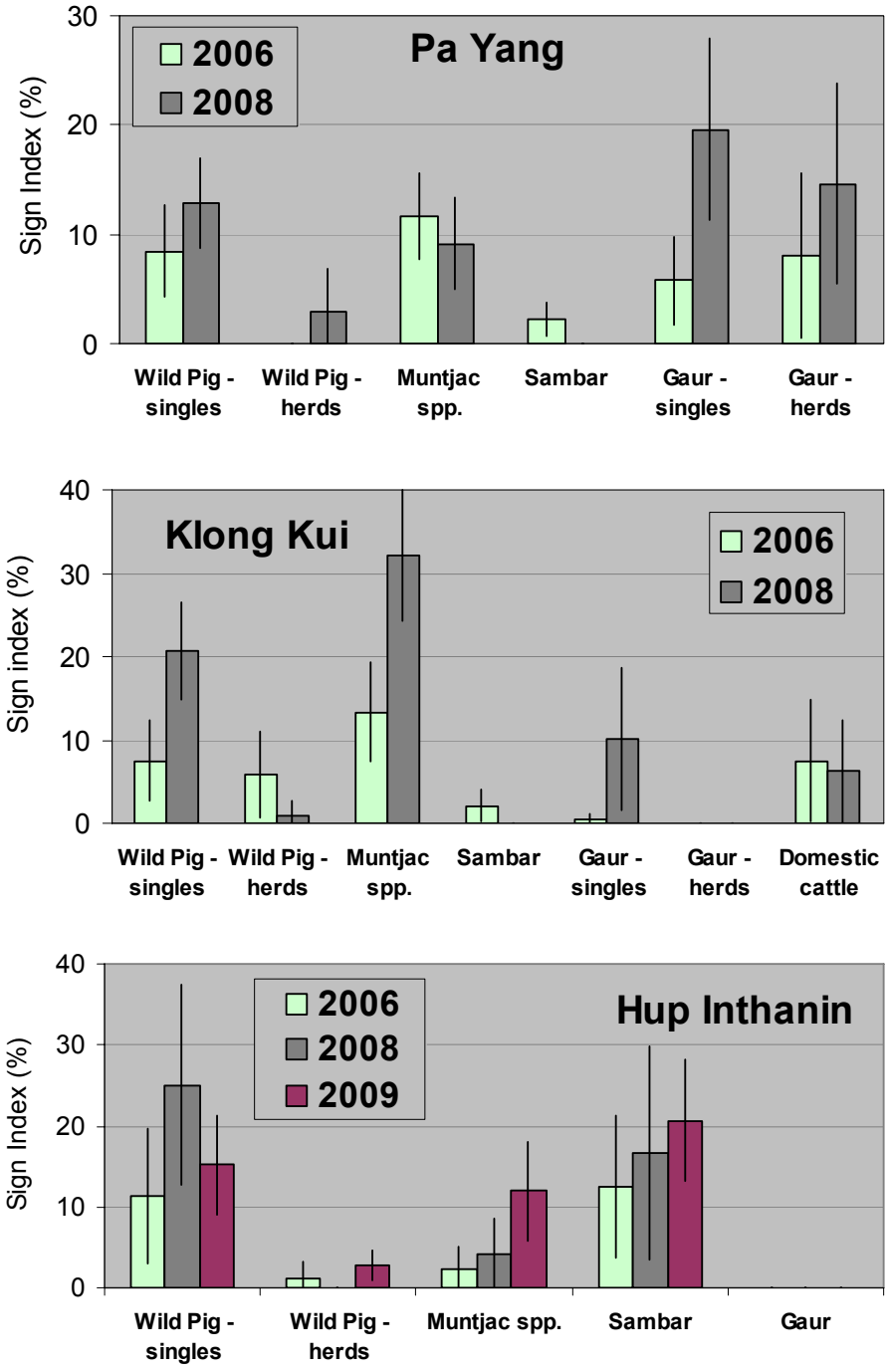


STATUS OF PREY SPECIES

Prey species abundance

- Populations of 4 major prey species—wild pigs, muntjacs, sambar, and gaur—were stable or increased between 2006 and 2009 in each prey recovery zone (Fig. 6).
- Gaur increased significantly (i.e., non-overlapping 90% CIs) at Pa Yang and Klong Kui, and muntjac increased significantly (non-overlapping 90% CIs) at Klong Kui and Hup Inthanin.
- Sambar remained scarce in two zones (Pa Yang, Klong Kui) but showed a steady increase at Hup Inthanin, which holds the largest remaining sambar population in the park (see Box 2). Sambar occurred at Pa Yang and Klong Kui in 2008 and 2009 (single camera-trap photos were obtained in each area) but we did not find signs in transects (Fig. 6), reflecting the scarcity of sambar in these areas.
- Camera-trap detection rates (numbers of photos per 100 trap nights; not shown) increased from 2007 to 2009 for all prey species. This suggests increased abundance, although confidence intervals overlapped widely in almost all cases. Thus, trends in relative abundance inferred from camera-trapping were qualitatively similar to trends inferred from sign transects. The correspondence of these 2 independent methods increases the reliability of our inference that prey abundance is generally increasing.

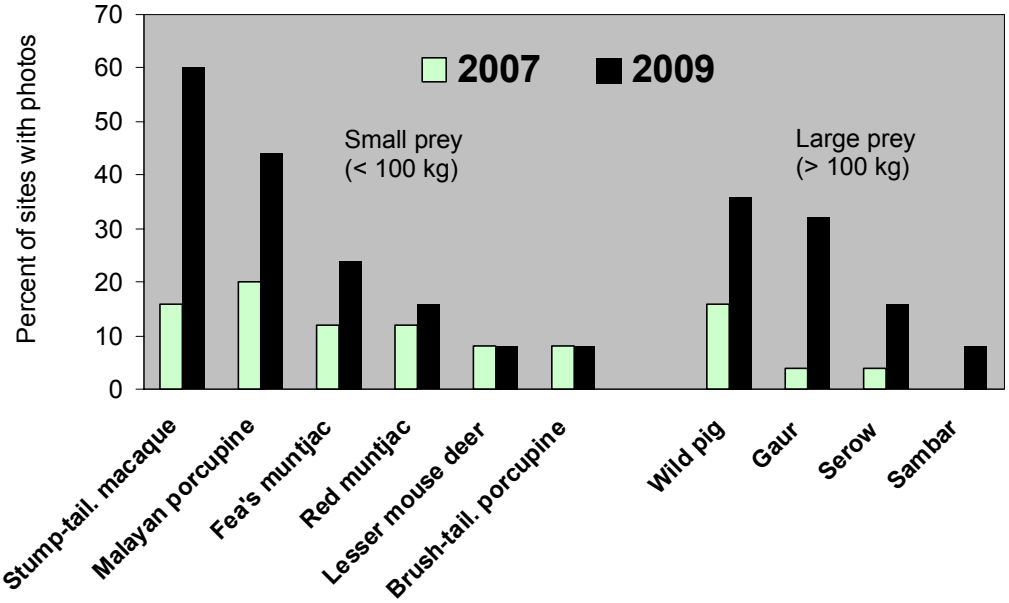
Figure 6. Trends in abundance of ungulates (tiger prey) in 3 prey recovery zones of Kuiburi National Park, 2006–2009, based on indices of relative abundance derived from the mean percent of transect segments with signs of a species. We monitored 11 to 30 sign transects each year per zone. Bars show 90% CIs.



Prey species distribution

- Both small prey (porcupines, macaques, muntjacs) and large prey (gaur, pig, sambar) were photographed more widely in 2009 compared with 2007 (Fig. 7). Mean increases in numbers of locations at which species were photographed were 17% for small prey and 21% for large prey species. Thus, within the 131 km^2 camera trap area (which includes the Pa Yang and Klong Kui prey recovery zones), the distribution of prey species appears to have generally increased.
- For example, in 2007 gaur were largely restricted to the Pa Yang recovery zone, resulting in numerous photos from just 1 site (4% of camera locations). In 2009 they were still present in Pa Yang, but photos were also obtained from 7 additional sites (32% of camera locations).
- Detections of Fea's muntjac doubled from 12% to 24% of sites, driven by increasing distribution and abundance in the Klong Kui recovery zone, which is covered with evergreen forest that is the main habitat of this species. We have photographed Fea's muntjac only in evergreen forest in Kuiburi.
- Elephants (not shown) were the most widespread mammal in Kuiburi, occurring at 52–72% of camera sites in 2007 and 2009.
- Observations of project and park staff during field surveys and ranger patrols suggested that prey spatial distribution was increasing also outside the camera trap area. For example, tracks of a gaur herd, including calves, were observed by rangers in Hup Ma Hon (southern Klong Kui area) in August 2008. Since the project started in 2006, gaur had never been observed in this area (we visited the area 2-3 times per year).

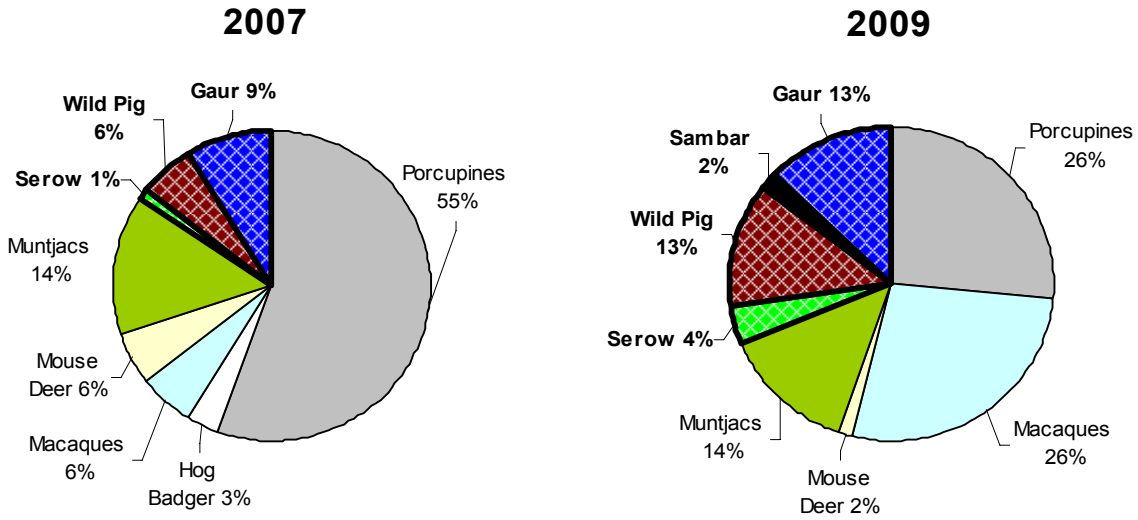
Figure 7. Percent of camera trap sites (*n* = 25–26 per year) at which tiger prey species were photographed in Kuiburi National Park, 2007 and 2009.



Prey species composition and diversity

- The percent of all independent photographs that were from large prey species (gaur, sambar, pig, serow) increased from 16% in 2007, to 32% in 2009 (Fig. 8). This increase was driven mostly by gaur (4% increase) and pigs (7% increase).
- Muntjacs (species combined) made up 14% of photographs in both years, whereas porcupine photos diminished by about half (56% to 27%), and macaque photos increased almost 5 times (6% to 27%). Our direct field observations corresponded to camera trap data for macaques (which are diurnal): we observed them more frequently in 2009 than in preceding years, suggesting increased abundance.

Figure 8. Prey species composition in Kuiburi National Park, 2007–2009, based on percent of independent camera-trap photos from each species. Large prey species (> 100 kg) are in bold. 'Muntjacs' includes Fea's and red muntjac; 'Porcupines' includes brush-tailed and Malayan porcupines.



Summary of prey status

- Our data suggest that the status of prey in Kuiburi National Park is improving, in two respects. First, increasing sign abundance of most species in most recovery zones indicates increasing population abundance. Second, increasing numbers of locations at which prey species were observed or photographed suggests an increase in distribution, and perhaps activity due to safer conditions (reduced hunting pressure; see below).
- Camera trapping occurred in different months in 2007 and 2009. Thus, differences in percent of sites with photos (Fig. 7) might also reflect seasonal differences in factors that influence animal movements, such as food availability. However because increases in percent of camera locations were widespread among tiger prey species (occurring for 8 different species), and considering that population abundance was

also increasing in this same area (Fig. 6), it is likely that these data reflect increasing spatial distribution rather than seasonal effects.

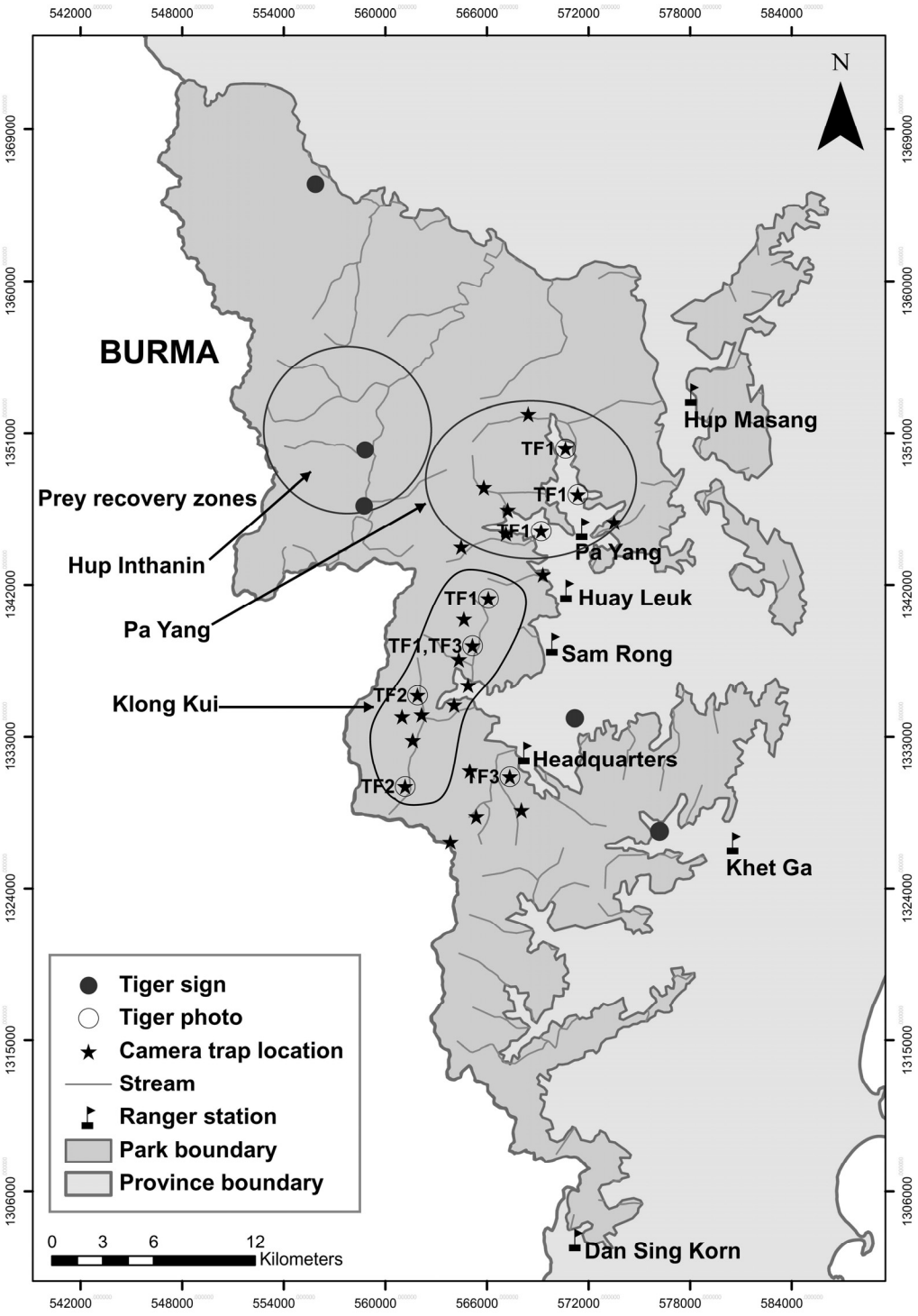
- Despite the overall improved outlook for most prey species, some species are not doing well in some locations. For example, in 2009 sambar remained almost as scarce throughout the park as in 2006, except at Hup Inthanin. And gaur remained largely concentrated at Pa Yang, as when the project began.

STATUS OF TIGERS

Tiger distribution

- Surveys in 2006 and 2007 showed that most of Kuiburi's tigers occurred in the central portion of the park, and they were rare in the north and south (Steinmetz et al. 2007). This general distribution of tigers in Kuiburi has changed little since 2006.
- Figure 9 shows the current distribution of tigers based on camera trap photos and signs from 2008–2009. Project and park staff encounter tiger signs frequently (about 50 to 80% of trips in the forest) in central Kuiburi (where camera trapping was conducted), but signs are consistently scarce in the north, south, and far east. For example, ranger patrols in the southern (Dan Sing Korn) and far eastern (Hup Masang) portions of Kuiburi have never encountered tiger signs on their patrols.
- The tiger sign on the northern edge of the park (see Fig. 9), observed by park staff in early 2008, may represent a transient animal, since tiger signs are consistently rare in the entire northern portion of the park.

Figure 9. Tiger distribution in Kuiburi National Park, based on camera trap sites (stars) where tigers were photographed (circled stars), Dec 2008–Mar 2009, and observations of tiger sign (black circles) by park and project staff from 2008–2009. Only signs outside of the camera trap area are shown. Codes (i.e., TF 1) denote individually identified tigers; see Table 5 and Fig. 10. No camera trapping occurred in Hup Inthanin.



Tiger abundance

- A total of 9 individual tigers—5 females, 1 male, and 3 cubs—have been photographed in Kuiburi National Park between 2006–2009 (Table 5, Fig. 10). Of these, 4 were photographed during capture-recapture sampling in central Kuiburi and used to estimate density. Of the other 5 tigers—2 were adults that were photographed also in the camera trap study area, but not during our sampling period; 2 were cubs in the camera trap study area (only adults were counted for density estimation); and the last tiger was photographed outside the sampling area (Khet Ga) where we set up cameras specifically to capture a cattle-killing tiger (Table 5, see Box 1).
- Tigers are breeding in Kuiburi National Park: 2 tiger cubs, approximately 5 months old, were photographed during camera trapping in 2007 in the Pa Yang recovery zone (Fig. 10). Prior to that, in March 2006, park staff Sompong Em-Oad took video of a presumed mother and cub standing on a weir, also at Pa Yang (Fig. 10).
- The camera trap sampling effort of 1055 trap nights in 2007 and 1458 trap nights in 2009 resulted in 4 photos of 4 tigers (including 2 cubs) in 2007, and 10 photos of 3 tigers in 2009 (Table 5). Individual tigers were captured 1–6 times in 2009; there were no recaptures in 2007.
- Abundance estimates from CAPTURE were 3 adult tigers in 2007 and 4 tigers in 2009, in the sampled area. Confidence intervals of abundance were similar each year, with upper limits of 10 tigers (Table 4).
- Maximum distances moved between recaptures in 2009 ranged from 5.6 km (for TF2) to 12.9 km (for TF1). The camera trap polygon was 131 km^2 in 2009, and slightly smaller in 2007. Half mean maximum distance moved by tigers was 4.5 km, resulting in an estimated trapping area of 396 km^2 in 2009, and 361 km^2 in 2007 (Table 4).
- Estimated tiger densities (adults) were 0.8/100 km^2 in 2007 and 1.0/100 km^2 in 2009 (Table 4).
- Detection probability of tigers in 2009 was 0.09, i.e., there was a 9% chance of photographing a tiger during a 1-week sampling occasion. We borrowed this detection probability to adjust our tiger abundance estimate in 2007, for which no detection probability was available, as no tigers were recaptured. We followed the method in Lynam et al. (2009) to do this. The probability of not detecting a tiger in 1 occasion is $1 - 0.09 = 0.91$. Thus, the probability of never detecting a tiger over a 12-occasion sampling period, as in 2007, would be $(1 - .09)^{12} = 0.32$. Finally then, the probability of detecting a tiger at least once in 12 occasions would be $1 - 0.32 = 0.68$. We divided our raw abundance estimate in 2007 (2 tigers) by this value to derive an estimate of abundance that was adjusted for imperfect detectability ($2/0.68 = 2.9$).

Table 4. Abundance and density estimates of tigers and leopards in Kuiburi National Park, based on capture-recapture camera-trapping, 2007 and 2009. SE: standard error, CI: confidence interval, MMDM: mean max. distance moved.

Year / Species	No. photos	No. individuals	Detection probability	Estimated abundance (SE)	95% CI	½ MMDM (km)	Eff. trap area (km^2)	Density per 100 km^2 (SE)
Tiger								
2007	4	4[1]	*no data*[2]	2.9 (1.7)[3]	3–10	4.46[5]	361	0.8 (0.5)
2009	10	3	0.09	3.9 (1.4)	4–10	4.46	396	1.0 (0.6)
Leopard								
2007	6	5	0.07	7.3 (3.4)	6–24	2.37[4]	222	3.3 (2.4)
2009	14	9	0.06	12.6 (3.6)	10–27	2.37[4]	261	4.8 (2.8)

[1] Number of adults was 2; one photo included a mother + 2 cubs; cubs were not included in density estimate.
[2] No animals were recaptured so probability of detection could not be estimated.
[3] Abundance estimated using detection probability borrowed from 2009.
[4] ½ MMDM borrowed from Ngoprasert (2004).
[5] ½ MMDM for 2007 borrowed from our 2009 survey.

Table 5. Tigers photographed in Kuiburi National Park, 2006–2009. Tigers were individually identified from stripe patterns. Tigers photographed during most recent capture-recapture sampling (2009) are in bold. TM: tiger male; TF: tiger female; TC: tiger cub. Brackets [ ] indicates provisional status. Tiger individuals photographed in multiple years were considered residents (other tigers may have been residents as well).

ID	Sex	Photo #	Location	Day/month /year	Note
TF 5	[Female]	1	Bor 3*	18/3/2006	Standing with TC 3 in same photo
TM 1	[Male]	1	Khet Ga	16/9/2008	-Track measurements indicated male (hindfoot pad width 8.5 cm) -Suspected cattle killer
TF 1	Female	1	Plaeng Ya	26/8/2007	
		2	Roeng Ta Noi	10/12/2008	
		3	Bor U Ka	23/12/2008	
		4	Praek Ta Sod 2	22/12/2008	
		5	Huai Luke Ridge	22/12/2008	
		6	Huai Luke Ridge	5/1/2009	
		7	Bor 5	25/1/2009	Resident
TF 2	Female	1	Chang Khao	24/4/2007	
		2	Chang Khao	10/1/2009	
		3	Ma Horn Valley 2	2/1/2009	Resident
TF 3	Female	1	Praek Ta Sod 2	2/1/2009	
		2	Wang Kai U Ridge 1	4/3/2009	
TF 4	Female	1	Plaeng Ya	26/8/2007	
TC 3	[Cub], sex unknown	1	Bor 3*	18/3/2006	Standing with TF 5 in same photo
TC 1, TC 2	[Cubs], sex unknown	1	Plaeng Ya	26/8/2007	-2 cubs in same photo

*Video by Sompong Em-Oad, Kuiburi National Park staff.

Figure 10. Individual tigers photographed in Kuiburi National Park, Thailand, 2006–2009. TM: tiger male; TF: tiger female; TC: tiger cub. Location name of each photo is shown.

TF 5 (left), **TC 3** (right) - Bor 3

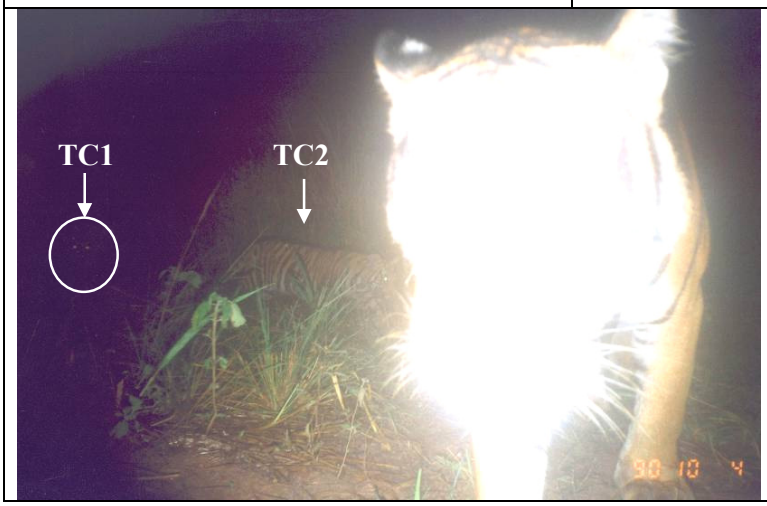
TF 1 - Roeng Ta Noi

TF 2 - Chang Khao

TF 3 - Praek Ta Sod 2

TF 4 - Plaeng Ya

TM 1 - Khet Ga



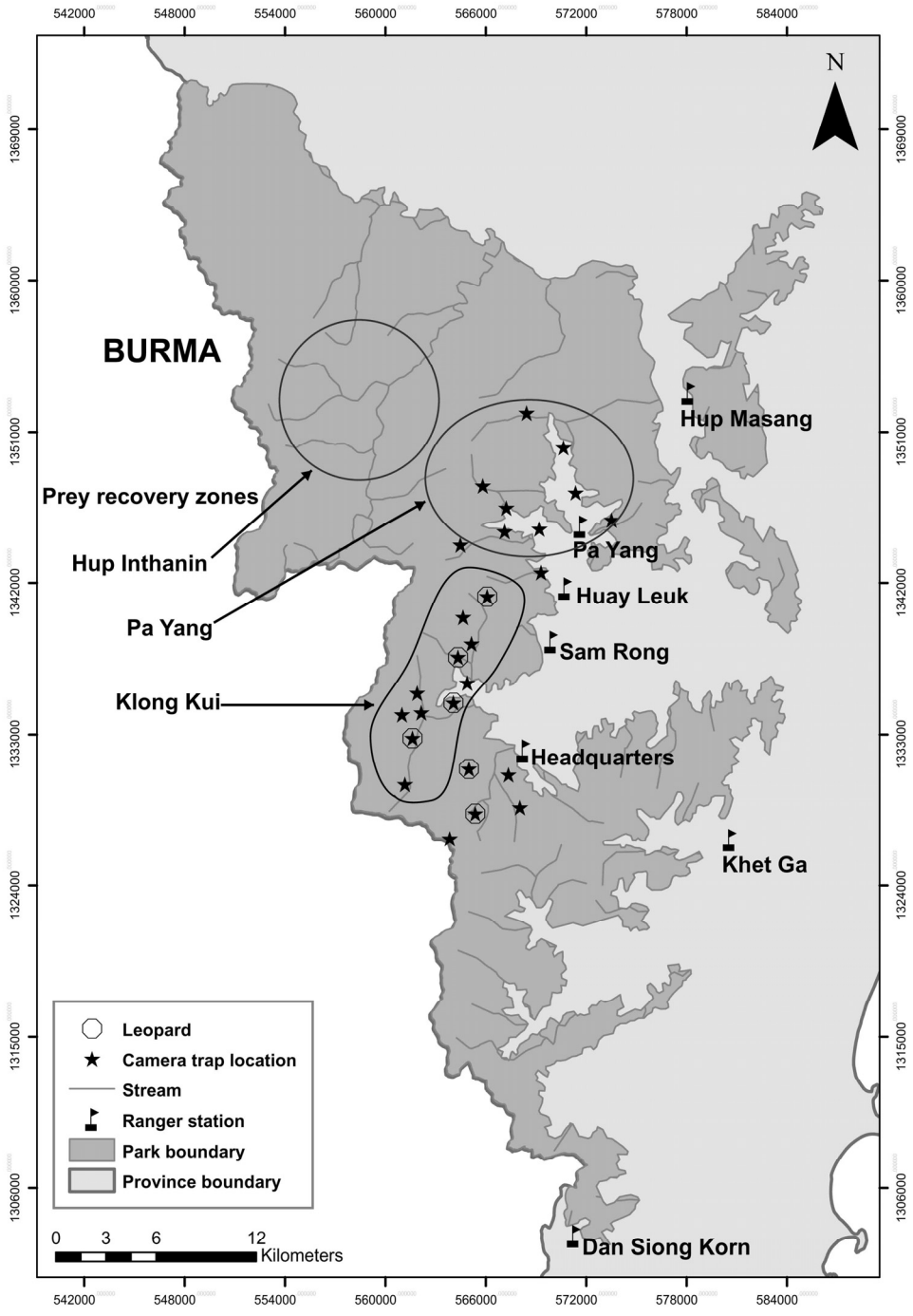
TC 1, TC 2 (cubs)
- Plaeng Ya

The tiger very close to the camera is TF1, presumably their mother

Leopards and dholes

- We obtained 6 photos of 5 leopards in 2007, and 14 photos of 9 leopards in 2009. Individual leopards were captured 1–2 times in 2007 and 2009.
- Leopard distribution in the camera trap sampling area is shown in Figure 11. Leopard signs, not shown, occur throughout the park, except the extreme south. Thus, leopards are more widely distributed than tigers in the park.
- Leopards in 3 photographs in 2009 could not be conclusively identified because photos were incomplete or blurry. These photos were excluded from analysis, but may represent up to 3 additional animals; thus, our abundance estimates are slightly conservative.
- Estimated abundance in the trapping area, from CAPTURE, was 7 leopards in 2007 and 13 in 2009. These estimates had widely overlapping confidence intervals (Table 4).
- Leopard density (adults) was 3.3/100 km^2 in 2007 and 4.8/100 km^2 in 2009 (Table 4).
- Black leopards were twice as abundant as spotted leopards (6 vs. 3 individuals photographed in 2009).
- Dholes appeared to be scarce in our camera trap area each year, especially in 2009. In 2007, 8 photos were obtained from 2 locations, whereas in 2009 just 1 photo from a single site was obtained. One set of dhole tracks was observed in Hup Inthanin, April 2009.

Figure 11. Camera trap locations (stars) were leopards were photographed (circled stars), Dec 2008–Mar 2009. No camera trapping was conducted in Hup Inthanin.



Status of large carnivores: summary and discussion

Tiger reproduction

- Tigers are breeding in Kuiburi. This finding is significant for 3 reasons.
    1. Evidence of breeding tiger populations is extremely rare in Thailand. Recent evidence comes from just 2 other protected areas: Huay Kha Khaeng (Simcharoen et al. 2006) and Thung Yai Naresuan Wildlife Sanctuary (Steinmetz et al. 2006).
    2. The cubs we observed appear healthy and well-fed. This indicates there is sufficient prey for the mother to successfully raise at least 3 offspring.
    3. Reproduction is occurring within a prey recovery zone. Thus, our approach to tiger recovery, which is to focus on prey recovery within specified zones, appears to have merit.
- Of the 3 recovery zones in Kuiburi, Pa Yang has the best prey conditions in terms of overall diversity, and abundance of large prey (Fig. 6). Female tigers need abundant prey, over and above maintenance quantities for themselves, to support cubs (Karanth & Stith 1999). Thus, it is probably no coincidence that tiger reproduction is occurring at Pa Yang but apparently no where else in the park.

Abundance and density

- Tiger and leopard density estimates were slightly higher in 2009 than 2007, and 95% CIs of abundance in 2009 reached slightly higher than in 2007 (Table 4). Based on these results, and our observations of tiger breeding in 2007, it is likely that populations of tigers and leopards have been stable or increased slightly between 2007 and 2009.
- Confidence limits on our estimate of tiger abundance in 2009 were 4–10 tigers. The actual tiger population at Kuiburi probably lies toward the upper end of this range (10 tigers), though not much higher. The upper limit of the estimated range in abundance seems most plausible because, over the past 3 years, 9 individual tigers have been photographed, mostly in 2008 and 2009. Some animals are residents, being photographed in multiple years (Table 5). At the same time, the park's southern tip and northern third have very few tigers, although a footprint in the far north of the park in 2008 (Fig. 9) suggests at least 1 additional tiger. Thus, we believe that most of Kuiburi's tigers have been identified, and the park's population is roughly 10.

Density comparisons in Southeast Asia

- Tiger density in Kuiburi (1.0/100 km^2) is similar to some other sites in Southeast Asia (see Fig. 12), including:
    - Bukit Barisan, southern Sumatra: 1.6 tigers/100 km^2 (O'Brien et al. 2003)
    - Nam Et, northern Lao PDR: 0.7/100 km^2 (Johnson et al. 2006)
    - Hukaung, northern Myanmar: 0.4–1.1/100 km^2 (Lynam et al. 2009).

  These similar densities might be the result of similar ecological conditions and threats at these sites. Notably, these sites share the following features that strongly influence tiger density: (1) tropical evergreen forest is the predominant habitat type, and (2) the prey base has been depleted by overhunting.

- Tiger density corresponds closely to prey density, which in turn is affected strongly by habitat type. The regional variation in tiger densities shown in Fig. 12 reflects such habitat differences, in addition to differences in hunting pressure. In closed canopy tropical evergreen forest, such as at Kuiburi, plant productivity is low at ground level due to the shady conditions. Thus, this habitat offers little food for terrestrial herbivores relative to more open deciduous forests and grasslands. As a consequence, tropical evergreen forest naturally supports relatively low densities of ungulates, resulting in relatively low tiger densities (even where hunting is minimal).
- Deciduous forest mosaics, such as at Huay Kha Khaeng in Thailand (Fig. 12), support higher ungulate density and biomass than tropical evergreen forest, and tiger density there is four times higher than at Kuiburi (4/100 km^2, Simcharoen et al. 2007). The highest tiger densities in Southeast Asia are in open grassland habitats which support even higher prey densities, such as at Kaziranga (Fig. 12), where there are almost 60 ungulates per square kilometer (Karanth et al. 2004).
- In Southeast Asia, tropical evergreen forest is the predominant habitat in peninsular Thailand (including Kuiburi) Malaysia, and Indonesia, whereas deciduous forest mosaics are common in the rest of Thailand, Lao PDR, Cambodia, and Myanmar. As seen in Figure 12, this environmental gradient is reflected in generally lower tiger densities in southern sites and higher densities in more northerly sites.
- However, tropical evergreen forest sites can support relatively high tiger densities if prey is abundant. For example, at Taman Negara National Park (Malaysia), a tropical evergreen forest site in which hunting of tigers and their prey has been minimal, tigers attain densities of 1.2–2.0/100 km^2 (Kawanishi et al. 2004), higher than at Kuiburi. And in logged evergreen forest in northern Malaysia, tigers reach 2.6/100 km^2 (Rayan & Mohamad 2009). Logging opens the forest canopy and promotes secondary growth that many prey species can benefit from.

Conservation challenges at Kuiburi

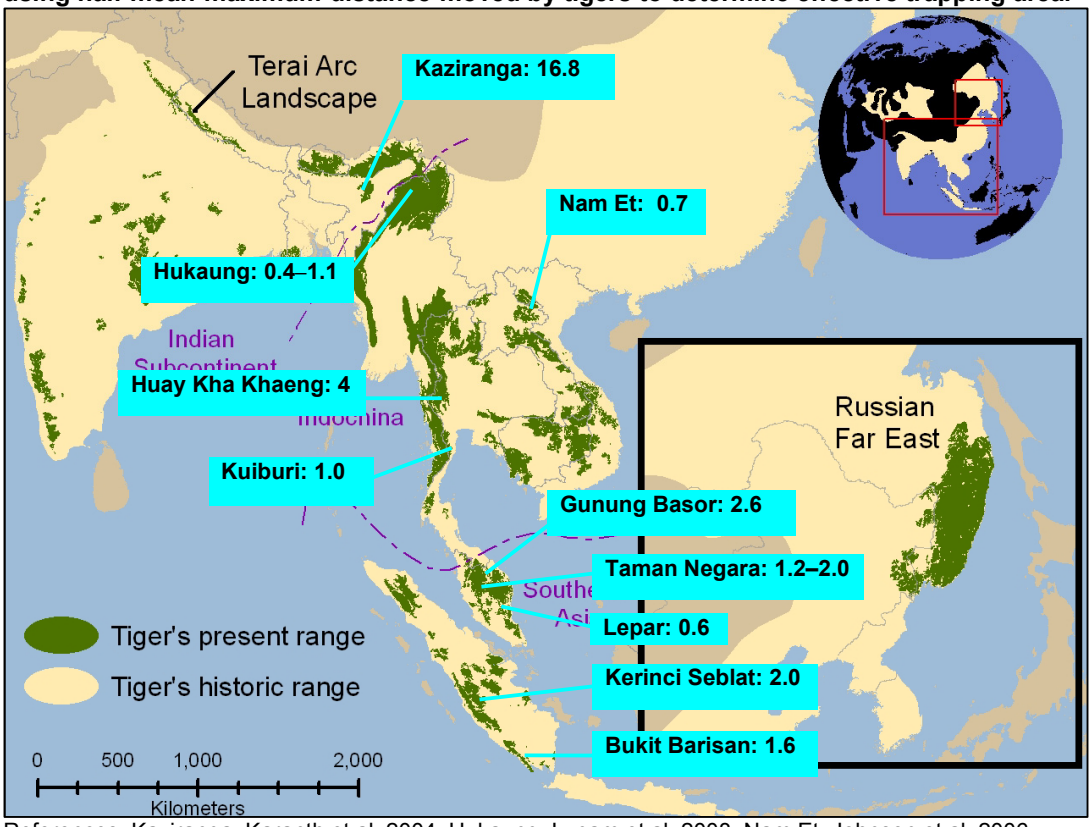
- The inherently low carrying capacity of evergreen forest for tigers is a challenge for tiger conservation because tiger populations will always be relatively smaller, and thus more vulnerable, than populations in more seasonal parts of tropical Asia, such as Kaziranga or Huay Kha Khaeng.
- Nonetheless, Kuiburi National Park could probably support at least twice as many tigers as currently exist, if prey density is increased. As a comparison, tiger densities in Kerinci Seblat (Linkie et al. 2006) and Taman Negara (Kawanishi & Sunquist 2004) which are also evergreen forest habitats, reach 2 per 100 km^2. The main difference is that those sites are less heavily hunted and thus have more prey.
- The tiger population in Kuiburi National Park is part of a larger effective tiger population that includes contiguous forest habitat in Myanmar. Kuiburi rangers and villagers report extensive intact forest cover on the Myanmar side of the border, and tigers have been confirmed to occur in this region of Myanmar (Lynam 2003).
- There is no evidence that tiger poaching is occurring in the park. Evidence would have included tiger snares in the forest, ranger observations, local reports, and historical information from village elders.
- Tiger-human conflict has not historically been a major management concern in Kuiburi but flared suddenly in 2008. The responses of farmers, and of the project, are discussed in detail in Box 1. Tiger-human conflict represents a potentially serious

problem for a small tiger population such as at Kuiburi, where just a single tiger killed in retribution for an attack on livestock would represent 10% of the population.

Status of leopards and dholes

- Leopard density in Kuiburi (4.8/100 km^2) is similar to nearby Kaeng Krachan National Park (see Fig. 1), which has about 5 leopards/100 km^2 (Ngoprasert 2004). Black leopards are more common than spotted in Kuiburi, whereas the reverse holds in Kaeng Krachan.
- Leopards have not been photographed in the Pa Yang area (Fig. 11), despite the relative abundance of prey there, nor have we not encountered their sign along the main paths and roads of this area. In contrast leopards and tigers regularly use the same trails in other parts of the park, such as Klong Kui. Pa Yang is mostly grassland and secondary forest, with few large trees that leopards might climb to avoid tigers. Thus, leopards might be avoiding the Pa Yang area (at least its major trails) because of the presence of tigers combined with lack of escape trees.
- Dholes appear to be uncommon and sparsely distributed in central Kuiburi. This might be due to the relatively high abundance of tigers in this area. However, dholes are relatively abundant in the northern portion of the park, where tiger abundance is very low (see Steinmetz et al. 2007). The inverse relationships between the abundance and distribution of dholes and tigers in Kuiburi could be the result of competition for a limited prey base (Steinmetz et al. 2007).

Figure 12. Tiger density estimates (adult individuals/100 km^2) in Southeast Asia. All estimates were derived similarly, using capture-recapture sampling with cameras, and using half-mean-maximum-distance-moved by tigers to determine effective trapping area.



References: Kaziranga: Karanth et al. 2004; Hukaung: Lynam et al. 2008; Nam Et: Johnson et al. 2006; Huay Kha Khaeng: Simcharoen et al. 2007; Kuiburi: this study; Gunung Basor: Rayan & Mohamad 2009; Taman Negara: Kawanishi & Sunquist 2004; Lepar: Lynam et al. 2007; Kerinci Seblat: Linkie et al. 2006; Bukit Barisan: O'Brien et al. 2003.

Box 1. Tiger–human conflict at Kuiburi National Park

Throughout Asia tigers come into conflict with humans by attacking livestock. This can create negative feelings among local people towards tiger conservation, or, worse, lead to retaliatory killing of tigers by people in defense of their livelihoods. Until recently, tiger predation on livestock was not a major concern at Kuiburi National Park. Tiger predation on livestock used to be infrequent (years between events), probably because the tiger population was small, and cattle-raising is not a major or widespread occupation.

Tiger-human conflict flared suddenly in mid-2008. Over 7 weeks from July to September, a tiger killed 7 cattle belonging to 2 farmers of Khet Ga village. *Loong* (Uncle) *Lot* and *Loong Jai* kept small herds of cattle in narrow valleys where their farms were located, adjacent to the park. This topography left cattle almost completely surrounded by forest, thus making it easy for a tiger to attack from cover. *Loong Lot* and *Loong Jai* (who happened to be brothers) responded by moving their remaining cows away from the forest edge, and corralling and guarding them at night. These swift responses effectively curtailed the tiger attacks.

We visited affected farmers to survey the kill sites and reconstruct the tiger's tactics, in order to better understand the situation and avoid future conflicts. In 2 valleys we located numerous fresh kills, some covered by the tiger with debris, as well as older bone piles. Most kills occurred along the forest edge. In one case the tiger had attacked a cow that wandered up a shady stream which linked grazing land with forest. A tree on the stream bank next to the tiger's feeding site had been freshly scraped by the tiger. In one valley we located a trail that the tiger regularly used to move between forest edge and the surrounding, thickly forested hills. Footprint size suggested it was probably a male. With park rangers we set cameras along this trail and eventually obtained a single photo of the suspected cattle killer ("TM 2" in Fig. 10).

Discussions with *Loong Lot* and *Loong Jai* centered on tiger behavior and reasons for the killings. They recognized that wild prey were in fact much reduced in this area (our previous surveys found only muntjac at low density in this area), and that insufficient wild prey could have driven the tiger to kill cows. We explained that the Kuiburi Tiger Project, by working to increase prey abundance *inside* the park, was actually working to prevent conflicts, like this one, *outside* the park. We asked them to help by raising awareness about prey recovery with their neighbors. Both men told us that, although they were discouraged with cattle-raising, they were not angry at tigers, as tigers had a right to be here too, and killing prey was in their nature.

Our objective in Kuiburi National Park is zero tigers lost due to tiger-human conflict. We hope to achieve this through working with farmers in these dangerous (to cattle) narrow valleys, by responding quickly to conflicts that do occur, and by improving prey status inside the park.

Investigating the site where a tiger killed a domestic cow, September 2008

Tiger scrape at kill site

Remains of a cow eaten by a tiger

EDUCATION & OUTREACH

The quantitative data presented in the preceding section show trends in the status of our conservation targets, tigers and their prey. However, recovery efforts should focus not just on the biological status of conservation targets, but also on threat reduction, management capacity of park staff, and engagement with local stakeholders. To truly assess the impact of our interventions on shaping biological trends, we also need to consider the social and management context of those trends (Stem et al. 2005). The next two sections, Education & Outreach, and Adaptive Management, consider these contexts.

What did we do?

- From December 2007 until June 2009 project and park staff spoke to about 700 people at over 30 events including: village meetings in 12 villages, environmental youth camps at the park, schools around the park, temple fairs, government meetings at the county and district levels, and scientific seminars (Table 6, Fig. 13). This list does not include activities by park staff alone, which were frequent (perhaps doubling the listed effort) and usually included messages about tigers and prey.
- We returned field research results (i.e., showed photos, distribution maps) at village meetings in 3 key villages (Ruam Thai, Yan Seu, Pa Mak).
- We produced 2 posters and a brochure for use in outreach activities; these were disseminated widely.
- Park outreach staff have incorporated project results (tiger and prey status, prey recovery initiatives, camera trap photos) into their own presentations, and they regularly update and use these presentations.
- Park Superintendent Boonlue Phunil compiled the project's camera-trap photographs in 2008 and presented them to the provincial governor.
- Outreach activities also focused on local youth. For example, we organized a track and sign identification trip in the forest, and took village youth to set up camera traps.

Outreach approach, and local responses

- We regularly returned results of field research to key villages, by, for example:
  - (a) demonstrating how a camera trap worked,
  - (b) showing tiger footprint plaster casts,
  - (c) displaying camera trap photos,
  - (d) showing wildlife distribution maps
  - (e) describing abundance trends and discussing their causes.
- By returning results we intended to:
  - (a) make our work transparent to local people,
  - (b) engage villagers in scientific discussion,
  - (c) expand their awareness and understanding of local ecology, and

(d) clarify the rationale for park management decisions such as prey recovery zones.

- In addressing the public, we often tried to set Kuiburi into a broader context. For example, most people in Prachuap Khirikan province do not know that tigers are extinct in 95% of Thailand; thus, the occurrence of tigers in nearby Kuiburi National Park represents an extremely special situation compared to the rest of Thailand. Illustrating the bigger picture of the status of tigers justifies why our project exists here in the first place (tigers are close to national and global extinction), expands people's awareness, and can generate local pride that eventually promotes support and participation in conservation activities.
- We sometimes tried to promote the link between tiger conservation and local ecosystem services, especially the maintenance of water supplies in the 2 major rivers that flow from the park. Our line was that "healthy forests ensure healthy rivers", and tigers were part of intact, healthy forests. Local people in general seemed well-aware that the forested mountains of Kuiburi provided reliable water supplies. But they did not necessarily accept that tigers were crucial to this ecosystem service: 1 man questioned whether forest cover itself would really suffer were tigers to disappear. This question acknowledges the truth that tigers are only distantly linked to forest cover.
- Our outreach efforts consistently emphasized the urgency of prey recovery, and we advertised our prey recovery zones, using maps and local names to show people where they were. We asked for local people's help to recover prey, by raising the issue with their neighbors, and thinking twice about hunting or eating tiger prey.
- Discussions with villagers sometimes provoked interesting and difficult questions about our work. One woman agreed with the concept of prey recovery, but asked: Is it morally wrong to intentionally increase the abundance of deer for tigers to then kill? In her view, tigers were vicious killers whereas deer were peaceful: why were we sacrificing peaceful animals for savage ones? We replied that, although tigers were indeed killers, they only ate as much as they needed to survive, which is actually a moral way of life.

What did we achieve?

Outreach efforts were evaluated by park outreach staff and WWF project staff in May 2009. We asked ourselves the following questions and tried to produce honest answers:

1. Has local people's knowledge and awareness of tiger conservation increased?
   Answer: Yes, but spatial coverage is localized. Many people around the park are now aware of our efforts because we have spoken often at numerous events over the past year. As an indication of increased awareness and interest, 2 local officials recently spoke (on their own initiative) to villagers in their constituency about wildlife conservation in Kuiburi. They also linked wildlife conservation with potential ecotourism and local pride. Despite this progress, we felt our influence was localized, since outreach efforts were concentrated in 3 villages (Ruam Thai, Yan Seu, Pa Mak).

2. Has local collaboration in conservation efforts increased? *Answer: Yes, particularly with local youth.* Youth groups from local schools frequently visit the park, and park outreach staff facilitate an exciting program of events that includes habitat improvement activities such as grass planting and creating mineral licks in the Pa Yang and Klong Kui prey recovery zones. This represents progress in initiating collaboration toward conserving tigers. We felt that these efforts should be institutionalized in a multi-school "Wildlife Recovery Network"; this will be started in the next phase of the project.

3. Have outreach efforts resulted in reduced hunting in the park? *Answer: We do not know, exactly.* Although we know that wildlife numbers are generally increasing in the park, we are unable to attribute this change exclusively to our outreach program, or to our patrolling efforts However, because ungulates increased during a period with low patrol effort (see Adaptive Management, below), we believe that our outreach efforts have had some influence on people's behavior. This question is almost impossible to answer satisfyingly, however, without asking local people themselves whether project activities influenced their behavior. We plan to do this in the next phase of the project. Increasing trust between project and park staff and local people will permit such direct questioning.

Table 6. Education and outreach activities of the Kuiburi Tiger Project, December 2007–June 2009.

Date	Activity	Audience / Participants
Dec 18–19, 2007	**Poster presentation** at annual national wildlife research conference, Kasetsart University, Bangkok	Scientists, professors, tiger conservationists
Mar 1, 2008	**Scientific seminar** to present project results, Kasetsart University, Bangkok	Scientists, professors, tiger conservationists
Mar 13, 2009	**Poster display** at National Elephant Day celebration, Kuiburi NP	Local public
Apr 5, 2008	**Presented project** and gave posters to Yan Sue village headman	Village leader
Apr 23, 2008	**Presented project** and spoke about tiger conservation, at village meeting, Pa Mak village	Local people
Apr 24, 2008	**Interviewed elders**, Pa Mak village	Local elders
Jul 8, 2008	**Presented project** and spoke about tiger conservation, at village meeting, Yan Sue village	Local people
Jul 10, 2008	**Addressed Hat Kham District leaders** (monthly breakfast meeting of the "Coffee Council")	District-level leaders, government officials, police
Jul-08	**Posters given** to Praek Tacraw village and school	Local people, schoolkids
Jul-08	**Posters given** to teachers at 3 schools: (1) Sam Roi Yot, (2) Kuiburi Witaya, (3) Yang Chum Witayakhom	Teachers, schoolkids
Jul 12, 2008	**Presented project** and gave posters to Headwoman, Dan Sing Korn village	
Jul 12, 2008	**Presented project**, put up posters at Dan Sing Korn District Chamber of Commerce Tourist Info Center	Tourists, District officials
Jul 25, 2008	**Environment Camp**, Kuiburi National Park; 4 local high schools attended: (1) Kuiburi Witayakhom, (2) Yang Chum Witayakhom, (3) Sam Roi Yot, (4) Prachuap Witayalai	Schoolkids, teachers

Aug/Sep 2008	**Meeting with Headman**, Hat Kham village, to discuss recent hunting incident	Village leader
Sep 12, 2008	**Visited and advised 2 farmers** who lost cattle to a tiger	Local villagers
Sep 13, 2008	**Thai television** program filming on elephants and tigers	National public
Oct-08	**Posters distributed** at local temple fair	Local public
Nov 3, 2008	**Presented project** at monthly Amphur (county-level) meeting	County-level officials
Jan 3, 2009	Visited 1 farmer whose cattle killed by tiger	Local villagers
Jan 19, 2009	**Environment Camp**, Kuiburi National Park; Kuiburi Witaya school	Schoolkids, teachers
Feb 3, 2009	**Spoke at police station** and gave brochures, Kuiburi town	Police
Feb 9, 2009	Meeting with Ajan Chaweng to **discuss school network** for prey recovery	Teachers
Mar 13, 2009	**Poster display** at National Elephant Day celebration, Kuiburi NP	Local public, schoolkids (5 local schools)
Apr 24, 2009	**Village meeting**, Pa Mak village, to update villagers on tiger and prey status	Local people
Apr 24, 2009	**Recognition ceremony to thank Pa Mak village**, whose cultural traditions protect sambar in Hup Inthanin recovery zone	Local people
May 1, 2009	**Discussed survey results** with Pa Mak headman and village committee	Local leaders
May 3, 2009	**Youth group helped improve prey recovery zone**: created 1 mineral lick in Klong Kui Recovery Zone. 3 local schools: (1) Yang Chum, (2) Kuiburi, (3) Ratchapat Petchaburi College	Local school kids and college students
May 16, 2009	**Presented project display** (posters, photos, brochures) and spoke, Ruam Thai village event	Local people
May 14, 2009	**Presented posters** to Tourism Authority of Thailand to display at Prachuap Khirikhan Provincial Office	National tourists

Figure 13. Outreach and education activities to promote tiger conservation at Kuiburi National Park, 2007–2009.

Track and sign identification course for local school groups.

Local school groups help build a mineral lick for tiger prey in Klong Kui prey recovery zone, April 2008.

Camera trapping for Sambar with Pa Mak village children, April 2009 (we did not get any sambar photos!)

Returning research results to Pa Mak village, April 2008

Tiger project display, Ruam Thai village, May 2009

Local officials [(Nai Amphur of Kuiburi District (left) and Assistant Head of the Hat Kham Sub-District Administration Office (right)] address Ruam Thai villagers about the rare wildlife residing nearby in Kuiburi National Park.

ADAPTIVE MANAGEMENT FOR TIGERS

The Kuiburi Tiger Project is implemented through a process of adaptive management with park staff, whereby monitoring and evaluation are integrated into the project. We rely on an iterative process of research, planning, action, monitoring, and finally evaluation to systematically examine our interventions. Our experience with implementing adaptive management for tiger conservation is detailed in this section.

Training and capacity-building

- Project field work is interspersed with park management workshops (about every 2 months; Table 7), in which WWF and park staff discuss the application of survey and monitoring results to park management. This cycle of field work and management workshops is our mechanism for implementing adaptive management. The process promotes systematical learning that helps us improve our conservation interventions.

Table 7. Kuiburi Tiger Project management workshops at Kuiburi National Park, January 2008–June 2009.

Date	Activity	Participants
Feb 18 2008	Survey results analysis and interpretation	Park Superintendent, all park staff
Mar 11, 2008	Tiger project 1 year plan	Park Superintendent, all park staff
Apr 3, 2008	Creating outreach messages	Outreach staff
Apr 4, 2008	Patrol team planning	Patrol rangers
Sep 11, 2008	Project review	Park Superintendent, all park staff
Nov 7–8, 2008	Patrol and monitoring system training	Patrol rangers, ranger station heads
Feb 4, 2009	Patrol system 3-month review	Park Superintendent, patrol rangers, ranger station heads
Apr 3, 2009	Patrol system refresher training and review	Patrol rangers, ranger station heads
May 15, 2009	Planning for 11 school Wildlife Recovery Network	Outreach staff
May 19, 2009	Outreach review meeting	Outreach staff

- About 25 park staff work directly with the project, either on field surveys, data analysis, or outreach efforts.
- Although WWF project staff conduct formal trainings (for example, to initiate a patrol system, or teach how to identify and measure tiger signs), we emphasize on-the-job training, and work side-by-side with park staff to build skills and confidence incrementally and steadily. Each component of the project offers on-the-job training: surveys in the forest, outreach in the villages, and park workshops in which park staff apply scientific data to park management.

- Participating rangers have told us that they like the project's emphasis on consistent on-the-job training. They felt that, compared to traditional short-term trainings, this style of training was more comprehensive and effective. Park staff also appreciated the project's long-term commitment.
- Project staff helped train 2 park staff to input survey and patrol data into Excel and conduct basic descriptive analyses. These staff members now regularly produce graphs and maps (used in our park workshops) that display monitoring system results. Data analysis and information management capabilities of the park have therefore been improved.
- Since 2007, the project has provided the park with the following equipment that it needs for effective conservation:
    - 1 desktop computer,
    - 7 GPS units for ranger stations,
    - 1 video camera,
    - 1 digital camera,
    - waterproof notebooks for patrol teams,
    - 20 sets of field gear for rangers (including backpacks, hammocks, mosquito nets, and tarps), and
    - partial funding to build a ranger station on Kuiburi's northern border (Hup Takien).

Prey recovery

Concept of prey recovery zones

- Previous surveys in Kuiburi by the project showed that prey scarcity was the primary threat to tigers in the park (Steinmetz et al. 2007). These surveys also revealed the spatially uneven arrangement of prey throughout the park—some locations had relatively intact, though depleted, prey communities, whereas in other places little prey remained at all. Tigers only used about 50% of the park as a result, occurring mainly where diversity and abundance of prey was highest.
- One of the main achievements of the project was to diagnose this critical situation, and, together with park management, act quickly to implement prey recovery zones as an experimental solution to prey scarcity (Table 8, Fig. 14).
- Prey recovery zones are 30–50 km^2 sites that (a) retain extant populations of ungulates, (b) provide good habitat for ungulates, and (c) provide focus for more effective ranger patrols and community outreach. With management effort focused on such locations, prey abundance should increase, perhaps within 2–4 years. In the longer term, as the zone becomes "filled up", prey should disperse, thereby helping replenish surrounding areas. Thus, prey recovery zones should ultimately function as population source areas.
- Recovery zones provide a geographical and logistical focus for park management efforts, in terms of both ranger patrolling and outreach. The concept recognizes and accommodate the unavoidable management limitations of the park: there are simply not enough rangers to effectively patrol the entire park all the time. Thus, it seems better to focus effort strategically so that success is achieved somewhere, and hopefully expand efforts spatially in the future.

- The availability of grazing resources and minerals are important for supporting high densities of ungulates and, most important, promoting rapid population increases. Thus, we chose areas with the best possible such habitat conditions.

Table 8. Attributes of prey recovery zones in Kuiburi National Park.

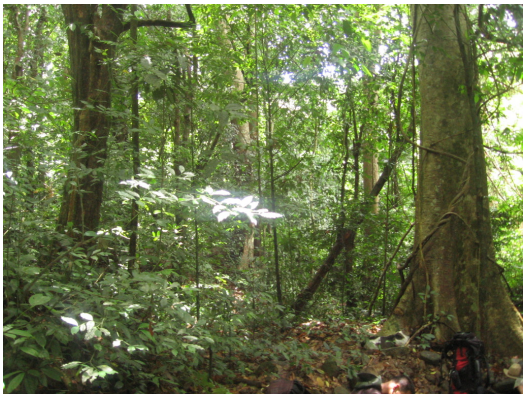
Name	Location	Status in 2009	Habitat conditions for ungulates	Management conditions
Pa Yang	Center	Ongoing: patrolling occurs > 10 ×/mo.	Regenerating forest interspersed with grasslands provides grazing resources that are rare elsewhere in Kuiburi. High density of gaur. Receives intensive habitat management: park has created 2 large grasslands, and created many artificial mineral licks.	Ranger station inside the zone; effectively protected.
Klong Kui	Center	Ongoing: patrolling occurs Up to 5 ×/mo.	Semi-evergreen forest with alluvial grasslands maintained by natural flooding along streams. One mineral lick present. Ungulates at low density but increasing. 1 artificial mineral lick created, 2009; more planned	Accessible by rangers from Headquarters (2 hours walk). Rangers can monitor and patrol the zone frequently.
Hup Inthanin	Center-west	Ongoing: under local community protection	Mixed deciduous forest with grass and bamboo: good food conditions for ungulates. 1 natural mineral lick (Mon Tu). Holds the largest remaining sambar population in park.	Very remote. Rangers do not patrol here, but a partnership with *Pa Mak* village has been established.

Figure 14. Prey recovery zones in Kuiburi National Park.

Pa Yang. This is the only area in the park with extensive secondary forest (left) and grasslands (right). These habitats provide abundant grazing resources for ungulates, especially gaur (right). Water and mineral licks are also abundant. Gaur photo: Sujin Wongsuwan.

Klong Kui. Like much of the park in general, Klong Kui is mountainous and covered with evergreen forest (left), which is relatively poor habitat for many tiger prey species. However, Klong Kui is interspersed with alluvial grasslands (right) and 1 mineral lick, which provide important resources for ungulates.

Hup Inthanin. This area has closed forest (left) and also extensive bamboo groves with a more open structure (right). This habitat heterogeneity increases the capacity of the area to support ungulates. Hup Inthanin presently supports the park's most abundant remaining sambar population.



Management of prey recovery zones

- Prey recovery to promote tiger recovery in Kuiburi National Park requires increased, focused patrolling in prey recovery zones combined with stronger relations with local people. Prey recovery will be much easier if local people understand, respect, and participate in recovery efforts.
- Our strategy in recovering prey in these zones combines:
    1) Increased patrolling frequency by rangers in zones, and
    2) Building local support for prey recovery through outreach activities with surrounding villages (see Education & Outreach).
- The Pa Yang and Klong Kui recovery zones are relatively close to ranger stations and rangers can realistically be expected to patrol them frequently. In contrast, the 3rd zone, Hup Inthanin, is remote from ranger patrolling but is being protected through a partnership with Pa Mak, a key village in Hup Inthanin. This collaboration is detailed in Box 2.
- Active park management of Pa Yang and Klong Kui began in January 2007. Park rangers initially increased their patrolling frequency of these areas from 1–3 ×/month to 3–4 ×/month. This increased patrol frequency was maintained for about 6 months, then diminished due to management changes in the park. Thus, mean monthly patrol days actually decreased in Pa Yang from 2006 to 2007 (Table 9).
- Between 2007 and 2008, however, patrol frequency in these 2 recovery zones increased substantially—in 2008 patrolling was five times higher than before at Pa Yang and doubled at Klong Kui (Table 9).

Table 9. Patrol effort in 2 prey recovery zones, Kuiburi National Park, 2006–2008.

Year	Pa Yang			Klong Kui		
	No. patrol days	Monthly mean	Monthly range	No. patrol days	Monthly mean	Monthly range
2006	39	3.3	0–6	11	0.9	0–2
2007	16	1.3	0–5	15	1.3	0–4
2008	185	15.4	0–30	21	1.8	0–5

Box 2. Community conservation of Sambar in Hup Inthanin

Sambar are an important prey species for tiger but are rare in Kuiburi (and throughout Thailand) due to poaching. Surprisingly, in 2006 we discovered an abundant remnant population in the Hup Inthanin valley in western Kuiburi. This area is also the homeland for local Karen people who have lived in the park for about 100 years. Why were sambar still abundant here but scarce everywhere else?

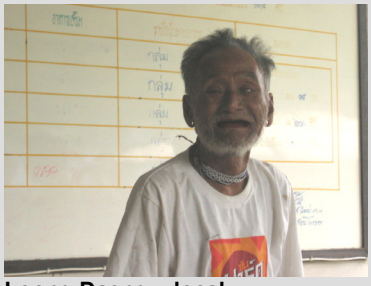
Discussions with villagers of Pa Mak, in Hup Inthanin, revealed a tradition of not hunting sambar. This tradition began with Loong Daeng, an influential village elder who was concerned about diminishing sambar numbers over the previous 20 years. He attributed this decline to local subsistence hunting combined with sport and commercial poaching of outsiders. Over 10 years ago he decided that his village must act to reverse this trend, for the sake of future generations. With support from the village headman and council, Pa Mak village instituted a rule to not hunt sambar, and this has become a living tradition.

The effects of this local protection are clear: sambar tracks are abundant and widespread not just deep in the forest, but even in fallow fields 100 m from the village. As tiger conservationists working on prey recovery, we could not have asked for better conservation partners than Pa Mak. Here, existing local practices converged with our own priority of reviving ungulate populations in Kuiburi. This was a clear starting point for collaborative management, and Hup Inthanin is now one of the park's 3 prey recovery zones, and it is managed mainly by local people.

Our prey surveys over the past 3 years (2006–2009) show a stable or increasing trend for sambar, as well as muntjac (see Fig. 6). Today, Hup Inthanin retains the largest remaining sambar population in the park. This area is too remote from ranger stations to rely on ranger patrolling, but with indigenous assistance deer are doing well. Besides prey surveys, we also organize education activities in the village, such as taking Pa Mak children to set up camera traps in fields where recent sambar tracks were seen.

In 2009, we officially recognized the efforts of Pa Mak in conserving sambar and contributing to tiger conservation. In a special ceremony, park officials and project staff said "Thank You", by presenting a framed camera trap photograph of a handsome sambar. This recognition also helps strengthen and support their tradition.

Of course, Pa Mak has some negative impacts on park resources too. But the positive working relationship being developed, which involves giving credit where it is due, opens doors for constructive discussions about otherwise contentious livelihood issues. For example, our observations indicate diminishing numbers of leaf monkeys in Hup Inthanin; we have initiated discussion with Pa Mak villagers about whether hunting is involved, the parties responsible, and what to do about it.



Loong Daeng – local conservation leader

Karen villagers, park staff, and tiger project staff

Young male Sambar, Kuiburi National Park, 2009

Abundant bamboo groves in Hup Inthanin provide good forage for ungulates

April 2009- Recognizing Pa Mak for helping protect rare Sambar

Prey are recovering in recovery zones, but why?

- Prey increased in all recovery zones between 2006 and 2009 (see Fig. 6). Was this the result of patrolling efforts, outreach efforts, or both? We addressed this same surprisingly difficult question in evaluating the results of park outreach efforts (see Education & Outreach–*What did we achieve*?).
- In the case of Hup Inthanin, there has been no ranger patrolling, so the answer is clear (at least for sambar and muntjac)—prey are increasing because local people help protect them from hunting (Box 2).
- But prey recovery in Pa Yang and Klong Kui is more difficult to attribute to any single factor. Rangers thought that hunting had decreased in 2007 in both these recovery zones. This was based on fewer encounters with people or signs of hunting in these areas, and few village reports of hunting inside recovery zones. But this reduced level of hunting could not have been driven solely by ranger patrolling, since patrol effort was actually sparse in 2007 (Table 9). Thus, it appears that outreach efforts in villages may have contributed to reduced poaching pressure.
- At Pa Yang, habitat improvement by the park, in particular the maintenance of 2 large grasslands and creation of numerous mineral licks, is also probably contributing to population growth of prey, especially gaur (Fig. 14).
- The realization that we could not readily evaluate management interventions led to a major initiative to improve the capacity of the park to monitor hunting pressure through more systematic patrolling. This is described in the next section.

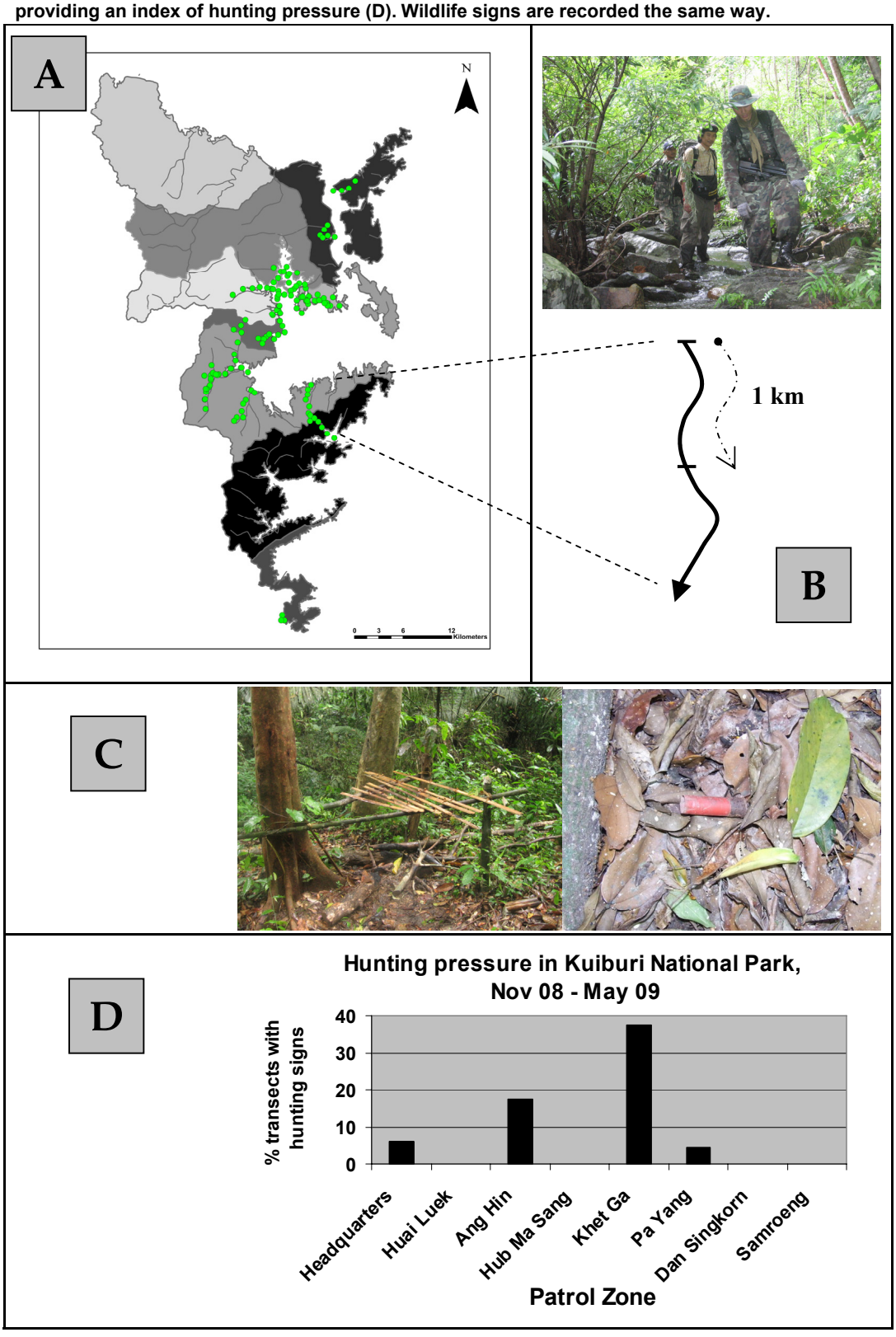
Establishing a systematic patrol system

- Kuiburi rangers actually patrol quite frequently, somewhere, in and around the park. However, there is little systematic documentation of what they observe and thus no way for the park to evaluate the effectiveness of its own patrolling efforts. For example, in project review meetings, we were unable to answer seemingly straightforward questions such as "Has poaching decreased in site X this year?" In mid-2008 park and project staff agreed that the park-wide patrol system should be improved.
- The system we developed organizes patrol observations in a simple format that illustrates (a) the intensity and scale of poaching and (b) patrol effort in space and time (Fig. 15). Most importantly, the relationship between these can be monitored, resulting in improved capacity to understand whether patrol efforts are having an effect. Rangers also collect presence/absence data of signs of tigers, prey species, and other wildlife of interest to the park (elephants in particular).
- The first step in creating this system was to zone the park into management zones, which are looked after by designated ranger stations (Fig. 15). Next, we agreed on specific indicators to record (hunting signs, wildlife signs), and devised and field tested standardized data sheets to record these observations. Finally, ranger stations were equipped with GPS units and waterproof field books.
- Rangers record evidence (i.e., signs) of hunting and focal wildlife species as present or absent in 1 km segments of patrol routes (Fig. 15). Resulting data (i.e, percent of 1 km segments with signs of X) provide indices of hunting pressure (Fig. 15), and of

wildlife relative abundance. An park staff person is being trained to enter and analyze incoming data, using Excel.

- Implementation began in November 2008. Review meetings are held every 3 months. Rangers said they were satisfied that the system was "easy to implement" and "added little extra work". So far rangers have accumulated 285 km of patrol effort in 8 patrol zones between Nov 2008–May 2009.
- An example of the potential usefulness of the information resulting from this improved patrol system is shown in Figure 15D. This graph indicates that, between Nov 2008 and May 2009, hunting pressure has highest in Khet Ga, and relatively low in Pa Yang. Such information provides immediate guidance for park management. Other uses are maps of patrol routes (Fig. 15A), which clearly show where spatial gaps in patrol effort exist.
- Despite its potential usefulness, there is an inherent difficulty with this patrol system. Assessing poaching based only on evidence found in the forest is difficult because poaching activities can happen without leaving evidence. For example, camps, shotgun shells, and snares might be absent even though poaching had occurred. Also, it can be difficult to discern whether indirect signs such as campsites are from legitimate forest product collectors (NTFP, fishing, honey collection) or dedicated poachers. Rangers must often rely on their field experience in interpreting signs of people in the forest.
- However, there is another source of information about poaching pressure that can be used, although it is not quantifiable. Informal gossip and local news that filters out of surrounding villages provides information about poaching pressure, and is an important supplement to formal patrol records. Since rangers themselves are from these villages, they are privy to this info.
- Poachers are rarely encountered directly by rangers on patrol. Poachers are sometimes captured, but only when rangers are tipped off by their contacts in villages (friends and neighbors) and know when and where to go. Thus, patrol effort is meant to deter hunting, rather than arrest people.
- Wildlife poaching is typically portrayed to be a problem caused by local villagers. This viewpoint is an inaccurate oversimplification of a complex problem, and therefore unhelpful for designing solutions. A large portion of the poaching at Kuiburi is actually conducted, not by local villagers, but by distant urbanites and local state officials. For example, in the 2 known hunting incidents in 2009 in Kuiburi (as of this writing), sport hunters from Bangkok, and, in 1 case, an official from the Department of National Parks were directly involved. Often, local villagers are part of these groups, sometimes hired as guides. Thus, wildlife poaching (as well as land encroachment) commonly involves strata of society that are ignored or overlooked because of their wealth, status, or links to state power. We hope to address this problem in the future, perhaps through a provincial level committee, under the governor, that is mandated to inform, educate, and berate state institutions against participating in wildlife poaching and consumption.

Figure 15. Kuiburi National Park's monitoring and patrolling system, 2009. Patrol zones (shown by different shades of gray) were established (A). Patrol routes (green dots on map) are divided into 1 km segments (B), in which rangers record presence / absence of hunting signs (C), providing an index of hunting pressure (D). Wildlife signs are recorded the same way.



Interest and involvement of rangers

- Rangers' recollections and story-telling about project activities are clearly positive, suggesting a sense of pride and of being part of something with significant implications (saving endangered tigers). This is indicated also by the fact that park staff regularly request to join our trips, whether to monitor prey status, set camera traps for tigers, or visit a village.
- The project established a ranger support fund each year ($2000–3000 annually), through which rangers receive direct financial benefits based on their time in the forest specifically on project surveys. They also draw from this fund to pay field-related medical expenses, and for loans when money is tight. Establishing this fund has shown rangers that their involvement was highly valued, indeed crucial.
- In sum, we think the project has boosted ranger self-confidence in their roles as important care-takers of the park.

Wildlife meat restaurants

- We conducted 3 surveys of wildlife meat restaurants around the park in 2008: (1) Dan Sing Korn district (southern zone of the park), July 12; (2) Bor Nok and Kuiburi districts, central zone, September 12; and (3) Pranburi and Hua Hin districts, north zone, October 17.
- To locate restaurants selling wildlife meat, we used existing knowledge of park staff, local interviews at markets, and intuition based on what a wildlife meat restaurant should look like.
- 71% of restaurants checked (17 of 24) had wildlife meat for sale. There are undoubtedly an unknown number of additional restaurants that we missed.
- The most common meat sold was muntjac (6 restaurants), followed closely by sambar (5 restaurants) and wild pig (4 restaurants). We could not ascertain which species were sold at 9 restaurants, but they include tiger prey species.
- At 3 restaurants we were told that "wild pig" meat was actually farmed. One restaurant told us the sambar meat they offered was from a farm as well. These claims may be true, especially in the case of wild pig.
- We publicized these survey results at a major county-level government meeting of officials from every district, in November 2008. However, we have not acted further on this survey information yet.
- A serious deficiency in our information is this: we do not know the extent to which wildlife meat restaurants obtain their animals from Kuiburi National Park. We are therefore unable to decide how much effort to allocate towards addressing this threat. Nonetheless, wildlife restaurants are certainly a threat to tiger conservation in this landscape, and eventually must be addressed.
- The park superintendent and project staff are preparing to approach the provincial governor (in 2009) to enlist high level support for making the Prachuap Khirikan a "wildlife-meat free" province. Further, we hope to eventually extend this concept to the entire forest complex covering 2 provinces (Prachuap Khirikan and Petchaburi).

- Addressing the problem of wildlife meat restaurants may, or may not, involve traditional enforcement activities. The main focus may instead be on an education and media campaign—with provincial support from the governor's office, and local support and action through a wildlife recovery network of local youth groups active in towns and local markets—to turn consumers against eating wildlife meat. If successful, this would diminish the source of the problem, leading to more lasting conservation results. In contrast, traditional police arrests focus on a manifestation of the problem: the restaurants themselves. Because this tactic ignores the actual source of the problem (market demand and consumer recklessness), and police effort is inevitably not maintained in the long term, the problem resurfaces.

The future of tigers in Kuiburi National Park

The tiger population in Kuiburi National Park is small compared to some other sites in Southeast Asia. But it is not small compared to the many sites where tigers are now extinct. Extinction is a process that occurs population by population; in turn, saving species from extinction means saving populations. The present status of tigers in Kuiburi National Park probably resembles the pre-extinction stage of many parks in the region that used to have tigers, but whose small populations eventually succumbed to prey depletion and other factors. Hopefully, Kuiburi National Park has acted soon enough to reverse this course, and pull its tigers back from the brink of extinction.

Kuiburi's tiger population is small due to prey loss and historical habitat conversion, but also reflects the naturally low carrying capacity of mountainous evergreen forest for large terrestrial mammals. Despite this challenge, we think tigers in Kuiburi National Park have a good chance for recovery—to 2 or 3 times their current abundance—for the following reasons:

1) The status of tigers, their prey, and conservation threats and opportunities in the park are now well-understood, providing a sound basis for conservation planning and decision-making.
2) Park management is aware of the urgency with which tiger conservation must be implemented, and they are acting to tackle the main threat to tiger recovery, which is prey depletion.
3) The status of prey species is improving, in terms of abundance and distribution.
4) Tigers are reproducing in the park.
5) Tiger poaching is not a problem.
6) Small tiger populations can recover from low numbers if prey densities are increased (Karanth et al. 1999), and even small, isolated tiger populations containing 6 breeding females can be demographically viable (Karanth & Stith 1999).
7) It is likely that tigers in Kuiburi National Park are part of a much larger effective tiger population that includes contiguous forest habitat in Myanmar.

Recommendations for improvement

Park management

1) Conservation work dedicated to tigers and prey should continue for at least the next 4 years, as a joint project between Kuiburi National Park, the Department of National Parks, Wildlife, and Plant Conservation, and WWF-Thailand.
2) Rangers should continue patrolling at least 3-4 times per month in the Klong Kuiburi and Pa Yang prey recovery zones.
3) The possibility of reintroducing sambar into Pa Yang should be considered. Advice should be sought from other protected areas where ungulate reintroduction has recently occurred, particularly Huay Kha Khaeng.
4) The patrol and monitoring system should continue to be reviewed by park staff every 3 months.

Research and monitoring

1) The response of prey to recovery efforts should continue to be monitored annually in recovery zones, using relative indices of abundance derived from sign transects and camera-traps.
2) Increasing prey abundance in Pa Yang, which has a relatively open habitat structure, may make distance sampling based on direct observation of animals feasible there in the next few years.
3) Tiger occupancy surveys should be repeated throughout the park in 2010, to determine if large-scale distribution patterns have changed compared to 2006 (when occupancy surveys were last conducted).
4) Capture-recapture camera-trapping should be repeated in 2010 to monitor the numbers of tigers in central Kuiburi.
5) The tiger scats accumulated by the project need to be analyzed to determine what tigers are eating.
6) Primates, especially leaf monkeys (*Semnopithecus*, *Presbytis* spp.), are eaten by leopards, and therefore represent an important prey species that our project has largely overlooked. Also, leaf monkeys are a popular target for hunters. Thus, the distribution and relative abundance of leaf monkeys should be monitored as well as other prey species. Observations of leaf monkey groups per day could be noted during field surveys; this would provide a rough index of abundance in different areas.
7) Camera trapping should be conducted in the northern third of the park with the goal of identifying the few tigers there: are they different individuals from the main population in the center of the park? This should <u>not</u> be done using capture-recapture sampling (tiger abundance there is too low to make the method worthwhile).

Human-tiger conflict

1) Tiger predation on livestock should be closely monitored. Ranger station heads should be reminded of the critical nature of this potential problem. The park should be ready to rapidly respond by sending staff, within 1 day, to any site with livestock killing by tigers.

2) Potential tiger-human conflict sites should be identified, in advance of any livestock losses. These will be sites where cattle are raised in close proximity to the forest edge. Ranger stations nearest to such sites should be responsible for contacting cattle owners, warning them of potential problems, and seeking preemptive solutions, i.e., moving cattle at least 500 m from the forest edge.
3) All cattle owners who previously lost cattle to tigers responded swiftly and cooperatively by adjusting their cattle husbandry methods (see Box 1). These farmers and their families should be publicly recognized for their positive involvement in tiger conservation in the park. Their story should also be used to further promote prey recovery as a long-term solution to the problem of human-tiger conflict.
4) We believe that compensation schemes, which pay farmers for their livestock losses, might create as much trouble as they alleviate. However, there might be increasing and unavoidable pressure for compensation in the future. In advance, the park should develop clear criteria for such a scheme (in case the park is ordered to implement one): Who will investigate livestock kills? Under what conditions would compensation be considered? Only when tigers come out of the park? What about cattle right on the edge of the park? How much money will be paid? Where will this money come from?

Outreach and Collaboration

1) It is difficult to assess the project's effects on people's behavior, yet behavior change is a key outcome to achieve and understand. In the future, villagers should be asked, in interviews or focus group discussions, what effect the project has had on behavior in their village. This type of direct questioning will become feasible as trust between park staff, project staff and local people builds further.
2) Outreach staff at Kuiburi National Park do an excellent job of organizing numerous youth camps and activities for local schools during the year. These efforts should be magnified, by drawing local schools into a network that actively assists wildlife recovery efforts (while fulfilling learning requirements in science and ecology at the same time). The vision is to nurture a net of concerned, active citizens around the park. Examples of school group activities include: helping improve habitat, monitoring recovery zones, visiting captive tigers, being ambassadors in their villages to promote prey recovery, and conducting campaigns at wildlife markets to educate consumers.
3) Project outreach efforts need to expand spatially to reach many more villages around the park, especially in the south and north. This will require an additional dedicated staff of the project.
4) A study tour to see the Huay Kha Khaeng tiger project should be organized for Kuiburi staff. There are just a few active tiger research projects in Thailand and so far they have little contact with each other. The confidence, commitment, and knowledge of Kuiburi staff would be increased as a result.

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PHOTO APPENDIX

Landscape and habitats

Kuiburi National Park is in the Tenasserim Mountains. This photo looks west across the Klong Kui prey recovery zone. The Myanmar border is on the horizon.

Semi-evergreen forest is the predominant habitat type in Kuiburi National Park.

The lowlands surrounding Kuiburi National Park (mountains in background) were covered by mixed deciduous forest 30 years ago. Today, lowland areas have been completely converted to pineapple fields.

Tiger project activities in Kuiburi National Park

Investigating a tiger scat

Last camera trap for the day!

Conducting a sign transect for tiger prey

…the walk back to base camp

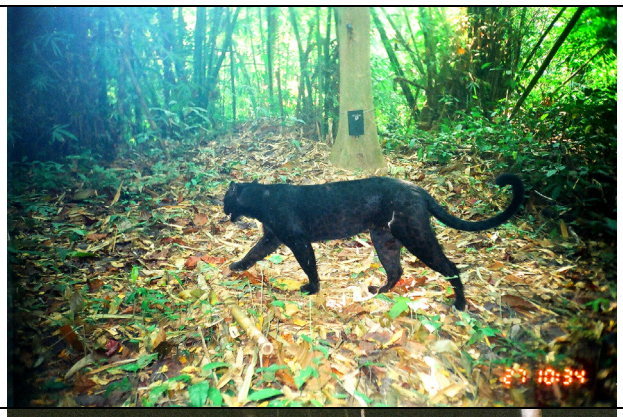
Boonlue Poonnil, Superintendent of Kuiburi National Park, gets local school children involved in conservation

Using survey data for tiger conservation planning at Kuiburi National Park

Tiger behavior in Kuiburi National Park

	Tiger female 1 (TF1), spraying urine on a tree. Tigers spray trees to mark their territories and advertise estrous. Tiger female 1 had the most widespread movements of all camera-trapped tigers (up to13 km between photographs).
	Tiger female 2 (TF2) lives to the southwest of TF1
	Tiger female 3 (TF3) also lives to the southwest of female 1. She has the habit of closely investigating our camera traps.
	Tigers communicate using visual and chemical signals, such as this scrape. This was one of numerous tiger scrapes we observed one day in an area where both TF2 and TF3 (above) had been photographed. The scrapes were probably made by one of these female tigers, delineating its territory.

Leopards at Kuiburi National Park

		Black leopards are about twice as common as spotted leopards in Kuiburi National Park.
		Leopards in Kuibiri are active during both day and night. In contrast, tigers here are active only at night.
		Leopards communicate using visual and chemical signals like tigers. We commonly find leopard scrapes like this along trails and ridges in Kuiburi. [Footprints inside the scrape are measured to determine whether it was made by a leopard or tiger.] In this particular scrape the leopard also left a scat (near the pen).

Major prey species of tigers

Wild pig

Gaur

Sambar

Fea's Muntjac

Lesser Mouse Deer

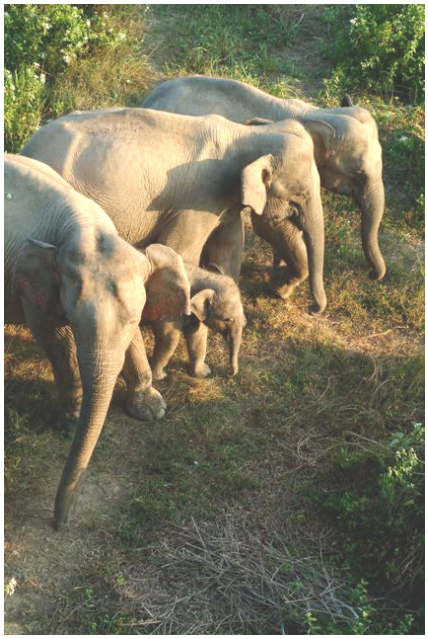
Red Muntjac

Malayan Porcupine

Stump-tailed Macaque

Wildlife of Kuiburi National Park

Sun bear
Helarctos malayanus
Camera trapped by
Kuiburi Tiger Project.



Elephants
Elephas maximus
Photo by Lou Petho.

Asian Tapir
Tapirus indicus
Camera trapped by
Kuiburi Tiger Project.