Results from A Camera Trapping Exercise for Estimating Tiger Population Size in the Lower Foothills of Royal Manas National Park

Ugyen Wangchuck Institute for Conservation and Environment

Results from A Camera Trapping Exercise for Estimating Tiger Population Size in the Lower Foothills of Royal Manas National Park

Ugyen Wangchuck Institute
for
Conservation and Environment
(UWICE)

Prepared by:
Tshering Tempa[1], Nawang Norbu[1], Pema Dhendup[1] and Tshering Nidup[2]

Citation:
Tempa, T., Norbu, N., Dhendup, P. and Nidup, T. 2011. Results from A Camera Trapping Exercise for Estimating Tiger Population Size in the Lower Foothills of Royal Manas National Park. UWICE and RMNP: RGoB. Lamai Gompa, Bumtang.

www.uwice.gov.bt

Design by Karma Loday Yeshey & Thinley Zam
Printed at KUENSEL Corporation Ltd.

ISBN No: 978-99936-817-2-4

1 Ugyen Wangchuck Institute for Conservation and Environment
2 Royal Manas National Park

ACKNOWLEDGEMENT

Tigers thrive in Royal Manas National Park. Our field work and the success of our camera trapping exercises has been made possible by the support, dedication and commitment of many individuals and institutions.

First and foremost, we are grateful to the park staff of Royal Manas National Park (Jamtsho, Dorji Duba, Karpola, Sonam Choeda, Dew Bhadhur, Dew Kumar, D.B Gurung, Lhap Dorji, Choney Zangpo, Nachen Wangchuk, Jamyangla, Pema Namagy, Sangye Lhendup, Jigme, Tshewang Dorji, Dawa Sharpa, Mamongpa, Nungpola, Karma Pradan, Pema Tobgay, Pema Khandu, Lepcha, Ugyen Orro, Sangay Melong, Mr. Tshering Dorji and Mr. Tshering Nidup). We remain inspired by their sacrifice and dedication and thank them for providing armed escort to our research team.

In particular, we would like to thank the CFO of RMNP, Mr. Tenzin Wanghcuk for his support and enthusiasm in this research initiative. We are also truly appreciative of Mr. Yeshi Wangdi and Mr. Dorji Wangchuk's support and assistance.

We thank Dr. Scott Mills, Dr. Mark Hebblewhite, Dr. Marcella Kelly and Dr. Ronald Wakimoto, for their help in study design and suggestions for analyzing the data.

This study would not have been possible without the support of the Bhutan Foundation. We acknowledge their financial support for this work. The newly established Jigme Singye Wangchuck Research and Training Fund at UWICE has also provided support for this study.

We have had the opportunity to work with some truly exceptional leaders within the Ministry of Agriculture and Forests. We thank His Excellency Lyonpo Dr. Pema Gyamtsho for his continued support and commitment to conservation efforts in Bhutan. We also acknowledge the guidance and support of Dasho Sherub Gyaltshen, Honorable Secretary and Mr. Karma Drukpa, Honourable Director of the Department of Forests and Park Services.

Dedicated to the foresters who patrol our forests to ensure tigers live forever

Lists of Figures

Lists of Tables

EXECUTIVE SUMMARY

Tiger (*Panthera tigris*), a highly endangered large carnivore is used as a flagship species in conserving wildlife and wild lands in many parts of Asia. Currently, less then 3500 tigers live in the wild occupying a mere 7 percent of their historical range. The fate of tiger have never looked more uncertain than the current plight. A failure to reverse these trends will result in not only the loss of wild tigers, but also bring about profound changes to ecosystem structures and dynamics throughout the Asiatic region. The main threats to tigers are poaching, habitat destruction and fragmentation, and depletion of their main ungulate prey species.

To stem the loss of tigers, range country governments, international agencies and NGOs are expediting their efforts at all levels. The Royal Government of Bhutan (RGOB) is committed to conserving this species and has set aside more than 51 percent of the country's total geographic area as protected areas in the form of National Parks and Biological Corridors. Such initiatives should be grounded on a proper understanding of tiger population status in the wild.

We used remotely triggered camera traps in conjuncture with the Capture-Marked Recapture method to estimate the population size of tigers in a lower foothill habitat within the Royal Manas National Park of Bhutan. A total of 60 camera traps at 30 trapping stations were set.

We acquired 448 photographs of 10 individual tigers. To estimate population size, we used information from only 9 individuals as 1 female tiger was photographed outside our sampling period of 60 days (1620 trap nights).

We estimate a population size of 10 (±2.7) tigers in our sampling area.

This gives an estimated density of 4.47 tigers/100 km^2 or 1 tiger/20 km^2). The effective sampling area was calculated using ½ MMDM (Mean Maximum Distance Moved).

In addition to tigers, our cameras also captured pictures of 6 others cats and 22 other species. These results provide insights into the ecosystem dynamics within lower foothill forests of Bhutan and suggest that Manas is an extremely productive and rich landscape.

Our results vindicate our assertion that Manas as a landscape is crucial for the future of tigers. This region also forms an indispensible corridor between the Terai regions (of Nepal and India) with landscapes of Northeastern India, Myanmar, and SE Asia.

CHAPTER I: INTRODUCTION

Tiger (*Panthera tigris*), a highly endangered large carnivore (IUCN 2010) is often used as an effective flagship species in conserving wildlife and wild lands in many part of Asia (Karanth *et al.* 2002). A consummate predator and tolerant of an unbelievably wide range of habitats (Schaller 967, Sunquist 2010), tigers were historically found from the Indo-Chinese Archipelago to the Caspian Sea.

Today, tigers occupy a mere 7% of their historical range (Sanderson *et al.* 2010), and within the last decade alone, habitats decreased by 41% (Dinerstein *et al.* 2007). Currently, tigers are potentially distributed across 1,190,000 km^2 in 13 range countries in isolated populations (Sanderson *et al.* 2010) and their numbers have dropped below 3500 individuals in the wild and continues to fall. A failure to reverse these trends will result in not only the loss of wild tigers, but also bring about profound changes to ecosystem structures and dynamics throughout the Asiatic region. The main threats to tigers are poaching, habitat destruction and fragmentation, and depletion of their main ungulate prey species (Karanth and Nichols, 1995; Dinerstein *et al.,* 2007; Sunquist, 2010).

In the Indian subcontinent, conservation of the Royal Bengal tiger subspecies is at a critical juncture. The chilling revelation of extirpations of tigers in Indian tiger reserves designed specifically for tiger conservation has led to the growing realization that this subspecies is declining rapidly where they were thought to be thriving (Wright, 2010). The Bengal tiger's fate has never looked more uncertain. Recent studies reveal that half of all Bengal tiger populations have disappeared in the last decade, largely due to massive forest destruction in India, as well as poaching. The northern-most tiger conservation landscape for Bengal tigers is the southern Himalayan foothills in Bhutan, Nepal and India. This population is potentially separated from other populations in nearby Myanmar and

South East Asia, and there are growing concerns over connectivity between populations as population size in existing reserves declines. Bhutan, given its largely intact wild habitats is key to ensuring connectivity of tiger populations in the region.

In Bhutan the tiger can be found from sub-tropical jungles near the Indian plains to above tree line on the Tibetan border (Dorji and Santiapillai, 1989). The RGoB is committed to conserving this species and has set aside more than 51 percent of the country's total geographic area as protected areas in the form of National Parks and Biological Corridors. Buddhist ethos and conservation policies have allowed their existence without much threat to their survival. Poaching of tigers for wildlife trade is not a major threat in Bhutan unlike in other tiger range countries, but as human populations grow and settlements expand, their survival is coming under threat due to habitat loss and increasing human wildlife conflicts.

Global initiatives to conserve tigers by international organizations and NGOs have helped in raising awareness of the precarious state of this species. The tiger summit in Russia in 2010 further reiterated the commitment of international agencies and tiger range countries to save this species. Through concerted efforts of these international conservation agencies, NGOs and tiger range countries, many programs are being initiated and implemented at global and regional level to increase the number of tigers in the wild. However, despite huge financial investment and effort from these agencies and nations, tiger numbers continue to dwindle in most of the tiger range countries.

Global and regional level initiatives will need to be anchored to on the ground actions at the local habitat level. We are of the opinion that conservation actions and initiatives at the local level are crucial to realize the global mission of preventing extinction of tigers in the wild. To implement effective local level actions and to have meaningful global dialogues, an understanding of how many tigers remain in the wild is of crucial importance. It is with this objective that we have initiated a long-term tiger monitoring study in Royal Manas National Park (RMNP) from 2010.

We used remotely triggered camera traps in conjuncture with the

Capture-Marked Recapture method to estimate the population size of tigers. This method is currently the most effective and efficient technique to get reliable population estimates of many species like the tiger. This method takes advantage of the unique stripe patterns on tiger pelage to distinguish individuals.

The objectives of our study were to:

1. Estimate and monitor the size of tiger population and density in an intensive study area (lower foothills of Manas Range).
2. To understand predator and prey relationships
3. Document species occurrence in the sub-tropical wilderness of Manas

CHAPTER 2: ROYAL MANAS NATIONAL PARK AND FIELD WORK

2.1. Study Area

Royal Manas National Park is located in the southern foothills of Bhutan (90⁰ 35′ 03.61″ E to 91⁰13′28.51″E and 26⁰46′16.16″N to 27⁰ 08′38.70″ N) and borders with India's Manas Tiger Reserve, thus forming a trans-frontier conservation landscape. To its north, it borders with Jigme Singye Wangchuck National Park and is further connected to Thrumshingla National Park and Phibsoo Wildlife Sanctuary by biological corridors (Figure.1).

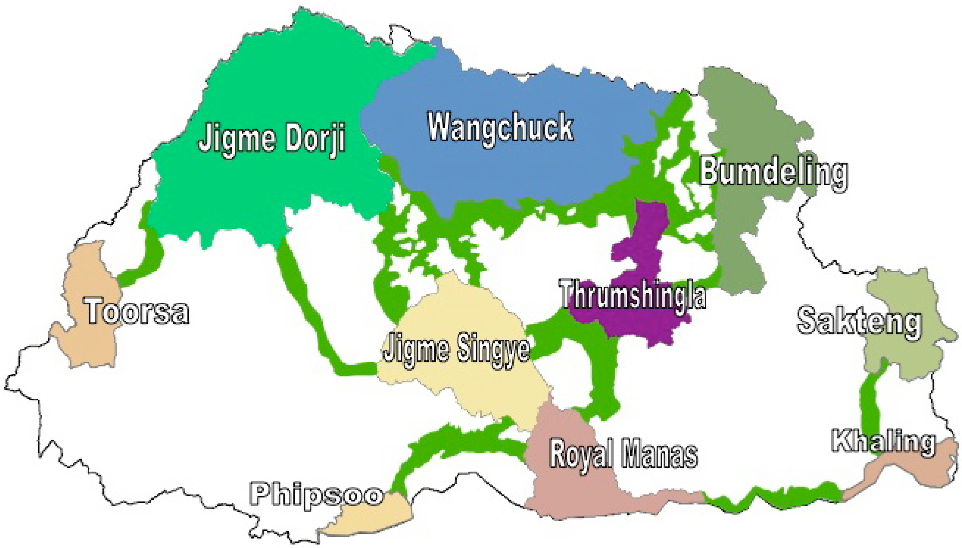


Figure1. Map of Bhutan showing protected area network system including Biological Corridors (Shaded in green)

RMNP stretches over an area of 1057 km^2, with elevations ranging from as low as 80m asl at the southern foothills up to 2900m asl in the north. Most parts of Royal Manas National Park experience hot and humid summers followed by cool and dry winters with annual maximum temperatures ranging from 20°c to 34°c . Owing to varied climatic and topographic features, the park has diverse ecosystems (Figure 2).

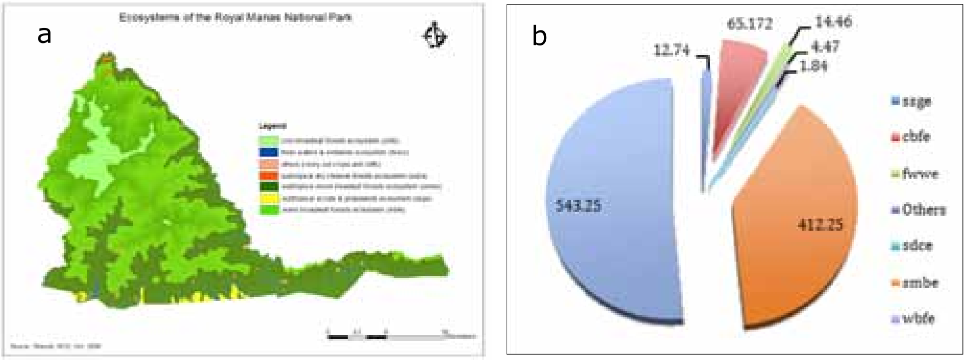


Figure 2. (a) Map of RMNP showing different habitat types; (b) pie-chart showing RMNP area (Sq. Km.) under different habitat types

Royal Manas NP is home to many endangered wildlife species including tiger (*Panthera tigris*), Indian one-horned rhinoceros (*Rhinoceros unicornis*), elephant (*Elephas maximus*), asiatic water buffalo (*Bubalus arnee*), wild dog (*Coun alpinus*), golden langur (*Trachypithecus geei*), and critically endangered species like pigmy hog (*Sus salvanius*) and hispid hare (*Caprolagus hispidus*). Manas is also home to more than 350 species of birds.

Major prey species for carnivores like tiger are gaur (*Bos gaurus*), sambar (*Cervus unicolor*), Asiatic water buffalo (*Bubalus arnee*), barking deer (*Muntiacus muntjak*), wild pigs (*Sus scrofa*), serow (*Capricornis sumateriensis*), goral (*Naemorhedous goral*), Himalayan crestless porcupine (*Hystrix brachyura*), golden langur (*Trachyphithecus geii*), capped langur (*Trachypithecus pileatus*), Assamese macaque (*Maccaca assamensis*) and elephant calves.

Carnivores other than tigers in RMNP are common leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), jungle cats (*Felis chaus*), Asiatic golden cat (*Catopuma temminckii*), leopard cat (*Prionailurus *bengalensis*), marbled cat (*Pardofelis marmorata*), Himalayan black bear (*Ursus thibetanus*), large Indian civets (*Viverra zibetha*), small Indian civets (*Viverra indica*), Himalayan yellow throated martens (*Martes flavigula*), mongooses (*Herpestes* sp.), otters, ferret badger (*Melogale sp*.) and binturong (*Arctictis binturong*).

The current camera trapping study was conducted within Manas range of RMNP (Figure 3) in an area 74 km^2 of sub-tropical moist broadleaved forest ecosystem and grassland in the southern foothills of Manas.

2.2. Methods

2.2.1 Camera-Trap Data Collection (Field Techniques)

Camera-trap field data for tiger and their presumed prey were collected from our study area of 74 km^2 in the lower foothills of Manas range. The study area was divided into 2.5x 2.5 km grid. A cluster of 30 grids were selected that were accessible from the trails and nearby villages and camps. As there are no motor roads in Manas, all grids had to be covered on foot. Hence, accessibility to these selected grids was an important consideration while choosing which ones to select. This selection was done based on reasonable access and ability to regularly monitor camera stations.

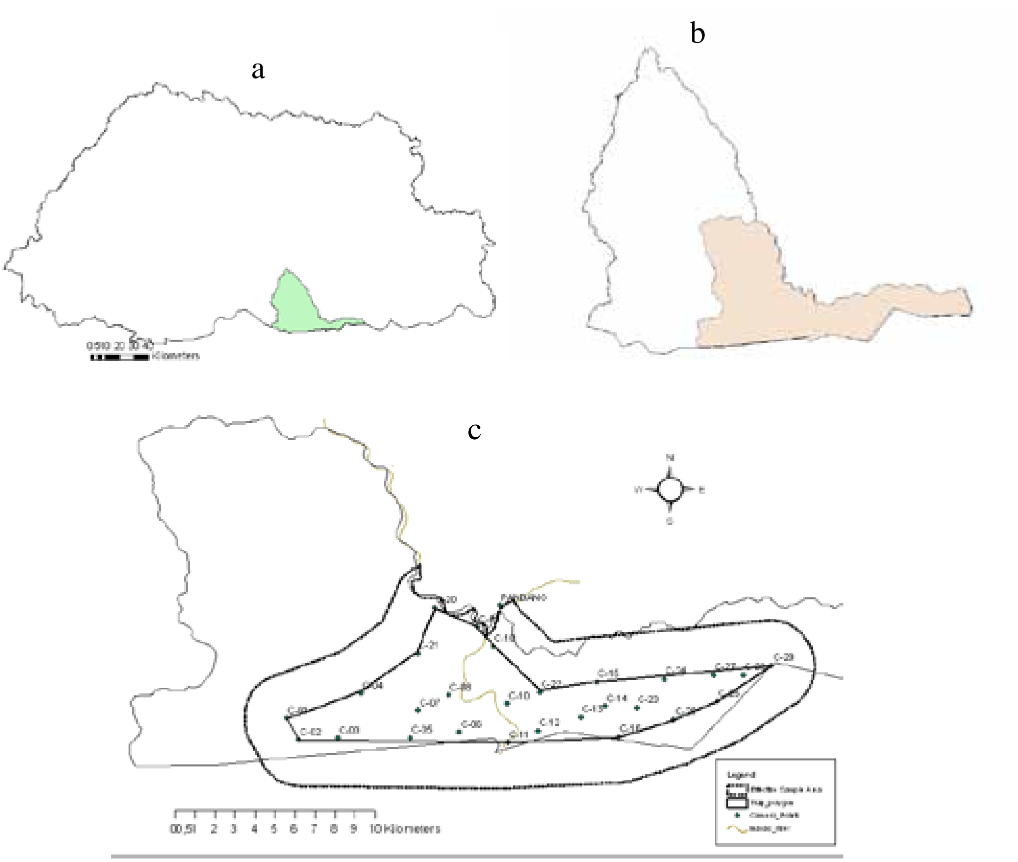


Figure 3. Map showing: a) location of RMNP in Bhutan; b) location of Manas Range within RMNP; c) lower foothills of Manas range showing trap polygon, effective sampling area, and the trap location

Once grids were selected, we looked for optimal location to set camera in each grid based on the presence of tiger signs such as pugmark, scrape marks, scent marks, scats and kill sties. In the month of September and October 2010, RMNP field staff conducted a detailed sign surveys and the GPS locations of all tiger signs were available for our team. No separate sign surveys were conducted specially for this study. To maximize the capture probability of tiger by our cameras, we placed cameras along the trails and river basin/beds that had the highest density of tiger signs within the selected grids (Karanth 1995).

At each station two cameras (Reconyx HC500 Hyperfire) "passive infra-red system (triggered by body heat as the animal passes in front of the heat sensor inbuilt in the camera)" were set to photograph both the flanks of the tiger. The cameras were placed 6-7 meters away from each other at a height of 45 cm from the ground and positioned in such a way that two cameras were not in the same line of view to avoid the flash of one disturbing pictures on the other camera. Efforts were made to place two cameras at each location, but sometimes our camera station would accommodate only one camera. In such cases, we placed the other camera few meters away from the location (10-15 meter) forward or backwards along the same trail. In addition to monitoring tigers, this exercise was also to record biodiversity, particularly the fauna of Manas, so we set the sensitivity of camera to very high to capture anything that moved and had a different temperature from the surrounding environment. To deter and avoid damage from elephants, we placed fresh elephant dung on our cameras and camouflaged them to blend with surrounding environment.

Each camera-trap was given unique number (e.g. C1-C30) and all the locations were recorded by GPS and marked on a map. The GPS coordinates of each location were recorded on the data sheet. At each location, additional information of the habitat type, ground cover, canopy cover, and canopy height, were recorded.

Camera traps were monitored twice a month where ever possible, but some cameras traps could only be monitored once in a month due to logistical constraints and lack of human resources. We monitored camera battery status, and if battery status were below 75% we replaced whole set with new battery sets (recharged ones), but if battery status were above 75% we changed batteries from top row during first monitoring and bottom row in the next monitoring phase. SDs card (memory card 2GB) from each camera were swapped with new cards at each camera station, and camera id properly marked on the SD card for correct ID of photos from each camera. Once in the camp, we downloaded all the pictures directly from SD cards to computers. Photos were segregated into different groups according to our objectives and questions. For tigers, we identified each individual based on stripe patterns on flanks, head, tails, and limbs (Karanth, 1995, Schaller, 1967) and gave unique identification numbers according to their sex. For example, a male tiger was given an unique id. as MST_01_M, similarly for female as MST_05_F, for cub as MST_03_C and MST_09_U for unknown sex.

Although this is a part of the long-term predator prey-dynamic study in the subtropical forest of Bhutan, we used data collected from 18th November 2010 to 16th Jaunary 2011 for 60 days (1620 trap nights) to avoid closure issues. The cameras are still in the field and are being monitored regularly by our researchers and field staff from RMNP.

2.2.2. Data Analysis

Individual capture histories were developed for all the identified tigers captured in the camera traps. The capture history for animal *i* consists of a row of vector of *j* entries, where *j* denoted the number of trapping occasions for our study area. Each entry, denoted as X*ij* X matrix (Otis *et al*., 1978) for individual *i* on occasions *j* assumed value of either "0" if the animal was not captured on the particular occasions, or "1" if animal was captured (photographed) on that occasion. For example, a capture history of 0001100010 of a tiger indicates that it was captured on the fourth, fifth and ninth occasions during the survey of occasions. We pooled captures from five days (trap nights) into one occasion to get more recaptures, instead of using each trap night (24 hours) as once (Mills and Kelly, pers. com), so we had 12 occasions instead of 60 for our 60 days trap nights.

The capture history data were analyzed using the program CAPTURE (Otis *et al.*, 1978; White *et al.,* 1982; Rextad and Burnham, 1991) developed to compute abundance estimate of demographically closed populations. This program uses different models to generate abundance estimates for a sampled area, based on the number of individual animals captured and the frequency of recaptures. These models differ in their assumed source of variation in capture probability, including variation among individuals (individual heterogeneity), behavioral response, over time, and various combinations of these. Individual heterogeneity refers to variation in the capture probability among individuals such that each tiger is thought of as having its own capture probability, which may be different from all other animals. The behavioral response refers to changes in capture probabilities that result after an individual is captured for the first time. Therefore, an animal captured for the second time (marked) has different capture probability than the one captured for first time (unmarked) at any sampling occasion *j*. Time variation refers to variation of capture probability over time from one sampling occasion to another.

We selected the Jackknife estimator M_h (Otis *et al.* 1978, Nichols, 1992) to estimate the capture probability ($\hat{p}$) for our data set as this model has been used successfully for similar kind of tiger studies and found to be the most robust(Karanth and Nichols, 1995; Karanth and Nichols, 1995). Individual variation (heterogeneity)was assumed, owing to home range considerations (male and female has different home range size), sex, age, and camera locations.

We report the estimate of capture probability ($\hat{p}$) and the tiger population size ($\hat{N}$) computed by program CAPTURE for model Mh for our study area. The density ($\hat{D}$) of tigers in the study area was estimated using the Equation

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

[where $\hat{D}$- estimated density, $\hat{N}$- estimated population size, (A ($\hat{W}$))- effectively sampled area] (Karanth and Nichols, 1998 & 2002; Harihar *et al*., 2006).

We calculated the effective sampled area ($\hat{A}$) by drawing a trap polygon connecting the outermost camera traps and adding a strip width ($\hat{W}$) to the trap polygon. The strip width was calculated using half of the 'mean maximum distance moved (MMDM)' by all the tigers that moved between cameras.

We did not estimate the density of prey and other predators in our study area. Instead we calculated relative abundance indices using photographs of species (Carbone *et al.* 2001; Ahmed *et. al* 2010). We also investigated the temporal tiger-prey activity patterns and how other sympatric carnivores segregate and use the same area form pictures that were captured by our cameras. We used only information from the right side of cameras for this analysis.

CHAPTER 3: HOW MANY TIGERS ARE THERE IN MANAS?

3.1. Photographic Capture

Our study is long term and will be continued for many years. The current camera stations will serve as a permanent monitoring plots. For our first estimates of tiger numbers in Manas, we have taken data for 60 days from November 18th, 2010 (last camera was laid on this date, the first was on 7th Novembers) to January 16th, 2011. This was done to fulfill the closure assumption (no mortality, no new recruitment, no immigration and emigration during) for our sampled population during the sampling period.

The total sampling effort realized was 1620 trap-nights. We got total of 448 photographs of tiger of which 220 (from 25 independent events) were from left side and 228 (from 41 independent events) from right side. All the pictures were used for identifying individual tigers. Individual tigers have unique stripe patterns and are easily identified by comparing the stripe pattern of the same flank or same spot. Based on their unique stripe patterns, we conclusively indentified 9 individual tigers in our study area of which 4 were females, 3 were males, and 2 were sub-adult males. We developed capture history for 9 individuals (Table 1). Another individual tiger (female) was captured on January 24th, 2011, which put our total count to 10 individuals, but we did not use this tiger individual to calculate population size as it was outside our sampling period of 60 days. All the individual tiger photographs are presented in Annexure 1.

TABLE 1: CAPTURE HISTORY OF INDIVIDUAL TIGERS PHOTO-CAPTURED IN LOWER FOOTHILLS OF MANAS, RMNP; 9 INDIVIDUALS, 12 OCCASIONS (60 DAYS).

Individual tiger ID	Occasions											
	1	2	3	4	5	6	7	8	9	10	11	12
MST_01_M	1	0	0	1	0	0	0	1	0	0	0	0
MST_02_F	1	0	0	0	0	0	0	0	0	0	0	1
MST_03_F	1	0	0	1	0	1	0	1	0	0	0	0
MST_04_M	1	1	0	0	1	0	0	1	0	0	0	1
MST_05_M	0	0	0	1	0	0	1	0	0	0	0	0
MST_06_F	0	0	0	0	0	1	0	1	1	0	0	0
MST_07_M	0	0	0	0	0	0	0	0	1	1	1	0
MST_08_M	0	0	0	0	0	0	0	0	0	1	1	0
MST_09_F	0	0	0	0	0	0	0	0	1	0	0	0

3.2. Estimation of Capture Probabilities and Tiger Population Size

Using the M_h jackknife estimator (Otis *et al.* 1978) the tiger population of the sample area was estimated as ($\hat{N}$) 10 individual with standard error of 1.42 with capture probability ($\hat{p}$) of 0.2315. At 95 percent confidence interval, this gives tiger population size of ($\hat{N}$) = 10 ± 2.78. Since tigers cannot exist in half or one third, we rounded it to nearest full digit and in this case 2.78 was rounded to 3 individual tigers. Therefore, at 95 percent confidence interval, we estimated tiger numbers to be between 10-13 individuals in our study area. Our lower limit is 10 individuals, which is also corroborated from our camera trapped photographs. During this study, overall probability of capture of tigers ($M_{(t+1)}$/N) was very high (90% in the study area, refer table 2).

TABLE 2. SUMMARY OF THE CAPTURE RESULTS

Total Number of Traps	27
Sampling occasion (5 days pooled into one occasion)	12
Sampling effort (number of traps x sampling occasions)	1620 trap-days
Camera trap Polygon (A)	74 km^2
Estimated buffer width (1/2 MMDM) $\hat{W}$	2.37 km
Effective sampled area ($\hat{A}$ ($\hat{W}$)	205 km^2
Number of capture and recapture, n	25
Number of individual tigers captured, (M+1)	9
Estimated numbers of tigers in the sample area ($\hat{N}$) using model M_h jackknife estimator	10 ±2.78
Estimated tiger density in the effective sample area ($\hat{A}$ ($\hat{W}$))	4.87(±0.52)/100 km^2
Estimated tiger density in sampled area was	12.16 (±5.07)/100 km^2

3.3. Tiger Density Estimation

The area of the camera trap polygon ($\hat{A}$) formed by connecting outermost camera trap stations measures 74 km^2. The estimated boundary strip width ($\hat{W}$) was 2.37 km; the estimated effective sampling area $\hat{A}$($\hat{W}$) 205 km^2. The tiger density was obtained by dividing the estimated population size ($\hat{N}$) by the effective sampling area ($\hat{A}$($\hat{W}$)). The estimated tiger density for lower foothills of Manas area was 4.87(±0.52) tigers/100 km^2, which is about 5(±1) tigers/100 km^2. The tiger density estimated based on area of trap polygon was 12.16 (±5.07)/100 km^2.

CHAPTER 4: SYMPATRIC CARNIVORES, PREY AND THEIR ACTIVITY PATTERNS

4.1 Relative Abundance of Sympatric Carnivores and their Prey Species

Due to logistics and security issues, we were not able to conduct transect survey to estimate the density of prey animals of tigers during our study. However, we used the camera-trapped data of prey animals to calculate relative-abundance index (refer table 3). We also present a record of the number of independent events of different species in figure 4.

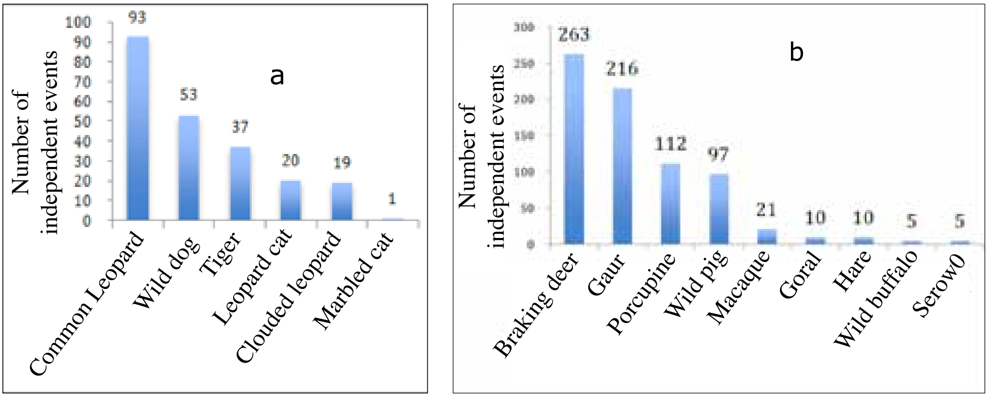


Figure 4. The relative abundance of wild animals in RMNP captured by camera traps (a) Carnivores (b) Prey species

TABLE 3. RELATIVE ABUNDANCE INDICES FOR PREY SPECIES RECORDED IN CAMERA TRAPS IN MANAS NATIONAL PARK. TOTAL EFFORT 2296 (FROM NOV. 15 2010 TO FEB. 12, 2011); RAI: 1 NUMBER OF DAYS REQUIRED TO GET SINGLE PHOTO CAPTURE, RAI: NUMBER OF PHOTOS PER 100 TRAP-DAYS.

Species	*Total Photo*	*Number Independent Event ***	*RAI_1*	*RAI_2*
Barking Deer	4484	263	8.77	11.37
Sambar Deer	4537	346	6.64	15.07
Gaur	2495	216	10.63	9.41
Wild Pig	2694	97	23.67	4.22
Common Leopard	663	93	24.67	4.05
Porcupine	667	112	20.5	4.88
Clouded Leopard	180	19	120.84	0.83
Himalayan Marten	10	4	229.6	0.44
Leopard Cat	134	20	114.8	0.87
Asiatic Golden Cat	12	5	459.2	0.22
Marble Cat	1	1	2296	0.044
Tiger	277	37	62.05	1.61
Serow	14	5	459.2	0.22
Goral	15	10	191.33	0.52
Crab-eating Mongoose	31	10	229.6	0.44
Hare	41	10	229.6	0.44
Asiatic Water Buffalo	14	5	51.022	1.96
Civet	321	45	51.022	1.96
Monkey	135	21	109.33	0.91
Wild Dog	466	53	43.32	2.31
Black Bear	18	3	765.33	0.13
Elephant	14073	3189	0.72	138.89

** Independent Event: if an animal was captured continuously without time break we considered it as a single event. For example there were 516 photos of one barking deer taken continuously in half an hour (single event).

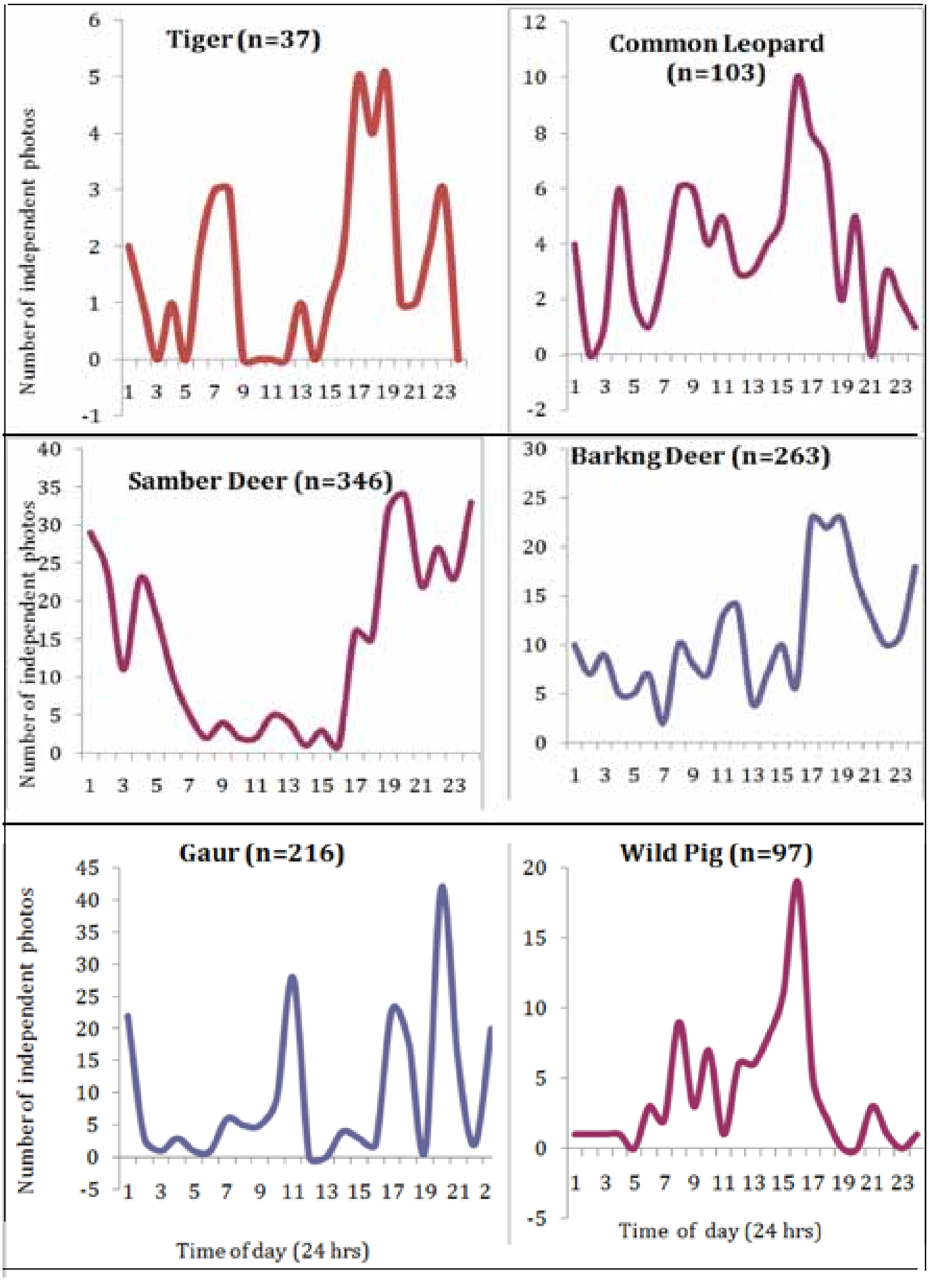


Figure 5. Activity patterns of tiger and leopard with their prey species

4.2. Activity Patterns of Important Carnivores and their Prey Species

From 2296 trap nights (from 15th November, 2010 – 12th February, 2011), we obtained a large number of independent photographs (one photo from each event) of sambar (*Cervus unicolor*), barking deer (*Muntiacus munjak*), gaur (*Bos gaurus*), and wild pig (*Sus scrofa*) all are principal prey species of tiger and leopard (Table 3). We plotted the number of independent events as surrogate of species activity against the time of the day the species was captured (Figure. 5). Pictures of different species captured are presented in Annexure II and III.

We found that tigers were active at all hours 24 hours (45% of pictures were taken between 06:00 to 17:00 hours), but activity peaked at dawn 06:00 to 08:00 and dusk 17:00 to 19:00 (51 %), indicating that tigers are crepuscular. We recorded the least number of photographs of tigers during the peak daylight hours from 09:00 to 15:00 (only 5%). Similarly, leopards were active throughout the day (64% of observation between 06:00 and 17:00) with its peak in the evening hours.

For main prey of tiger, sambar and gaur (Karanth and Nichols, 1995), our data showed that sambar were strongly nocturnal with only 15% of observations between 06:00 and 17:00. However, the peaks activity of sambar coincided with that of the tiger. Similarly, another important prey species, gaurs were nocturnal with only 29% of observations between 06:00 and 17:00. On the other hand, barking deer were active throughout the 24 hours with 43% of observations between 06:00 and 17:00, but peaked in the early hours of the night from 17: 00 to 19:00. Wild pigs were strongly diurnal with 88% of observations between 06:00 and 17:00. For all species, including predators, the peak activity was between 17:00 and 19:00 hours, except for wild pigs where they peaked between 15:00 and 17:00 hours.

We obtained enough photographs from camera stations to infer that tiger and leopard co-exist as sympatric predator sharing same space, contrary to earlier study in JSWNP (Wang and Macdonlad 2009). Perhaps this is possible because of the availability of wide range of prey species; large, medium, and small size prey species (Karanth and Nichols, 1998; Karnath and Nichols, 2002).

The large carnivores like tiger and leopard would select habitat that is most profitable in terms of energy use, where they would maximize to gain the most from the least energy they spent for searching and capturing large bodied prey with the least risk (Linkie and Ridout, 2011; Carbon *et al.* 2007). Therefore, if the preferred prey species of tiger are sambar and gaur, then it would be predicted for these three species to have strong temporal and spatial over lap. Our data (Figure.5) demonstrates that there is temporal over lap of activity patterns of tiger with gaur and sambar even though sambar tends to be strongly nocturnal. This is consistent with Karanth and Nichols (1995, 1998, 2002) that sambar and gaur are preferred prey species for tigers. Similar overlap of activity patterns was observed among leopard, barking deer, and wild pig indicating that leopard could be selecting barking deer and wild pigs as its main prey.

CAPTER 5: IMPLICATION FOR CONSERVATION IN BHUTAN AND BEYOND

Our results confirm that Manas is an extremely unique and rich landscape with seven species of wild cats and a host of different prey species. Other important carnivores like wild dog and black bear also share the same habitat with these cats.

Most importantly, our results of 10-13 individual tiger with an estimated density of 5 tigers/100 km^2 for our effective sampled area of 205 km^2 (using ½MMDM) is the highest tiger density recorded so far in the country. This gives us a density of about almost 1 tiger per 20 km^2. Similarly, during sign surveys of tiger, survey teams from RMNP recorded higher density of tiger signs in Umling range than Manas Range. Given similar habitats and rich prey base like Manas, we would expect comparable density of tigers in Umling range.

Camera trapping exercises are underway in Umling and Gomphu range. These would add up to an sampled area of 735 km$^{2.}$ Assuming that tiger density in these two ranges are comparable, we expect that these areas could be supporting about 15-20 tigers. This takes our total tiger estimate for Royal Manas National Park to 30-50 tigers. Given that Manas and Umling range are fairly pristine with minimum anthropogenic influences and ecologically productive ecosystems; we expect the tiger densities to be higher in Manas and Umling than other areas of Bhutan.

Our results are a clear indication that RMNP as a conservation landscape is critical for regional and global conservation of tigers in the wild. This region forms an indispensible corridor for the Terai-Arc Tiger Conservation Landscape between Terai regions (of Nepal and India) with landscapes in Northeastern India, Myanmar, and SE Asia.

We further suggest that studies (Waltson, *et al.* 2010) which try and prioritize landscapes for tiger conservation should include Manas as a source site for tigers and accord it the deserved priority. Such studies may have been better off had it been more inclusive by incorporating information from local biologists.

Our results show that the Manas is an extremely rich and productive ecosystem. Bhutan's stringent conservation laws and visionary leadership keeps this landscape alive. Future studies should address connectivity issues between landscapes in addition to continuation of long term monitoring of tiger populations and other associated species.

REFERENCES:

1. Ahmed, M. F., J. Borah, C. Das, A. Basumatary, R. N. Sarma, D. D. Gogoi, S. N. Buragohain, N. K. Vasu, B. K. Talukdar, Y. V. Jhala and Q. Qureshi. 2010. Monitoring tigers and Prey Animals of Kaziranga National Park, Assam, India. Technical Report, Aaranyak, TRCI:04/2010.50 pp
2. Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J. R. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnaird, 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation* 4, 75–79
3. Dinerstein, E., C. Loucks, E. Wikramanayake, J. Ginsberg, E. Sanderson, J. Seidensticker, J. Forrest, G. Bryja, A. Heydlauff, S. Klenzendorf, P. Leimgruber, J. Mills, T. G. O'brien, M. Shrestha, R. Simons, and M. Songer. 2007. The Fate of Wild Tigers. *Bioscience* 57:508-514.
4. Dorji, D. P. and C. Santiapillai. 1989. The Status, Distribution and Conservation of the Tiger Panthera-Tigris in Bhutan. Biological Conservation 48:311-319.
5. Harihar, A., B. Pandav and S. P. Goyal. 2008. Responses of tiger (*Panthera tigris*) and their prey to removal of anthropogenic influences in Rajaji National Park, India. *European Journal of Wildlife Research* 55: 97-105.
6. Jackson, R.M, J.D. Roe, R. Wangchuk, D.O.Hunter, 2006. Estimating snow leopard population abundance using photography and Capture-recapture techniques. *Wildlife Society Bulletin*; 34 (3), 772-781
7. Karanth, K. U. 1995. Estimating tiger (*Panthera tigris*) populations from camera-trap data using capture-recapture models. *Biological Conservation* 71: 333-338.
8. Karanth, K. U and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79: 2852–2862.
9. Karanth, K. U and J. D. Nichols. (Eds.). 2002. *Monitoring tigers and their prey. A manual for researchers, managers and*

conservationists in Tropical Asia. Bangalore: Centre for Wildlife Studies.

10. Karanth, K. U., R. S. Chundawat, J. D. Nichols and N. S. Kumar. 2004. Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture-recapture sampling. *Animal Conservation* 7: 285-290.
11. Karanth, K. U., J. D. Nichols, S. Kumar and J. E. Hines. 2006. Assessing tiger population dynamics using photographic capture-recapture sampling. *Ecology* 87(11): 2925-2937.
12. Linkie, M. and M.S. Ridout. 2011. Assessing tiger-prey interactions in Sumatran rainforest. *Journal of Zoology*:1-6
13. Melong, S. Jamtsho, and S. Duba. 2010. *Personal Communication*. Sangay Melong has been working in Manas as park guard for last 33 years; Jamtsho and Dorji Duba have been working as park guard for last 8 years in RMNP.
14. Mills L. Scott and M. Kelly 2011. *Personal Communication*. Scott Mills is a professor at University of Montana and Mercella Kelly is a professor at University of Verginia Tech
15. Otis, D. L., K. P. Burnham, G. C. White and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. *Wildlife Monograph* 62: 1–135.
16. Rextad, E. and K. P. Burnham. 1991. *User's guide for interactive Program CAPTURE.* Fort Collins: Colorado Cooperative Fish and Wildlife Unit.
17. Sanderson, E., J. Forrest, C. Loucks, J. Ginsberg, E. Dinerstein, J. Seidensticker, P. Leimgruber, M. Songer, A. Heydlauff, T. O'Brien, G. Bryja, S. Klenzendorf and E. Wikramanayake. 2006. *Setting Priorities for the Conservation and Recovery of Wild Tigers: 2005-2015.* The Technical Assessment. WCS, WWF, Smithsonian, and NFWF-STF, New York – Washington, D.C.
18. Schaller, G. B. 1967. *The deer and the tiger*. University of Chicago Press, U.S.A. 370 pp.
19. Sharma, R. K., Y. Jhala, Q. Qureshi, J. Vittakaven, R. Gopal and K. Nayak. 2009. Evaluating capture-recapture population and density estimation of tigers in a population with known parameters. *Animal Conservation* 2009: 1-10.
20. Sherub 2008. *Ornithological report of the Royal Manas National*

Park. Nature Conservation Division, Department of Forest, RGOB, THimphu, Bhutan.

21. Silveira, L., A.T.A. Jacomo, J. A.F.Diniz-Fillho, 203. Camera trap, line transect census and track survey: a comparative evaluation. *Biological Conservation* 114: 351-355.
22. Soisalo, K. M. and S.M.C. *Cavalcanti*, 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using camera-traps and capture-recapture sampling in combination of GPS radio-telemetry. *Biological Conservation*
23. Sunquist, M. E. 1981. Social organization of tigers *Panthera tigris* in Royal Chitwan National Park, Nepal. *Smithsonian Contribution Zoology*: 336: 1–98.
24. Walston J, Robinson JG, Bennett EL, Breitenmoser U, Fonseca GAB, et al. (2010) Bringing the Tiger Back from the Brink—The Six Percent Solution. PLoS Biol 8(9): e1000485. doi:10.1371/journal.pbio.1000485
25. Wang, S. W. and D. W. Macdonald. 2009. The Use of Camera Traps for Estimating Tiger and Leopard Populations in the High Altitude Mountains of Bhutan. *Biological Conservation* 142:606-613.
26. Wegge, P., C.P. Pokheral and S. R. Jnawali. 2004. Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. *Animal Conservation;* 7,251-256.
27. Wright, B.2010. *Will the tiger survive in India?* (Tigers of the World, ed. byTilson R, and Nyhus J., P. 2010)
28. Zhenxin, L., F. Zimmerman, M. Hebblewhite, A. Purekhovsky, Y. Kalashnikova, D. G. Miquelle, Y. Choude, and F. Morschel. 2009. *Technical report on a landscape conservation plan for the recovery of tigers in the Changbaishan ecosystem, Northeast China*. Report prepared by World Wildlife Fund, Wildlife Conservation Society, KORA, NE Normal University, and the University of Montana.

ANNEXURE 1:

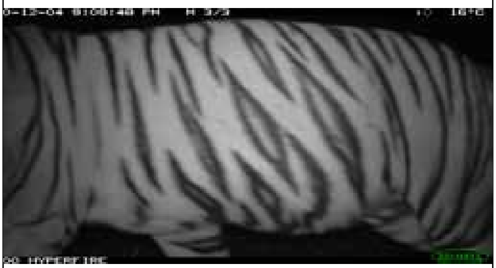
Individual Tigers Camera Trapped in the Royal Manas National Park (2010-11)

During the study 10 individual tigers were identified. All the tigers with their unique ID number and sex are presented below.

Unique code ‘MST_01_M’ read as Manas Tiger_No. 01_Male. L=left flank and R=right flank. M=Male, F= Female’

MST_01_M	R	L

MST_02_F	R	L



MST_03_F	R	L

	
MST_04_M R	L
	
MST_05_M R	L
	
MST_06_F R	L
	
MST_07_SM R	L

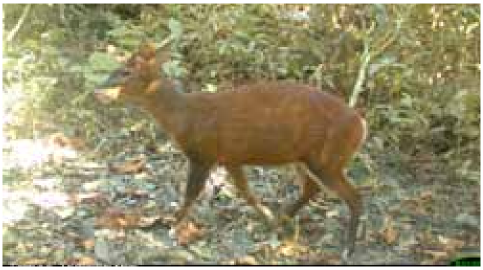
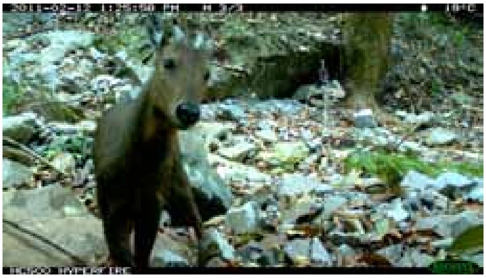
	
MST_08_SM R	L
	
MST_09_F R	L
	
MST_10_F R	

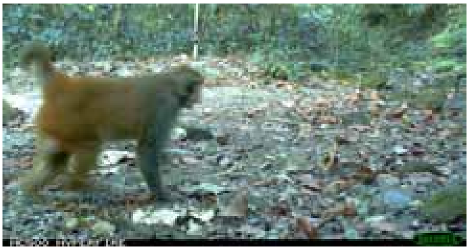
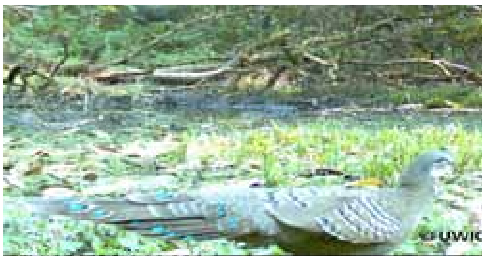
Annexure 2: Other Carnivore Species of Camera trapped in Royal Manas National Park

	
Asian golden cat *(Catopuma temminckii)*	common leopard *(Panthera pardus)*
	
clouded leopard *(Neofelis nebulosa)*	leopard cat *(Prionailurus bengalensis)*
	
wild dog *(Coun alpinus)*	crab-eating mongooses *(Herpestes urva)*

	
marbled cat *(Pardofelis marmorata)*	Himalayan black bear *(Ursus thibetanus)*
	
large Indian civets *(Viverra zibetha)*	common palm civet *(Paradoxurus hermaphroditus)*
	
yellow throated martens (*Martes flavigula*)	black panther (*Panthera pardus*)

Annexure 3: Photographs of prey and other animals camera trapped in the park

	
gaur *(Bos gaurus)*	sambar *(cervus unicolor)*
	
barking Deer *(Muntiacus muntjak)*	goral *(Naemorhedus goral)*
	
elephant *(Elephas maximus)*	serow *(Capricornis sumateriensis)*
	
Asiatic wild buffalo *(Bubalus arnee)*	Himalayan crestless porcupine *(Hystrix brachyura)*

	
rhesus macaque *(Maccaca mulatta)*	assamse macaque *(Maccaca assemensis)*
	
wild pig *(Sus scrofa)*	hodgson's flying squirrel *(Petaurista midnificus)*
	
Binturong *(Arctictis binturong)*	kalij pheasant *(Lophura leucomelans)*
	
purple heron *(Ardea purpurea)* Potentially new record for Bhutan	grey peafowl *(Polyplection bicalcaratum)*

Annexure 4: Activity Photographs of the Camera trap survey in the Royal Manas National Park.

Teams from Bhutan and Indian Manas discussing trans-boundary tiger survey.

UWICE Researcher presenting tiger survey design and sampling methods to biologist in Indian Manas.

Setting camera traps in the field.

Elephants caught on camera damaging camera traps


This report is part of a long term "predator-prey dynamics study" initiated by UWICE from 2010 in Royal Manas National Park. This report provides a snapshot of tiger numbers in the lower foothills of Manas.

Lamai Gompa Dzong
Bumthang

+975-3-631926 (PABX)
+975-3-631925 (Fax)

Supported by Bhutan Foundation

www.uwice.gov.bt