MAMMALS OF THE KHANGCHENDZONGA BIOSPHERE RESERVE, SIKKIM, INDIA

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ABSTRACT

We assessed distribution and abundance of mammals in Khangchendzonga Biosphere Reserve (BR), Sikkim, India, from April 2008 to May 2010, using field methods and remote cameras under varying rain and snow conditions, and interviews with local people. We report the occurrence of 42 mammals including 18 that have global conservation significance. Three leopards (*Panthera uncia*, *P. pardus*, *Neofelis nebulosa*), Tibetan wolf (*Canis lupus chanko*), wild dog (*Cuon alpinus*), red panda (*Ailurus fulgens*), Asiatic black bear (*Ursus thibetanus*), and two species of musk deer (*Moschus chrysogaster*, *M. fuscus*) were recorded. Species number decreased with increasing elevation, 22 were recorded in temperate habitats, 18 in subalpine, and 11 in alpine habitats of Khangchendzonga BR. The yellow-throated marten (*Martes flavigula*) and black bear were found to have the most diverse distribution extending from temperate to alpine. Red fox (*Vulpus vulpus*) was the most abundant carnivore (8.98 ± 2.31 photo capture/100 days) while goral (*Naemorhedus goral*) was the most abundant prey (9.14 ± 5.27). Camera trap detected most of the mammals in the area (35/39). Considering the benefits of camera traps and limitations of the study area, we recommend use of camera traps involving wildlife staff, along with sign surveys and interviews with local villagers for monitoring mammals in Khangchendzonga BR for effective management and conservation.

KEYWORDS: *Abundance, distribution, Khangchendzonga Biosphere Reserve, mammals, remote camera trapping*

The beautiful Blue sheep forms an important prey for the Snow Leopard and is fairly common in the alpine habitats of Khangchendzonga National Park

Red Panda (*Ailurus fulgens*) - State animal of Sikkim and a unique and endangered carnivore that has adapted to the herbivore mode of life and a resident of the Eastern Himalayas

INTRODUCTION

The mountainous state of Sikkim (7,096 km²) in the Eastern Himalayan region lying wedged in between the Himalayan nations of Nepal in the west and Bhutan in the east, is bounded by Darjeeling District of West Bengal in the south and a stretch of Tibetan Plateau in the north. This area is positioned at the convergence of three biogeographic realms, *viz.*, Palaearctic, Africo-tropical and Indo-Malayan (Mani 1974) and hence providing a variety of habitats for many primitive as well as newly evolved species resulting in high biodiversity in the region. This area is recognized as the global biodiversity hotspots (Myers et al. 2000; Mittermeier et al. 2004) and also one among the important Global 200 Ecoregions (Olson and Dinerstein 1998). Declared as an 'Important Bird Areas' (Islam and Rahmani 2004), it harbours two Endemic Bird Areas (Stattersfield et al. 1998) and several centers for plant diversity (WWF/IUCN 1995).

The Khangchendzonga Biosphere Reserve (BR) in Sikkim being the country's highest and world's third highest protected area is an important high altitude wildlife landscape covering about 36.92% of the state's biogeographic area. It is one of the most significant biodiversity hotspots of India with varying eco-zones from temperate to arctic (1,220-8,586 m), and a repository of many rare and endangered flora and fauna primarily due to its location and remarkable variations in altitude and rainfall. In spite of such rich biodiversity, there has been no scientific survey or study on the assessment of mammalian diversity with the exception of Biswas and Ghose (1982) who mentioned presence of some lesser cats in the region.

Effective conservation and management of biodiversity along with the maintenance of human use below the sustainable level is the major aim of BR management. For achieving this goal, prior knowledge of species diversity, distribution and abundance is essential, so as to detect significant changes for appropriate management interventions. Efficient and reliable methods for rapid assessment of species richness and abundance are crucial to determine conservation priorities (Silveira et al. 2003). With this background, a study for the establishment of baseline information on the mammalian assemblage of Khangchendzonga BR was initiated with the aid of modern noninvasive technique of remote camera trapping. Use of remote-triggered, infrared sensor camera units offers one of the best current techniques to reduce sampling discrepancies between habitats and observers (Swann et al. 2004). Despite of the merits of this method, some landscapes can be so remote, steep or so densely vegetated that the conventional sampling designs may be challenged.

This study was primarily aimed to fill the above mentioned research gap and to prepare an inventory for mammals of Khangchendzonga BR. In this chapter, we report the results of first such study on mammals conducted in the Sikkim Himalaya. We describe the distribution, conservation status and relative abundances of the mammals found in Khangchendzonga BR.

MATERIALS AND METHODS

The study area

The Khangchendzonga BR encompasses an area of 2,619.92 km² including the Khangchendzonga National Park (NP) (1,784 km²) and a buffer zone of about 836 km² (Tambe 2007). Located between 27° 30'-27° 55' N and 88° 02'-88° 37' E it is connected to the adjacent Khangchendzonga Conservation Area in eastern Nepal, Barsey and Maenam Wildlife Sanctuaries in Sikkim and Singalila BR in Darjeeling district of West Bengal, through a number of corridors (Tambe 2007). The area is classified as a biogeographic province 2C - Central Himalaya with the northern part included in biogeographic province 1B - Trans-Himalaya Tibetan Plateau (Rodgers *et al.* 2000). The varying elevation of 1,220 to 8,586 m within an aerial distance of just 42 km with about 90% area above 3000 m and 70% above 4000 m makes this park a unique natural heritage hotspot in the world.

The area of Khangchendzonga BR has been divided into seven watersheds or river subsystems (Fig 1) namely Lhonak (15%), Zemu (23%), Lachen (5%), Rangyong (36%), Rangit (6%), Prek (8%) and Churong (7%). In this study, Prek *chu* (27°21' - 27° 37'N, 88° 12' -88° 17'E) (*chu = river*) catchment area (182 km²) was selected as the intensive study area (Fig 2) because it represents all the habitat characteristics of Khangchendzonga BR (Sathyakumar et al. 2009), although surveys were also conducted in Lhonak, Zemu, Lachen and Churong watersheds. Its highest and lowest elevation being 6,691 m (summit of Pandim) and 1,200 m (Tambe 2007), the Prek *chu* watershed can be divided into six habitat classes, *viz*., mixed sub-tropical (1%), mixed temperate (16%), sub-alpine (36%), alpine pastures (5%), rock and snow cover (41%) and water bodies (1%). The *watershed has a typical oceanic climate with an average annual rainfall of around 2,230 mm (Tambe 2007).*

The study was conducted for a period of two years from April, 2008 to May, 2010. Due to the topography and remoteness of the area all field activities were carried out in the form of field expeditions i.e., camping in different areas of the Prek *chu* water shed. One field survey was usually of 7-8 days and all the sampling units were replicated and monitored after every 7-10 days.

Reconnaissance surveys

In order to get a fair knowledge of the area exploration surveys were carried out in the early months of the study period in the five watersheds (Churong, Lachen, Zema, Lhonak and Prek) of the Khangchendzonga BR. This was followed by application of some conventional sampling methods for the assessment of mammalian fauna (distribution and relative abundance) depending on the feasibility of the terrain.

Trail sampling, scanning and sign surveys

Trail sampling was used for detection of mammals in different habitats of the study area. These trails were identified with slight modification from conventional transects (Burnham et al. 1981) for Himalayan terrain (Sathyakumar 1994). Scan sampling, ridge walking and sign surveys along trails, ridges and *nullahs* (streams) (Bennett et al. 1940) were also carried out. Trail sampling (n= 22; 1.5 to 7 km) within the intensive study area (Fig 3) was repeated (223 walks), and sign surveys were carried out once in a month for the intensive study area (25 surveys). Trail sampling and sign surveys were carried out once in each of the other four watersheds.

Camera Trapping

Based on the knowledge acquired through reconnaissance surveys, as mentioned earlier Prek chu watershed was selected as the intensive study area for camera traps studies. For simplicity, the area was categorized into three different habitat zones, viz., temperate (1,200-3,000 m), sub-alpine (3,000-4,000 m) and alpine (above 4,000 m) and the camera traps were deployed corresponding to the area coverage of the zones and their accessibility. The study area was further divided into 2 km × 2 km sampling grids and cameras traps were placed along trails or paths that were actively used by study further divided into 2 km × 2 km sampling grids and cameras traps were placed along trails or paths that were actively used by study species evident from their signs such as, tracks, feeding signs, marking signs (spray, scrape), pug/hoof marks, digging signs, scats/feaces and other signs (Ahlborn and Jackson 1988), with at least one camera trapping unit covering each of the grids. Twenty seven cameras were deployed at 71 sites in 24 cells covering an area of 96 km^2 of accessible area in the study area (Fig 3). The camera trapping was done continuously in all the seasons using Deercam (2), Wildview (2), Stealthcam (18) and Moultrie (5) instruments. Head-on, oblique and side-view camera configurations were used to obtain photographs at varying body orientations (Blomqvist and Nystrom 1980; Jackson et al. 2006). Since the study species were rare and the area being vast, the strategy was to survey more sampling units less intensively rather than less sampling units more intensively (Mackenzie and Royle 2005), for rapid assessment of mammalian assemblage. Monitoring of camera traps was done at least twice a month which included changing the batteries and memory card. Monitoring of cameras deployed in temperate zone were carried out from the base camp located at Yuksam (1,900 m), while for those deployed in subalpine were done from first (Tsoka, 3,000 m) and second (Dzongri, 3,950 m) advance camps and for cameras in alpine zone from third (Thansing, 4080 m) and fourth (Lampokhri,

4,200 m) advance camps, respectively The number of camera trap-days was calculated from the date of deployment till the date of retrieval (if the memory card was not full) or till the date of the final photo.

One major problem faced during this study was the lack of adequate data from direct evidences (visual encounters and camera trapping) for abundance estimation in order to overcome this problem the method of photographic rate was used. Photographic rate is defined as the number of camera days (24 h) per study species (= 1 year old) photograph summed across all camera traps in the study (Carbone *et al.* 2001). Photo capture rate was calculated as the number of photographs of a species divided by the number of trap-days per site. Trap-days were computed as the number of 24-h periods from deployment of camera until the film was used up or the camera was retrieved. Instances where the same species were captured by the same camera more than once within 1 h were excluded from trap rate calculation (Bowkett et al. 2007). This was a compromise between scoring the same individual multiple times and missing individuals (Rovero et al. 2005) and is more conservative than other published studies (e.g. Kinnaird et al. 2003).

Based on photo capture rates, an index of relative abundance (RAI) as the number of days required for obtaining a photo capture of a species (Carbone et al. 2001) was calculated. Only independent pictures of a particular species were counted as valid to estimate RAI. Independence was defined following O'Brien *et al.* (2003) as each photo identified to species and rated as a dependent or independent event. An 'independent capture event' (Datta *et al.* 2008) was defined as (1) consecutive photographs of different individuals of the same or different species, (2) consecutive photographs of individuals of the same species taken more than 1 hr apart and (3) non-consecutive photos of individuals of the same species.

Total camera trap days in the study period were 6,278 with 1,407 in temperate zone (26 sites), 3,061 in sub-alpine zone (20 sites) and 1,810 in alpine zone (25 sites), respectively.

Local interviews

In order to assess the awareness of local people regarding the mammal diversity of the area and to verify it with camera trapping results (Can and Togan 2009), interviews and informal discussions (Mishra et al. 2006) were conducted in 15 villages viz., eight in Prek and Churong, six in Zema and Lachen and one in Lhonak watersheds. In Prek and Churong we sampled six villages at the border of the catchment and one each at the core and buffer zones. In the greater Himalayan zone of the northern part of Khangchendzonga BR i.e. Zema and Lachen, surveys were conducted in six bordering villages of the watersheds. In northern part (Lhonak), surveys were conducted in one village adjacent to the trans-Himalayan zone during which Dokpa Yak herders and Indo-Tibet Border Police personnel were also interviewed. In total, interviews and informal discussions were conducted with the heads of 72 households which included farmers, livestock herders, former hunters and trekking guides. The respondents were shown photographs and drawings of the mammal species provided in field guides (Prater 1971; Menon 2003) and their knowledge on species occurrence and natural history was recorded.

RESULTS

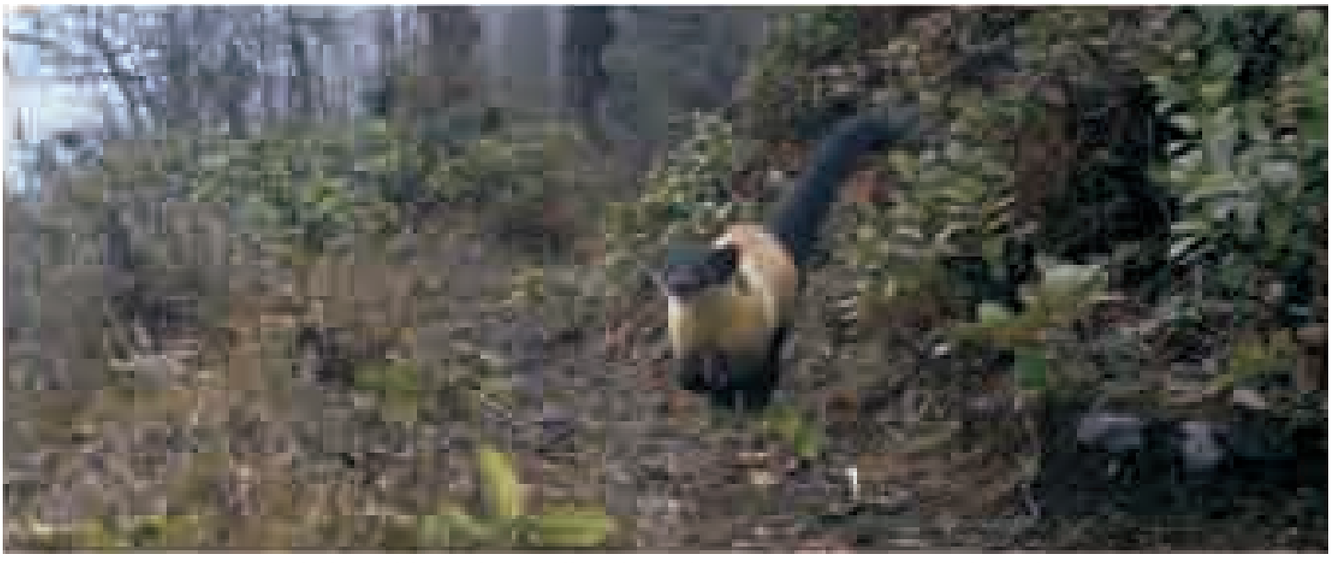
Mammal assemblage

We record the occurrence of 42 species (19 carnivores, 8 Ungulates, 2 Primates, 7 Rodents, 4 Lagomorphs, 1 Insectivore and 1 Chiropteran) of mammals belonging to 7 orders and 16 families in the Khangchendzonga BR out of which we confirm the presence of 40 species through visual encounters, photo-captures, signs and trails, and the rest two based on the information from the locals (Appendix 1). Out of the 42 species recorded, 18 are of high global conservation significance, categorized as critically endangered (1), endangered (4), vulnerable (4) and near threatened (9) on the IUCN Red List (IUCN, 2010). A total of 21 species recorded are characteristically high altitude fauna, although some of them occur over a wide altitudinal range (Table 1). Almost all the species of mammals (39) were recorded to occur in the Prek *chu* catchment except typical trans-Himalayan species- Tibetan wolf (*Canis lupus chanko*), Himalayan marmot (*Marmota himalayana*) and Plateau pika (*Ochotona curzoniae*). Photographic records of snow leopard *Panthera uncia*, wild dog *Cuon alpinus*, clouded leopard *Neofelis nebulosa*, golden cat *Pardofelis temminckii* and black musk deer

Moschus fuscus are the first of their kind in Sikkim (Plate 1 and Plate 2). Among them, presence of three cryptic species: golden cat, large Indian civet and black musk deer were reported from Khangchendzonga BR for the first time. Very interestingly, all the captured photographs of golden cats were of melanistic form which was reported as occasional. Villagers of Churong and Prek *chu* catchments reported presence of common leopard in Khangchendzonga BR as they mentioned about three livestock depredation incidents by common leopard in recent past. Binturong (*Arctictis binturong*) was reported from Prek chu catchment; many eco-tourist guides and local villagers confirmed its presence in the area as they readily identified the photograph of the species as Ruk-Bhalu (local, meaning tree-bear) in Nepali. Some aged livestock herders of Yuksam reported sighting of Chinese pangolin in lower moist temperate forests 20 years ago, but no recent sighting was reported, neither was it detected by any methods. Aged livestock herders and tourist guides of Prek *chu* area reported the presence of Himalayan tahr (*Hemitragus jemlahicus*) in adjacent Rangit catchment. But camera trap photo confirmed its presence in Prek chu catchment also.

In Lhonak catchment (trans-Himalayan zone), Dokpa Yak herders confirmed frequent sightings of Tibetan wolf as well as snow leopard while Indo-Tibet Border Police (ITBP) personnel confirmed presence of blue sheep (*Pseudois nayaur*) in large groups. Signs of Himalayan wolf, snow leopard, blue sheep and sighting of Himalayan marmot were obtained during trail sampling and sign survey.

The shy and secretive Black Musk deer is a small solitary forest ruminant that inhabits the subalpine and alpine scrub habitats of Khangchendzonga National Park and is well known for its musk due to which it is highly threatened.

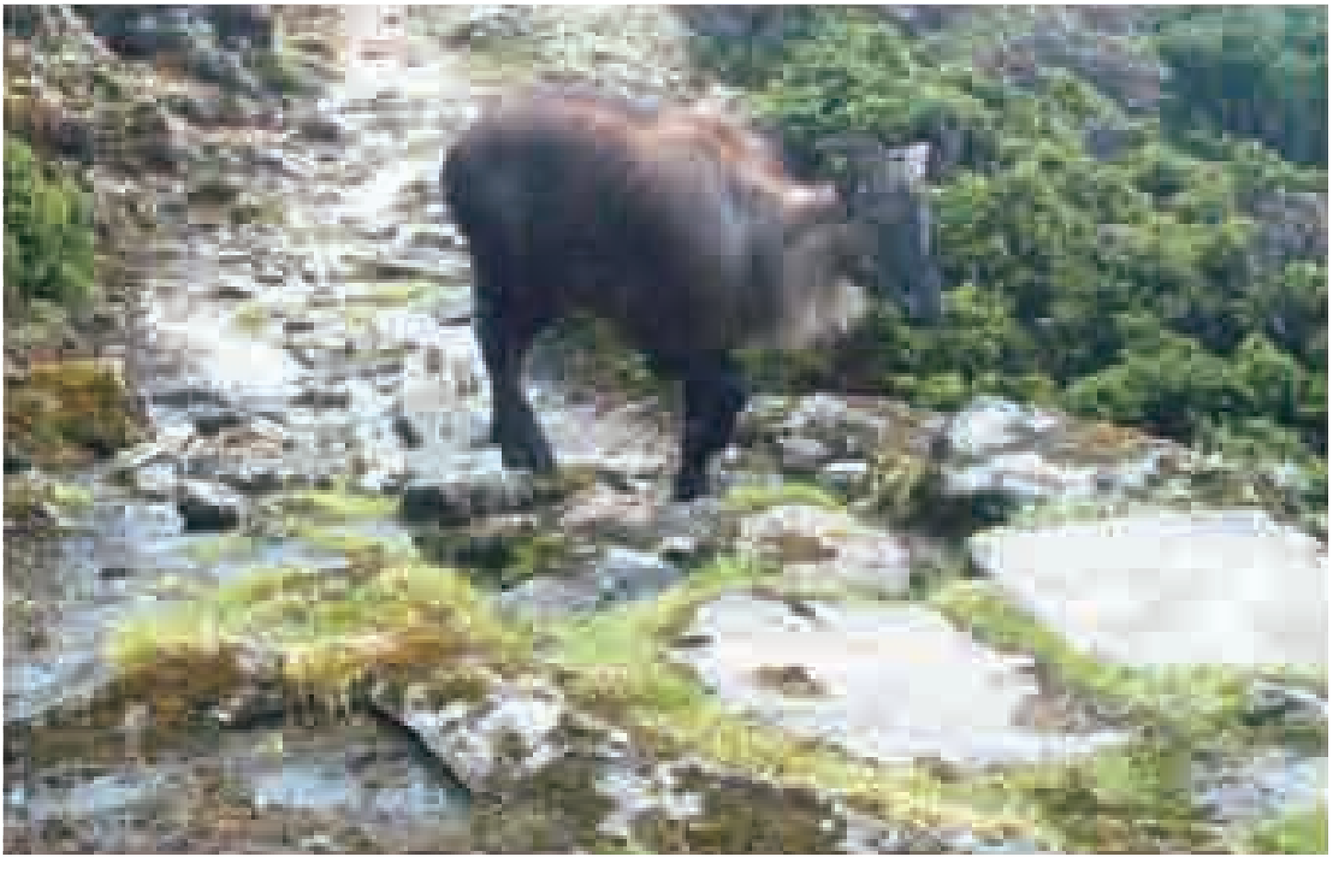


The beautiful Himalayan Yellow-throated Marten is an important predator of Khangchendzonga National Park.

The beautiful Golden Cat is one of the largest of Lesser cats of India. The picture is of the melanistic form of Golden Cat – a rare variety.

The Stone Marten is a little known small carnivore of Khangchendzonga National Park

The Serow is a relatively common mountain ungulate of the temperate habitats of Khangchendzonga National Park but generally shy and nocturnal



The majestic Himalayan tahr inhabits cliffs, steep and rugged slopes of Khangchendzonga National Park which is one of the eastern most populations of this species in the Himalaya

The gorgeous Red fox is the most common predator in the high altitudes of Khangchendzonga National Park

Goral – a common mountain ungulate of the temperate habitats of the Himalaya

The Pale Weasel is a little known small carnivore of Khangchendzonga National Park

Barking deer – the most common and well known ungulate of the lower temperate habitats of the Himalaya

The large Indian Civet is a little known Viverid due to its nocturnal and secretive behaviour

The Himalayan Crestless Porcupine is an interesting nocturnal species of the Himalaya.

The shaggy Asiatic Black Bear plays an important ecological role as seed dispersers as well as seed destroyers. Occasional conflicts with local communities due to crop raiding in villages.

The Hoary-bellied Squirrel is a little known small mammal of Khangchendzonga National Park

The beautiful Clouded Leopard is the largest of all the Lesser Cats and is rare in Khangchendzonga National Park

The adorable Red Panda is a rare mammal of Khangchendzonga National Park

The Flying Squirrel is a little known small mammal of Khangchendzonga National Park

The Jungle cat is a common lesser cat of Khangchendzonga National Park

The magnificent Snow Leopard is the most important top carnivore of Khangchendzonga National Park

The energetic Pika is a common small mammal of Khangchendzonga National Park

The wandering Wild dogs are rare in Khangchendzonga National Park

The Himalayan musk deer is a small solitary forest ruminant that inhabits the subalpine and alpine scrub habitats of Khangchendzonga National Park and is well known for its musk due to which it is highly threatened

Himalayan Palm Civet - another small carnivore found commonly in the cardamom gardens of the lower temperate forests

The stunning Leopard Cat is an important Lesser Cat of Khangchendzonga National Park

Distribution and abundance

Numbers of detected mammal species decreased with increasing elevation, 21 species were recorded in temperate habitats followed by 18 in subalpine and 11 in alpine habitats of Khangchendzonga BR. Snow leopard and blue sheep occurred in all the surveyed catchments inhabiting the alpine habitat above 4,000 m elevation, while the distribution of other species varied both across catchments and altitudes (Appendix 1). In this study, we document (photo captures) new altitudinal limits of distribution for certain species which were not known earlier, *viz.*, clouded leopard (3,720m), golden cat (3,960m), jungle cat *Felis chaus* (4,010m), Asiatic black bear *Ursus thibetanus* (4,120m), wild dog (4,010m), yellow-throated marten *Martes flavigula* (4,010m) and wild pig *Sus scrofa* (4,010m). Interestingly, the yellow-throated marten and Asiatic black bear were found to have the most diverse altitudinal range extending from temperate to alpine habitats, evident from their photo-captures at 4,010 m and 4,120 m, respectively although their main habitats of occurrence were temperate and sub-alpine. Clouded leopard (*Neofelis nebulosa*), red panda (*Ailurus fulgens*) and stone marten (*Martes foina*) were recorded to inhabit the subalpine forests up to 4,000 m elevation, while leopard cat (*Prionailurus bengalensis*), jackal (*Canis aureus*) and all the viverid species were found to occupy the temperate zone.

Relative abundance indexes (photo capture/100 cam days) showed red fox (*Vulpes vulpes*) to be the most abundant carnivore in the alpine zone (8.98 ± 2.31) and yellow-throated marten in both subalpine (1.58 ± 0.48) and temperate (6.85 ± 3.32) zones. Among the five species of felids, leopard cat was the most abundant (2.16 ± 0.72) and clouded leopard the rarest (0.03 ± 0.03) species. Among the prey species, blue sheep *Pseudois nayaur* (2.73 ± 1.90) was the most abundant ungulate in the alpine zone while serow *Naemorhedus sumatraensis* (1.01 ± 0.65) and goral *Naemorhedus goral* (9.14 ± 5.27) in the sub-alpine and temperate zones, respectively. In case of small mammals including rodents and lagomorphs, Sikkim rat *Rattus sikkimensis* (7.63 ± 3.57) and large-eared pika *Ochotona macrotis* (5.92 ± 2.76) were the most abundant. The camera trapping effort was not biased towards any weight class ($R^2 = 0.016$) and recorded most of the species irrespective of their body sizes (Fig 4).

DISCUSSION

Mammal assemblage

The minimum knowledge needed for effective management of mammals within protected areas includes knowing what species are present, their distribution within the area, and their relative abundance across different habitat types (Sheng et al. 2010). Presence of 18 globally threatened mammals depicts the priority of proper management interventions to protect their habitats in Khangchendzonga BR. This mammal assemblage is comparable with mammal diversity of some other eastern and central Himalayan landscapes such as the proposed high altitude National Park, Arunachal Pradesh (35 mammals, Mishra et al. 2009) and Langtang National Park, Nepal (32 mammals, Fox et al. 1996). Confluence of Palearctic and Indomalayan (Oriental) biogeographical realm and occurrences of diverse habitat types along the elevation gradient within small area coverage may be the reasons for high mammal diversity of the study area. Good contiguous cover, luxuriant vegetation growth due to heavy rainfall and inaccessibility (of human) to the inner parts of different valleys may provide adequate shelter and food to different mammals and thus help to create a diverse mammal assemblage in Khangchendzonga BR.

Distribution and abundance

Gradual increase in altitude results change in habitat conditions which affect the mammal distribution in Khangchendzonga BR. Low temperature, harsh climatic conditions and fewer resources restricted mammal assemblage to 11 species in alpine zone of the study area. Moist and relatively warm habitats harbored more mammal species in subalpine (18 species) and temperate zone (22 species) of Khangchendzonga BR. Use of intensive camera trapping in Prek *chu* may be the reason behind the good number of detections (39 mammals) whereas in some cases proper identification of different mammal species was not possible in other valleys which may have the potential to be as diverse as this area in terms of mammal assemblage.

Photo capture rates of different mammals in Prek *chu* catchment area indicate an altitudinal (thus forest type specific) pattern of mammal distribution. Comparison between photo capture rates in different habitats showed red fox

and snow leopard as the main predator of alpine zone and blue sheep as the main prey base there. Himalayan musk deer (*Moschus chrysogaster*), Pale weasel (*Mustela altaica*) and Siberian weasel (*Mustela sibirica*) were rarely detected in the alpine zone indicating their low abundance. According to the relative abundance index: yellow-throated marten, stone marten and golden cat were the major predators of subalpine zone, and yellow-throated marten, and leopard cat were the major predators of temperate zone. Similarly relative abundances of ungulate prey depicts serow as the major prey in subalpine and goral (and barking deer *Muntiacus muntjak*) in the temperate zone of the study area, respectively. In subalpine zone, clouded leopard and red panda (both semi-terrestrial in nature) were present and detected by the cameras very rarely. Chance of detection of these two mammals by the present sampling design (where cameras were deployed on ground level to detect other terrestrial mammals) was low, thus very low photo capture rate of these two species may not reflect their real status in the study area. Among other threatened mammals, infrequent detections and very low relative abundance of wild dog indicate towards their non-resident nature (local movements in between adjacent watersheds) about which local people had mentioned during interviews. Presence of Himalayan tahr was already reported from Rangit catchment area, sexual segregation during monsoon may have resulted in the photo capture of males in Prek *chu* during monsoon only. Asiatic Black bear was non-detectable in winter as they may have gone for hibernation, but overall low relative abundance (in comparison with yellow throated marten or red fox) in all the habitat types of the intensive study area may reflect the rarity of the species in Prek *chu* catchment area. However, local perception as reflected in the interviews indicates high abundance of the species in the area which may be due to crop raiding by bears. An interesting finding of this explorative study on mammal assemblage may be the non-detection of large carnivore (apart from seasonal presence of Asiatic black bear in low abundance) in the subalpine and temperate forests. Prey species diversity (Primates-2, Ungulates-4, Rodents-3) and relative abundance (Appendix 1) in the temperate zone may be adequate to harbour large carnivores such as common leopard (*Panthera pardus*), which is a common feature of the mammalian fauna of the same altitude zones at different Protected Areas throughout the Himalaya (Prater 1971; Aryal et al. 2009). Report of very infrequent presence of common leopard in the low altitude zones (1,200-1,850m) of different valleys of Khangchendzonga BR and only three livestock killing incidents at the lowermost part (1,830m) of the intensive study area in three years may indicate the very poor status of the predator in the study area possibility due to retaliatory killings in the recent past. This needs further verification and appropriate interventions by the management and local communities. It is important for the management to create awareness amongst the local communities with the help of NGOs on the importance of the presence of the common leopard in lower temperate forests as they help in controlling the populations of prey such as the wild pig which cause crop loss/damage. Livestock insurance schemes at the community level facilitated by the Department could be a viable option.

In the recent past, the Department and local communities have jointly demonstrated the success of the management interventions such as removing yak herders from the Khangchendzonga National Park (Tambe 2007). Such interventions have resulted in positive changes in the wildlife habitats and also in high encounters of blue sheep in the alpine areas of Dzongri that were earlier highly used by yak herders. Such initiatives have to be maintained in order to ensure long term conservation goals of the people of Sikkim.

Following the example of newly initiated mammals and birds monitoring protocol programme using camera traps in Chinese nature reserves (Sheng et al. 2010), we also suggest camera trapping for other watersheds of Khangchendzonga BR with active involvement of forest staff and local people. But prior to that, intensive training of field staffs on working principle, survey design and handling of camera-traps and village level awareness meets for local people will be of great help to popularize this technique. Thus, well-designed monitoring programmes using camera traps supplemented by local knowledge can provide robust data to wildlife managers to monitor the long-term population or biodiversity trends (Pereira and Cooper 2006; Marsh and Trenham 2008). We believe a higher initial outlay of funds and training for a camera trap based monitoring system will provide the framework needed for conservation programmes in Khangchendzonga BR to move forward.

Acknowledgements

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Table 1. Mammals confirmed or reported in the Khangchendzonga Biosphere Reserve, Sikkim, with their IUCN Red List status, the type of evidence, their occurrence in the five watersheds, photographic rates, main habitats occupied and the altitudinal range in the study area. Species names prefixed with asterisks indicate high altitude mountain fauna

Species	Red List status [1]	Presence [2]	Evidence [3]	Occurrence in five watersheds [4]					Photo-capture rate (photo/100 cam days) [5]			Photo-rate (days/capture)	Main habitat occupied [5]			Altitudinal range (m)
				P	L	Z	C	La	T	S	A		T	S	A	
Carnivores																
*Snow leopard *Panthera uncia*	EN	Conf.	PC, SC, TR, LI	+	+	+	+	+			0.257 ± 0.16	150.8			+	> 4000
Clouded leopard *Neofelis nebulosa*	VU	Conf.	PC, LI	+						0.03 ± 0.03		3061		+		2500-3800
Common leopard *Panthera pardus*	NT	Rep.	SC, K, LI	+			+	+					+			< 2000
Golden cat *Pardofelis temminckii*	NT	Conf.	PC	+					0.236 ± 0.19	0.618 ± 0.18		212.7	+	+		2100-3950
Jungle cat *Felis chaus*	LC	Conf.	S, PC, LI	+			+	+	0.136 ± 0.09	0.109 ± 0.06		744.7	+	+		1750-3950
Leopard cat *Prionailurus bengalensis*	LC	Conf.	PC, LI	+			+	+	2.157 ± 0.72			37.02	+			1750-2750
*Asiatic black bear *Ursus thibetanus*	VU	Conf.	PC, SC, LI	+			+	+	0.546 ± 0.23	0.190 ± 0.08	0.05 ± 0.05	279.2	+	+		2000-4250
*Red panda *Ailurus fulgens*	VU	Conf.	PC, LI	+			+	+		0.071 ± 0.05		1020.3		+		2500-3800
Wild dog *Cuon alpinus*	EN	Conf.	PC, LI	+						0.182 ± 0.07	0.08 ± 0.08	541.2		+		3100-4200
*Himalayan wolf *Canis himalayensis*	CR	Conf.	TR, K, SC, LI		+										+	> 4000
*Red fox *Vulpes vulpes*	LC	Conf.	PC, SC, LI	+			+	+		0.525 ± 0.36	8.98 ± 2.31	14.2			+	3750-4500
Jackal *Canis aureus*	LC	Conf.	S, PC, LI	+		+	+	+	0.08 ± 0.08			1407	+			< 2500
*Himalayan palm civet *Paguma larvata*	LC	Conf.	PC, LI	+			+		1.90 ± 0.78			46.9	+			1750-2700
Large Indian civet *Viverra zibetha*	NT	Conf.	PC	+					1.47 ± 0.66			67	+			1750-2700
*Yellow throated marten *Martes flavigula*	LC	Conf.	S, PC, LI	+		+	+	+	6.85 ± 3.32	1.58 ± 0.48	0.114 ± 0.09	30.7	+	+		1750-4200
*Stone marten *Martes foina*	LC	Conf.	PC, LI	+			+			0.623 ± 0.27		117.7		+		3200-3950
Binturong *Arctictis binturong*	VU	Rep.	SC, LI	+			+						+			2000-3000
Siberian weasel *Mustela sibirica*	LC	Conf.	S, PC	+						0.043 ± 0.03		1530.5		+		3000-4000

*Pale weasel *Mustela altaica*	NT	Conf.	S, PC	+							0.05 ± 0.05	905			+	> 4000
Ungulates																
*Blue sheep *Pseudois nayaur*	LC	Conf.	S, PC, LI	+	+	+	+	+			2.73 ± 1.90	21.04			+	> 4000
*Himalayan musk deer *Moschus chrysogaster*	EN	Conf.	S, PC, LI	+		+	+								+	3700-4500
* Black musk deer *Moschus fuscus*	EN	Conf.	PC	+						0.085 ± 0.06	0.13 ± 0.106	974.2		+		3500-4000
*Himalayan tahr *Hemitragus jemlahicus*	NT	Conf.	PC, LI	+						0.13 ± 0.07	0.05 ± 0.05	811.8		+	+	3700-4200
*Mainland serow *Naemorhedus sumatraensis*	NT	Conf.	S, PC, LI	+		+	+	+	1.064 ± 0.75	1.01 ± 0.65		65.7	+	+		2100-3800
*Goral *Naemorhedus goral*	NT	Conf.	S, PC	+		+	+		9.14 ± 5.27	0.97 ± 0.65		21.3	+	+		2000-3800
Barking deer *Muntiacus muntjak*	LC	Conf.	S, PC, LI	+		+	+	+	5.88 ± 2.67			19.5	+			2000-2600
Wild pig *Sus scrofa*	LC	Conf.	S, PC, LI	+				+	0.672 ± 0.29		0.03 ± 0.03	140.7	+			2000-4200
Primates																
Assamese macaque *Macaca assamensis*	NT	Conf.	S, PC	+		+	+	+	2.56 ± 1.07			42.6	+			2000-2700
*Central Himalayan langur *Semnopithecus schistaceus*	NT	Conf.	S, PC	+		+	+	+	1.40 ± 1.34			82.8	+			2000-2700
Rodents																
*Orange-bellied Himalayan squirrel *Dremomys lokriah*	LC	Conf.	S, PC	+		+	+	+	0.084 ± 0.06			703.5		+		2100-2850
Hoary-bellied Himalayan squirrel *Callosciurus pygerythrus*	LC	Conf.	PC	+			+		3.04 ± 2.43			25.1	+			1750-2300
Parti-colored flying squirrel *Hylopetes alboniger*	LC	Conf.	PC, LI	+						0.07 ± 0.047		1020.3		+	+	2000-3800
Five-striped palm squirrel *Funambulus pennantii*	LC	Conf.	S	+									+			
*Himalayan marmot *Marmota himalayana*	LC	Conf.	S		+										+	> 4000
Himalayan crestless porcupine *Hystrix brachyura*	LC	Conf.	S, PC, LI	+		+	+	+	2.245 ± 0.83			35.2	+			2000-2600

*Sikkim rat *Rattus sikkimensis*	LC	Conf.	S, PC	+		+	+	+	7.63 ± 3.57	0.63 ± 0.50		28.8		+		2000-3750
Lagomorphs																
*Large-eared pika *Ochotona macrotis*	LC	Conf.	S, PC	+							5.92 ± 2.76	22.9			+	> 4000
*Moupin's pika *Ochotona thibetana*	LC	Conf.	PC	+						0.10 ± 0.10		612.2		+		3000-4000
Forrest's pika *Ochotona forresti*	LC	Conf.	S, SP	+									+			?
Plateau pika *Ochotona curzoniae*	LC	Conf.	S		+										+	4500-5500
Insectivores																
Sherw		Conf.	SP	+									+			?
Chiroptera																
Pearson's Horseshoe Bat *Rhinolophus pearsonii*	LC	Conf.	S	+									+			<1850

[1]EN, Endangered; VU, Vulnerable; LR: Lower Risk: Nt: near threatened; DD: Data Deficient

[2]Conf., confirmed; Rep., reported

[3]S: Sighting, SP: Specimen, PC: Photo capture, SC: Scat/Dung, TR: Track, K: Kill, LI: Local information

[4]P=Prek, L=Lhonak, Z=Zema, C=Churong, La=Lachen

[5]T=Temperate; S=sub-alpine; A=Alpine

Figure 1 Location of Khangchendzonga Biosphere Reserve in Sikkim, India showing the different watersheds including Prek Chu catchment the intensive Study Area

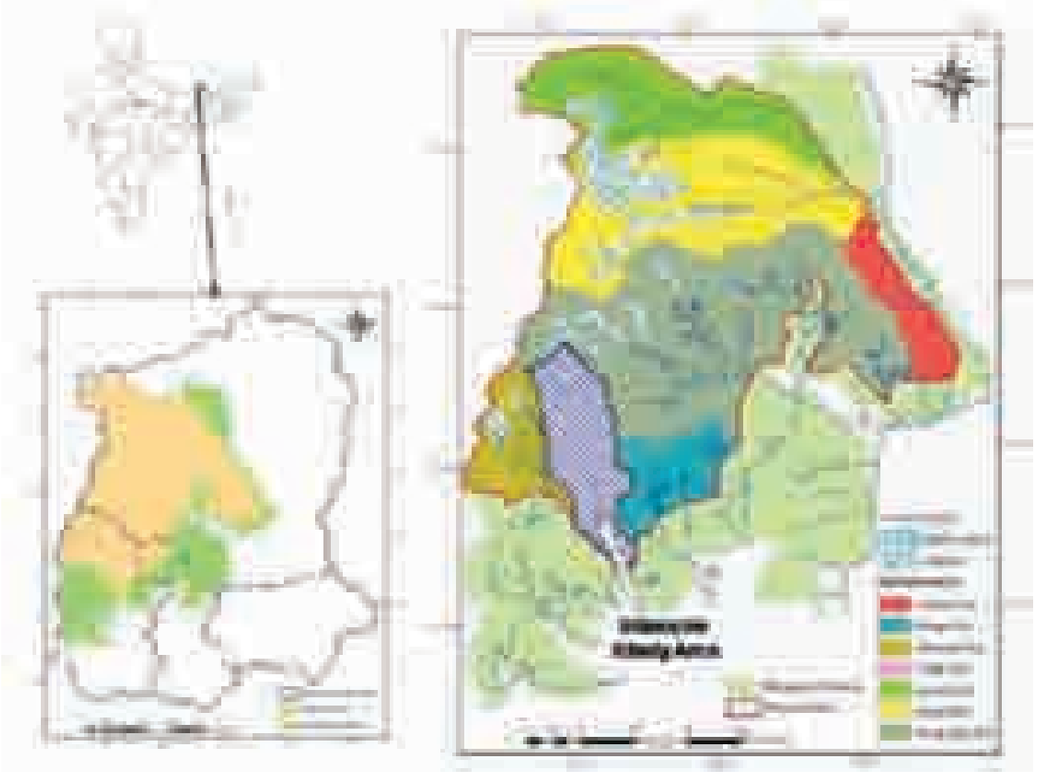


Figure 2 Major habitat categories and contours of Prek Chu Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India

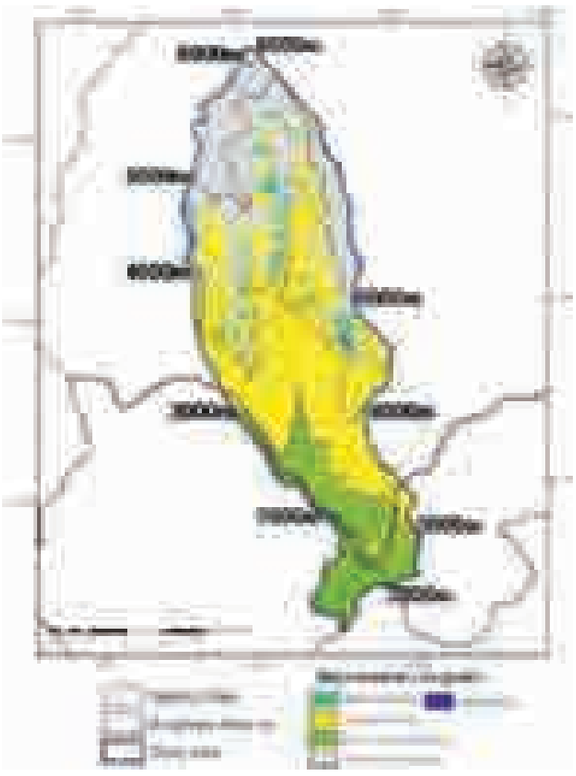


Figure 3 Map of Intensive study area showing Trails and locations of Camera traps in 2 km×2 km grids in Prek Chu Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India

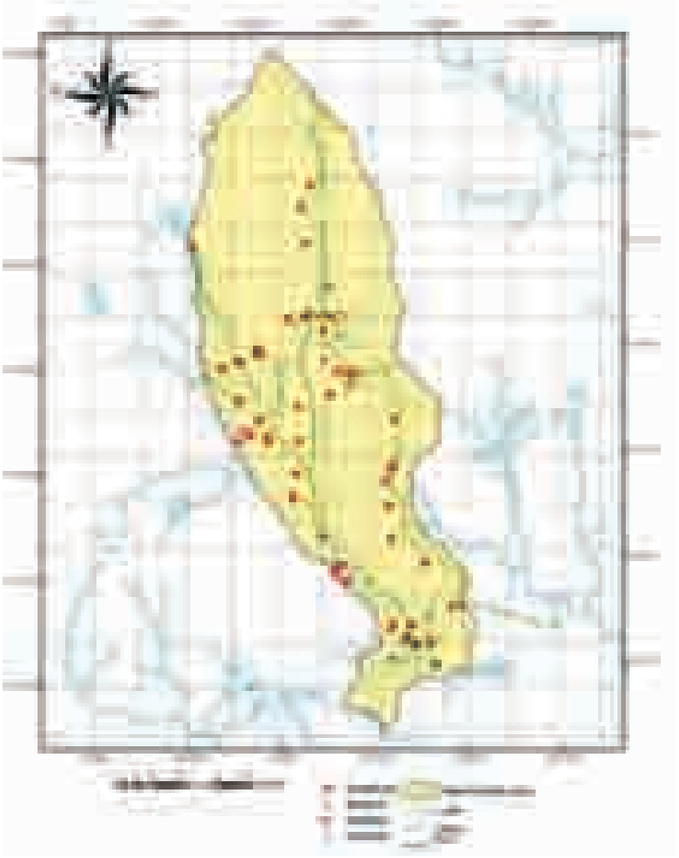
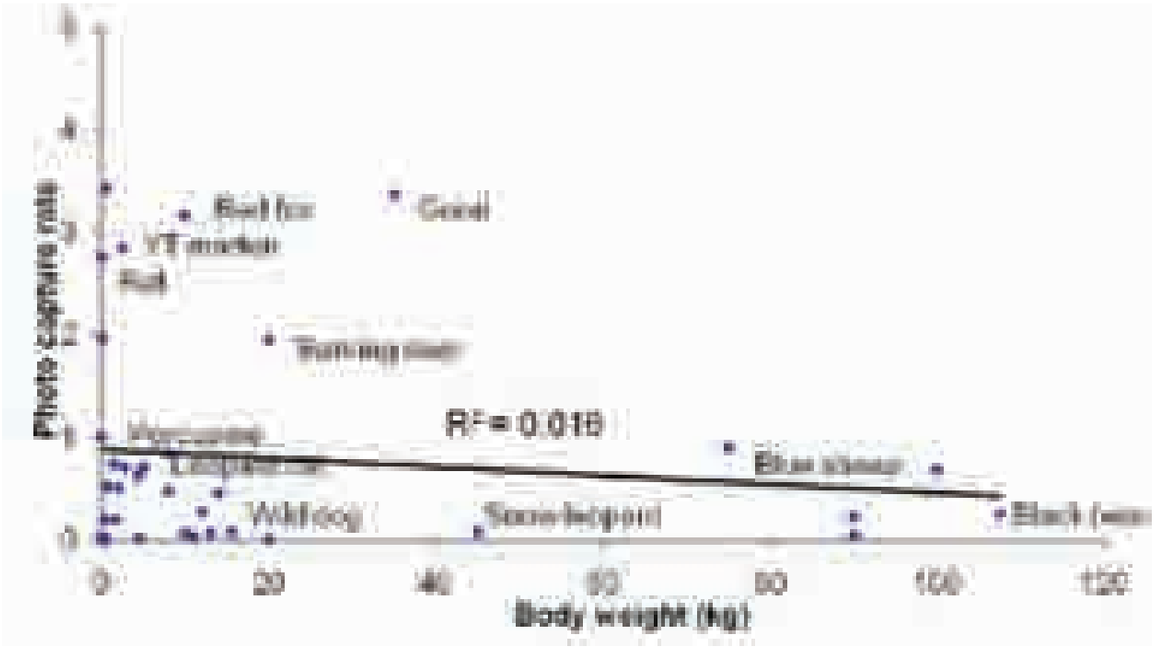


Figure 4 Scatter plot showing relationship between photo capture rates of species with their respective body weights



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