DEVELOPING A MONITORING PROGRAMME FOR MAMMALS IN HIMALAYAN PROTECTED AREAS: A CASE STUDY FROM KHANGCHENDZONGA NATIONAL PARK AND BIOSPHERE RESERVE, SIKKIM, INDIA

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ABSTRACT

We tested the applicability of wildlife field techniques such as trail monitoring, scan counts, camera trapping and dung counts in Khangchendzonga National Park (NP) and Biosphere Reserve (BR) in Sikkim, India, during 2008-2012 to develop appropriate monitoring programmes for mammals. In total, 42 species of mammals were confirmed in the Khangchendzonga NP and BR out of which 40 species were confirmed through visual encounters, photo-captures and signs. Camera trapping was found to be the most applicable field method for all carnivores and solitary ungulates. For snow leopard (*Panthera uncia*) populations, to detect 10 per cent annual decline with 70 per cent power, 800 effective camera days per year would be required for seven years. To detect desired percentages of annual decline/increase in mammal population with significant power, the required effort and time period were estimated as Rs. 3,067,000 (US$ 51,116) for a period of about 10 to 15 years. The most important habitats for the threatened carnivores and their prey in the Khangchendzonga have been identified. Regular monitoring of the most suitable habitats and strict patrolling of the condition of the alpine and *Krummholdz* zone can effectively reduce the negative effects of current anthropogenic activities such as unsupervised livestock grazing and unsustainable resource extraction for local use.

Key words: Khangchendzonga, India, monitoring, mammals, camera trapping

INTRODUCTION

For effective wildlife management, prior knowledge of species diversity, distribution and abundance is essential, so as to detect significant changes and thus appropriate management interventions. Efficient and reliable methods are required for monitoring changes in species abundance in protected areas. In the Himalayas, due to the remote and rugged high altitude terrain, monitoring of species is often a challenge for wildlife managers. In the Greater Himalaya, in particular, where road connectivity and other essential logistic support is minimal inside protected areas, monitoring of any animal population is difficult and thus monitoring programmes tend to be lacking. This paucity is apparent all over the Greater Himalayan range, including protected areas in India, Nepal and Bhutan. This case study helps fill this gap by assessing the requirements of an effective monitoring protocol for Himalayan protected areas in the context of Khangchendzonga National Park (NP) and Biosphere Reserve (BR).

The sacred mountain of Khangchendzonga (8,586 m) presides over the physiography of Sikkim, a small mountainous State in India that is wedged in between the Himalayan nations of Nepal in the west, Bhutan in the east, the Tibetan Plateau in the north and the Darjeeling District of West Bengal State in the south. In the eastern Himalaya, Khangchendzonga is positioned at the convergence of three biogeographic realms, viz., Palaearctic, Africo-tropical and Indo-Malayan (Mani, 1974) and thus provides a variety of habitats resulting in high biodiversity in the region. This area is recognised as a global biodiversity hotspot (Mittermeier et al., 2004; Myers et al., 2000) and is also one of the important Global 200 Ecoregions (Olson & Dinerstein, 1998).

The Khangchendzonga National Park (NP) and Biosphere Reserve (BR) is an important addition to the wildlife protected area network of India; it is the country's highest and the world's third highest protected area. It is an important high altitude wildlife landscape

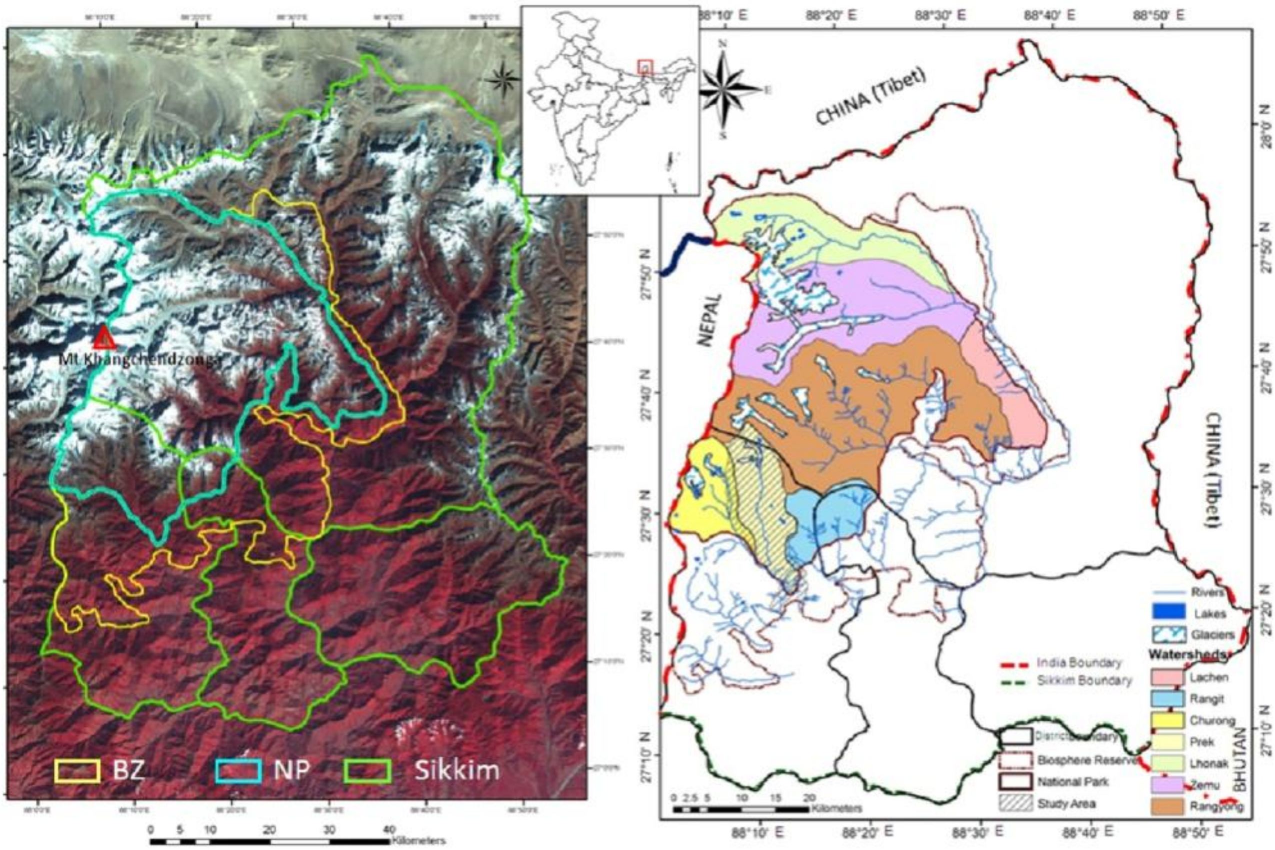


Figure 1. Geographic location of Khangchendzonga BR in Sikkim.
Left: Boundary of Khangchendzonga BR overlaid on False Colour Composite LANDSAT imagery. Right: Different watersheds in Khangchendzonga BR and *Prek chu* watershed as the study area

covering about 37 per cent of the State's biogeographic area and encompassing varying eco-zones from sub-tropical to arctic with an altitudinal range of between 1,200 to 8,586 m. In spite of such rich biodiversity, there have been only a few ecological studies and surveys on the mammals of the Khangchendzonga NP and BR (Sathyakumar et al., 2011; Bhattacharya et al., 2010, 2012; Bashir et al., 2013a, b, c).

Over the last 15 years, the Khangchendzonga NP and BR experienced several policy level changes and modifications (such as eviction of yak herders from inside the NP in Western part of Khangchendzonga NP) which may have altered the livelihood practices of the local communities (traditional livestock herding to eco-tourism initiatives) and have also changed the habitat status of wild animals (Tambe & Rawat, 2009). Findings of recent landscape-level remote sensing studies in Khangchendzonga BR (Tambe et al., 2012) revealed that, for the long-term security of this unique mountain landscape, the park management need to evolve innovative co-management models, take adequate safeguards for vulnerable habitats, strengthen buffer zone management and focus conservation measures on high impact areas. Monitoring wildlife species in the area would be useful to detect overall management effectiveness as many species are excellent indicators of habitat quality and management interventions.

Keeping these issues in mind, a research team from the Wildlife Institute of India collected baseline information on the mammalian assemblage of Khangchendzonga NP and BR including information on species distributions, habitat use and threats through conventional field sampling methods and by use of non-invasive remote camera trapping (Sathyakumar et al., 2011, 2014). We tested various wildlife field survey and monitoring methods and developed a monitoring programme for the mammals of Khangchendzonga NP and BR.

In this paper, we present the findings on the various monitoring methods, their applicability to different mammal species, monitoring frequency to detect significant changes in mammal populations and the costs for implementing the monitoring protocols in Khangchendzonga landscape.

STUDY AREA

The Khangchendzonga NP and BR is located in the State of Sikkim. According to the Biogeographic Classification of India (Rodgers et al., 2000), this region comes under 2C: Central Himalaya and adjoins the Himalayan regions of Nepal, Chumbi Valley and Bhutan, and the large expanse of the Trans-Himalayan regions in the north (Figure 1A). The Khangchendzonga NP and BR 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; there are also a number of conservation corridors (Tambe, 2007). The Khangchendzonga BR covers an area of 2,619.92 km², of which the NP (core zone) covers an area of 1,784 km² and the buffer zone covers an area of 836 km². The Singalila range separates Sikkim from Nepal and forms the western border of Khangchendzonga NP and BR. The varying elevations within an aerial distance of just 42 km, with about 90 per cent area above 3,000 m and 70 per cent above 4,000 m, make this park a unique global natural heritage hotspot. The entire landscape is enormously rich in biodiversity, highly important as hydrological, environmental and recreational resources and also represents a unique amalgamation of different cultures of several ethnic communities along with their traditional livelihood practices. A recent emphasis on community based ecotourism in selected parts of Khangchendzonga BR is currently bringing prosperity to these ethnic people (Tambe, 2007).

The area of Khangchendzonga BR has been divided into seven watersheds or river subsystems viz., *Lhonak* (15 per cent), *Zemu* (23 per cent), *Lachen* (5 per cent), *Rangyong* (36 per cent), *Rangit* (6 per cent), *Prek* (8 per cent) and *Churong* (7 per cent). 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 (Figure 1B) because it represents all the habitat characteristics of Khangchendzonga BR (Sathyakumar et al., 2011). Surveys were also carried out in *Lhonak*, *Zemu*, *Lachen* and *Churong* watersheds. The *Prek chu* watershed was divided into six habitat classes, *viz.*, mixed sub-tropical (1 per cent), mixed temperate (16 per cent), sub-alpine (36 per cent), alpine pastures (5 per cent), rock and snow cover (41 per cent) and water bodies (1 per cent). The watershed has a typical oceanic climate with an average annual rainfall of around 2,230 mm (Tambe, 2007).

METHODS

The study was conducted from 2008 to 2012. 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* watershed. 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 were carried out in the early months of the study period in the five watersheds (*Churong*, *Lachen*, *Zemu*, *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 and sign surveys

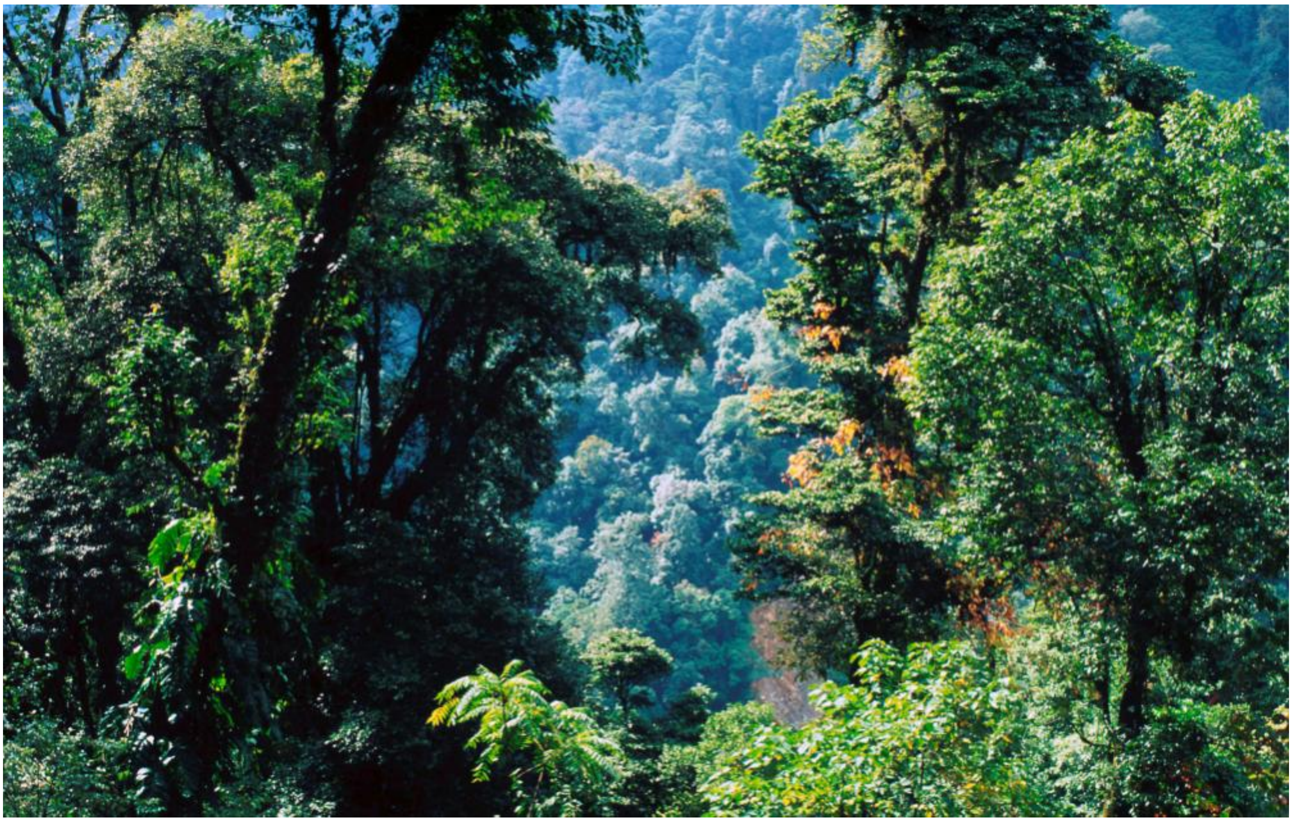
Trail sampling was used for detection of mammals in different habitats of the study area. These trails were identified with slight modification from conventional transects (Burnham et al., 1981) for Himalayan terrain (Sathyakumar, 1994; Vinod & Sathyakumar, 1999). Scan sampling, ridge walking (Bhatnagar, 1993; Green, 1978; Sathyakumar, 1994, 2004) and sign surveys along trails, ridges, *nullahs* (streams) and transects (Bennett et al., 1940; Chundawat, 1992; Fox et al., 1988; Rodgers, 1991; Sathyakumar, 1994) were also carried out. Trail sampling (n= 22; 1.5 to 7 km) within the intensive study area was repeated (784 walks), and sign surveys were carried out once a month for the intensive study area (32 surveys). Trail sampling and sign surveys were carried out once in each of the other four watersheds.

Scanning method

Scanning (Green, 1978; Sathyakumar, 1993, 1994, 2004; Bhatnagar, 1997; Kittur et al., 2010) from three vantage points (104 repeats) in *Prek chu* catchment area was carried out to detect mountain ungulates in the alpine areas. This technique involves careful scanning from vantage points using spotting scope and/or binoculars (8 × 40) for a specified period of time. The scanning was done between 0600h to 0900h and 1500h to 1800h. Scan duration varied from one to three hours, depending on the weather conditions.

Camera trapping

The map of the intensive study area was divided into 4 km² blocks using Geographic Information System (GIS) (ARC GIS 9.1). For simplicity, the area was categorised into three different survey zones according to the habitats, viz., temperate (1200–3000 m), sub-alpine (3000–4000 m) and alpine (above 4000 m) and the camera traps were deployed corresponding to the area coverage of the survey zones and their accessibility (10 blocks in temperate, 12 blocks in subalpine and 16 blocks in alpine). Twenty-seven camera traps were deployed at 71 sites in 38 blocks. The camera trapping was done continuously in all seasons (winter: January–March; spring: April–May; summer: June–September; autumn: October–December). Among the 71 camera locations, at 25 locations cameras stopped working within five days



The forest at approximately 3000 meters in Khangchendzonga National Park, Sikkim © Neyret & Benastar / WWF-Canon

due to malfunctioning or human interference. A total of 6,910 effective camera days effort was obtained from the remaining 46 locations from 2009-2011. Since the study species were rare and the area vast, the strategy was to survey more sampling units less intensively rather than less sampling units more intensively (Mackenzie & Royle, 2005). Monitoring of camera traps was done at least twice a month which included changing the batteries and memory card. In *Lhonak chu* catchment area, camera trapping was carried out in 2012, for one month.

Dung counts

Dung counts were used for estimation of dung density of mountain ungulates in the study area. Dung is a reliable indicator of animal presence and abundance in an area. Estimating dung density of an ungulate species in a habitat is an indirect way to know about its abundance or density (Bennett et al., 1940; Rodgers, 1991; Sathyakumar, 1994). The dung counts were made within a 20 × 2 m belt transect laid at every 100 m interval along the trails. For every trail, wherever possible, the dung plots were nested within the 10 m ´10 m plots laid for vegetation cover estimation. This gave a total of 337 plots. Specifically, power is defined as (1 – β) where β is the probability of wrongly accepting a null hypothesis when it is actually false (Type II errors; Gerrodette, 1987; Fairweather, 1991). Increasing power creates a trade off against the possibility of a Type I error (i.e. saying a trend exists [P = α] when it does not). Setting conservative α levels ($p < 0.05$) lowers the power to detect trends, but guards against wrongly alerting managers to significant population declines, which might not exist.

MONITORING MAMMALS: DETECTION OF CHANGE AT DESIRED POWER LEVEL

The identification of statistically significant changes in animal populations can be problematic (Macdonald et al., 1998; Toms et al., 1999). Adequacy of monitoring programmes depends on interactions between sample sizes (number of counts), duration (years of monitoring), frequency of surveys, and the ability to control variability in counts because of other factors (e.g. weather).

Power is often expressed as a percentage. For example, if power = 90 per cent, this means the statistical power of the monitoring programme is 90 per cent to detect a population trend of a specified magnitude. In other words, this means a Type II error (failure to detect a biologically significant trend) will be avoided with a probability of 0.9. Monitoring programmes must aim to maximise accuracy and minimise the possibility of wrong conclusions being drawn about trends. Type II errors can be costly for conservation managers. If a significant decline in a threatened species is not identified, then the population may decline beyond a threshold where recovery is impossible. In contrast, if managers respond to a perceived decline that is not real (managing a species that is not endangered), then resources may be wasted in the short term, but the 'false alarm' is likely to be recognised. If sample sizes and survey frequencies are insufficient, a monitoring programme will fail to provide the precision needed to detect population changes over time (Walsh et al., 2001).

Based on the findings of the base-line monitoring project we provide an example of applying power analysis to designing a long-term monitoring programme for mammals in the intricate eastern Himalayan habitats of Khangchendzonga NP and BR. To assess the efficiency of the mammal monitoring programme, power for several sampling designs were estimated with the use of the computer program MONITOR (Gibbs, 1995) based on the estimates of abundance and variance. To estimate abundance of the flagship species snow leopard, data from camera traps were used that had been collected over a five month period in 2011. To estimate abundance of blue sheep (*Pseudois nayaur*) (major prey of the snow leopard), the data from scan sampling were used which had been collected over the entire study period of three and a half years. To estimate relative abundance of two relatively abundant solitary mountain ungulates, such as goral (*Naemorhedus goral*) and barking deer (*Muntiacus muntjak)*, photo-captures obtained using camera traps were used.

For monitoring of snow leopard population, density (#/100 km^2) estimates and their variances using spatially explicit maximum likelihood method with respect to different sampling efforts (effective camera days/year) were used, powers were estimated (based on 500 simulations for two-tailed tests and for significance level (α) 0.05) for 4-15 years.

For monitoring of blue sheep population, powers were estimated (based on 500 simulations for two-tailed tests and for significance level (α) 0.05) for 10 years of surveys performed every year using 3-36 scan surveys/year (increasing the number of scan surveys by an order of three, for example: first set of analysis was carried out with the abundance estimate and variance derived from the data obtained in three surveys/year, next analysis was carried out with the abundance estimate and variance derived from data obtained in six surveys/year and so on up to 36 surveys/year).

For monitoring of goral and barking deer population using camera traps, different photo-capture rates and their variances with respect to different sampling efforts (effective camera trap days/year) were used (starting from 130 days/year to 1,300 days/year in case of goral and from 100 days/year to 600 days/year for barking deer). Powers were estimated (based on 500 simulations for two-tailed tests and for significance level (α) 0.05) for 4, 5, 6, 7, 8, 9 and 10 years.

Snow Leopard in Khangchendzonga NP - WII camera trap image © WII

IDENTIFICATION OF PRIORITY AREAS FOR HABITAT MONITORING AND CONSERVATION FOR THREATENED MAMMALS

Reliable information on the locations of animals is often difficult to acquire, either because they are rare or elusive (Buckland et al., 2000, 2005; Gu & Swihart, 2004; Vine et al., 2009; Paull et al., 2012). This scenario is a severe hindrance to conservation planning. Species distribution modelling is one way of confronting this deficiency of data; however, for many species, in particular those which are most threatened, there is basically inadequate primary information to perfectly predict their occurrence (Anderson et al., 2003; Engler et al., 2004; Pearson et al., 2007). The findings of the habitat suitability models aimed to fill this information gap at least at the Khangchendzonga NP and BR landscape scale (Sathyakumar et al., 2014). The habitat suitability models predicted several areas in Khangchendzonga NP and BR as suitable habitats (Suitability index: 60-100) for different mammals. Habitat suitability indices for these threatened carnivores and their prey in the study area (Snow leopard: Endangered; Asiatic black bear

Blue sheep in Khangchendzonga National Park © Tawqir Bashir

(*Ursus thibetanus*): Vulnerable; Golden cat (*Catopuma temminckii*): Near threatened; Large Indian civet (*Viverra zibetha)*: Near threatened; Musk deer (Moschus spp): Endangered; goral and serow (*Capricornis thar*): Near threatened (IUCN, 2012)) were combined and the mean values were extracted in a 1×1 km² grid basis for the entire Khangchendzonga NP and BR landscape for alpine and forest habitats. These mean values were further averaged for these species and multiplied by a conversion factor to derive an Important Habitat Index (from 0-100). The most suitable grids (Important Habitat Index 60-100) were identified and the nearest locations were also pointed.

RESULTS

In total, 42 species of mammals belonging to seven orders and 16 families were confirmed in the Khangchendzonga NP and BR out of which 40 species were confirmed through visual encounters, photo-captures, and signs (Sathyakumar et al., 2011). Of the 42 species recorded, 18 are of high global conservation significance, categorised 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. For details of these species and their distributions in Khangchendzonga NP and BR, please refer to Sathyakumar et al. (2011).

A comparison of monitoring methods for different carnivores and ungulates in the intensive study area is presented in Tables 1 and 2. Camera trapping was found to be the most applicable field method for all carnivores and solitary ungulates especially goral and serow. Detections of wild dog (*Cuon alpinus*), golden cat, large Indian civet, Himalayan tahr (*Hemitragus jemlahicus*) and wild pig (*Sus scrofa*) were achieved only through camera trapping, this method can also be used to carry out presence-absence surveys for musk deer in Khangchendzonga NP and BR. Trail sampling detected barking deer, goral, serow and wild pig, however, the number of encounters were very few and hence may not be a very applicable method in the dense and inaccessible forests of the Eastern Himalaya.

Monitoring mammals: Detection of change at desired power level

The results of the analysis show dramatically different levels of required monitoring efforts to detect changes in populations. Identifying small changes (e.g. 5 per cent increase or decline) requires significant monitoring effort. However, the ability to detect slightly larger change (e.g. 10 per cent or more change in populations) can be achieved with significantly less monitoring effort and over shorter timeframes. For snow leopard population, to detect 5 per cent annual decline with 70 per cent power, 1,000 effective camera days in every year were the minimum sampling effort required for 13 years; and to detect 10 per cent annual decline with 70 per cent power, 800 effective camera days per year would be required for seven years (Figure 2).

For blue sheep, power to detect annual population declines of up to 10 per cent per year changed little when survey effort was increased from 21 surveys/year to 24 surveys/year or more (Figure 3). To detect annual 5 per cent decline in blue sheep population with 70 per cent power, 33 scans per year would be required for 10 consecutive years. However, to detect 10 per cent annual decline with the same power level of 70 per cent, only nine scans per year would be required (Figure 3).

For goral population, to detect 5 per cent annual decline with 70 per cent power, 390 effective camera days per year for nine years would be the minimum sampling

Table 1. Recommended methods for monitoring carnivores in Khangchendzonga BR

Carnivores	Sign survey	Camera trapping	Trail/Transect
Snow leopard	√	√	×
Golden cat	×	√	×
Leopard cat	×	√	×
Red fox	√	√	×
Wild dog	×	√	×
Yellow-throated marten (*Martes flavigula*)	√	√	√
Stone marten (*Martes foina*)	×	√	×
Siberian weasel (*Mustela sibirica*)	×	√	×
Pale weasel (*Mustela altaica*)	×	√	×
Black bear	√	√	×
Tibetan wolf (*Canis lupus chanco*)	√	√	×

Table 2. Recommended methods for monitoring ungulates in Khangchendzonga BR

Species	Sign survey	Camera trap	Trail sampling	Scanning
Barking deer	√	√	√	×
Goral	√	√	√	×
Serow	√	√	√	×
Himalayan tahr	×	√	×	×
Musk deer	√	√	×	×
Blue sheep	√	×	×	√
Wild pig	×	√	√	×

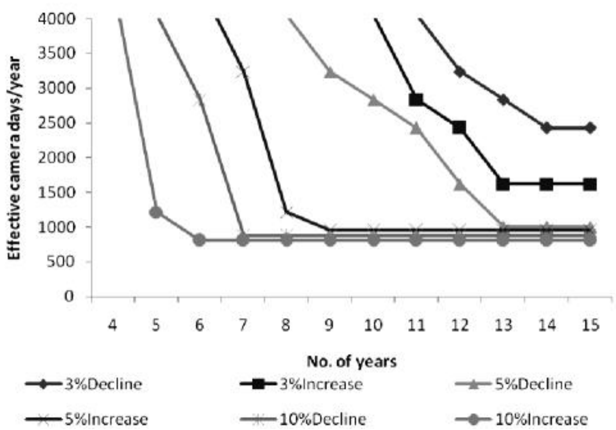


Figure 2. Relationship between number of years of monitoring and minimum sample size needed to achieve 70% power to detect existing changes of 10% per annum in snow leopard population in *Prek chu* catchment of Khangchendzonga BR (estimates based on two-tailed tests, α = 0.05 and 500 simulations)

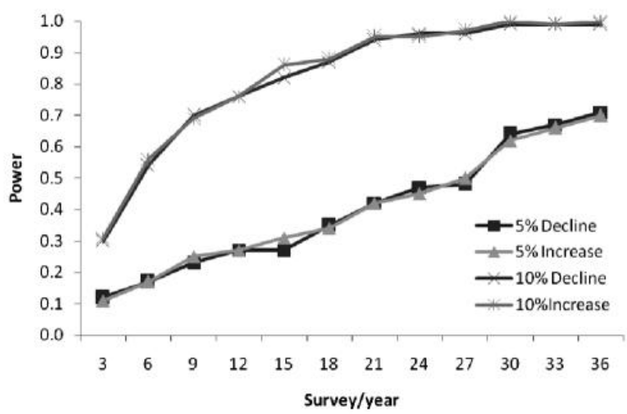


Figure 3. Estimated power to detect annual change (5 and 10%) in blue sheep abundance in *Prek chu* catchment of Khangchendzonga BR with different scanning efforts/year for 10 years (estimates based on two-tailed tests, α = 0.05 and 500 simulations)

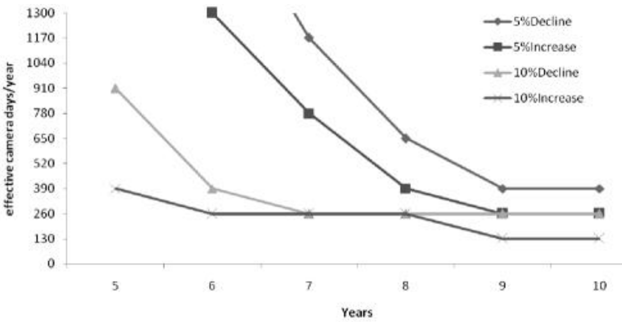


Figure 4. Relationship between number of years of monitoring and minimum sample size needed to achieve 70% power to detect existing changes of 10% per annum in goral population in *Prek chu* catchment of Khangchendzonga BR (estimates based on two-tailed tests, α = 0.05 and 500 simulations)

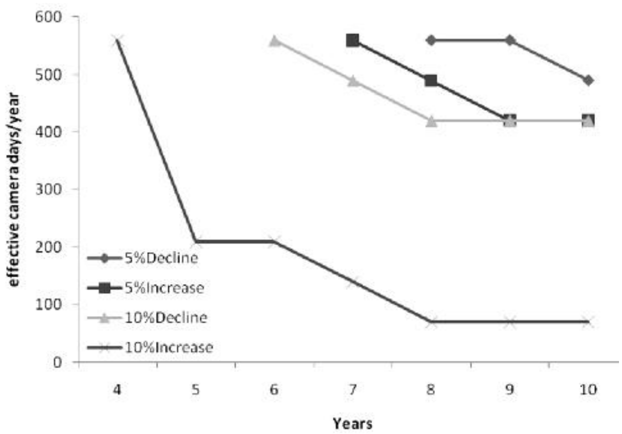


Figure 5. Relationship between number of years of monitoring and minimum sample size needed to achieve 70% power to detect existing changes of 10% per annum in barking deer population in *Prek chu* catchment of Khangchendzonga BR (estimates based on two-tailed tests, α = 0.05 and 500 simulations)

effort required; and to detect 10 per cent annual decline with 70 per cent power, 260 effective camera days per year would be required for seven years (Figure 4). For barking deer population, to detect 5 per cent annual decline with 70 per cent power, 500 effective camera days per year for 10 years would be the minimum required sampling effort. However, 10 per cent annual decline with the same power level could be detected with 400 effective camera days per year for eight years (Figure 5). Across all combinations of sampling effort and timing, for blue sheep, goral and barking deer, with power level of 70 per cent or above, effective detection of population increases could be achieved with less sampling efforts than the efforts required to detect population decline.

In the trans-Himalayan region, detection of Tibetan wolf packs was achieved both by sign survey and camera trapping; however, presence of red fox (*Vulpes vulpes*) was detected only through camera trapping. For gregarious ungulate such as blue sheep, the applicability of camera trapping was found to be limited as the complete group structure and composition could not be captured. Scanning from a vantage point was found to be the best applicable field method to monitor the blue sheep population in Khangchendzonga NP and BR. During the field work, only nine photo-captures of musk deer were obtained, however, pellet group count provided detection of 181 pellet groups of musk deer. As musk deer pellet groups are quite conspicuous in comparison with that of other ungulates, hence, along with camera trapping, this method can also be used to carry out presence-absence surveys for musk deer in Khangchendzonga NP and BR. Trail sampling detected barking deer, goral, serow and wild pig, however, the number of encounters were very few and hence may not be a very applicable method in the dense and inaccessible forests of the Eastern Himalaya.

DISCUSSION

Monitoring of ungulates in Khangchendzonga NP and BR

During the present study, all the field work was carried out in expedition mode, which involved camping in different parts of the intensive study area. For each expedition, the average expenditure was approximately Rs. 15,000/- (US$ 248 – Conversion rate 1 US$ = INR 60) including all the logistic expenses. On each expedition a maximum of three scan surveys could be carried out from different vantage points. If the initial cost of procurement of equipment is Rs. 50,000/- (US$ 827), then to achieve nine scan surveys/year for 10 years would incur a total cost of approximately Rs. 500,000/- (US$8,270). However, to detect 5 per cent annual decline in blue sheep population with 70 per cent power, at least 33 surveys would be required per year, and to achieve this the approximate expenses would be Rs. 1,700,000/- (US$ 28,125) in 10 years. In the case of barking deer and goral, 600-650 effective camera days per year would be required for eight years to detect 5 per cent annual decline with 70 per cent power. To achieve 600 effective camera days per year, deploying 10 cameras in the temperate and subalpine forests of the intensive study area for two months will be the most feasible option both in terms of logistics and inference. The cost of procuring ten camera traps and the required number of batteries may reach Rs. 107500/- (US$ 1,778). The experience of the present study indicates that camera traps will work efficiently for two and a half years if deployed for continuous monitoring. Thus, procurement of a new set of 10 cameras may become necessary after four years. Hence the total cost of camera trap procurement may reach Rs. 2 00,000/- (US$ 3,308) and the required cost

Wildlife Habitat in Khangchendzonga National Park © Tawqir Bashir

for batteries may reach Rs. 60,000/- (US$ 1,000) in eight years (Rs. 7,500/- [US$ 124] in each year). The cost of monitoring the cameras in each year may reach Rs. 30,000/- (US$ 500) (Rs. 15,000/- [US$ 250] per monitoring). In total, the monitoring of goral and barking deer population in the intensive study area using camera traps may cost up to Rs. 500,000/- (US$ 8,271) in eight years. Monitoring of snow leopard populations, will require more funds to achieve 800 effective trap days for 13 consecutive years. This would cost a total of Rs. 3,067,000 (US$ 51,116) for an implementation period of about 10 to 15 years.

Habitat monitoring and conservation of ungulates in Khangchendzonga NP and BR

For blue sheep conservation, the areas near *Goechela* and *Younglathak* were already identified as important conservation zones (Tambe, 2007). Similarly for musk deer, areas near *Relli* and *Aurelongchuk* were previously identified as conservation zones (Tambe, 2007). However, this study has indicated more areas suitable for threatened carnivores such as snow leopard and identified the grids most important for habitat monitoring. The grid-based approach will help to delineate the appropriate areas where the regular monitoring of habitats can be carried out. The identified grids in *Prek chu* catchment are situated adjacent to the *Yuksam-Dzongri* trekking trail which is a favourite destination for tourists worldwide. The impact of tourism on the habitat structure was studied for bird and butterfly communities (Chettri, 2000), however, the current position, after the enhancement of eco-tourism in this part of the protected area in the years 2004-2006, has not been assessed. The effect of tourism related extractive disturbances such as firewood extractionand pack animal grazing as well as the effect of non-degradable waste accumulation in these habitats should be assessed and monitored regularly.

In other watersheds apart from *Prek chu*, eco-tourism is still not the main livelihood option. In *Churong chu* watershed, the *Yambong* valley trek may have the engagement of local youth in eco-tourism, however, the magnitude of tourism is not currently comparable with *Prek chu*. In the northern part of Khangchendzonga BR, religious tourism in *Tolung gompa* is practised, however, the best habitats for ungulates in *Panchpokhri* areas are more or less untouched by tourists. Similarly the *Lachen-Thepala* area is only used by local people and has suitable habitats for Asiatic black bear, musk deer, serow and goral. Regular monitoring of habitats is thus needed mostly in the south western part of the Khangchendzonga BR. In the northern area, active participation of the villagers is necessary for monitoring.

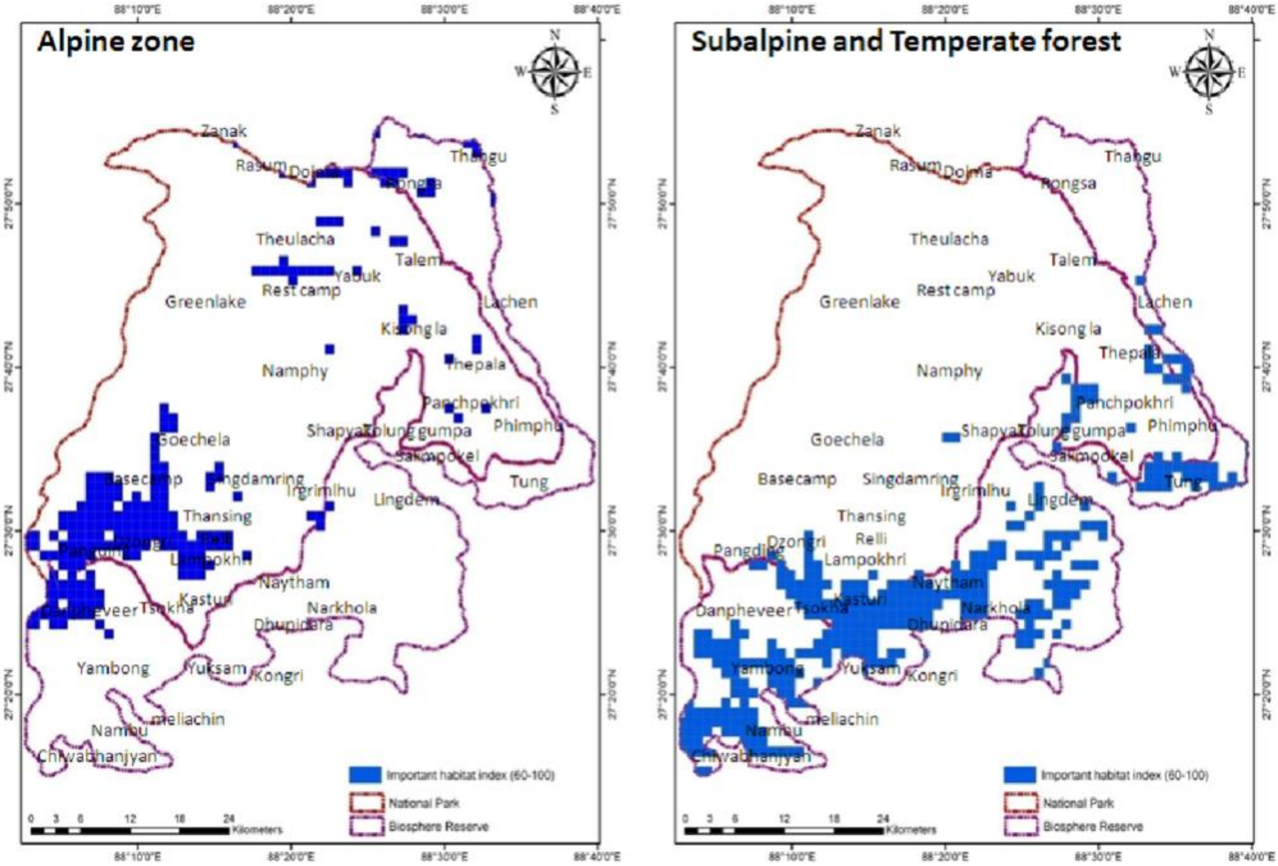


Figure 6. Identified 1×1 km^2 grids as most suitable habitats of threatened carnivores and their prey in alpine zone and in subalpine and temperate forest in Khangchendzonga BR

Identification of priority areas for habitat monitoring and conservation for threatened carnivores and their prey

In the alpine zone, the grids where the Important Habitat Index is 60-100, are situated in the south western part (Figure 6) of Khangchendzonga NP and BR. The trans-Himalayan habitats of *Zanak, Rasum* and *Dolma* along with the Green lake area were depicted as the most important habitats for threatened carnivores and their prey in the northern part of Khangchendzonga BR. In the subalpine and temperate forest, most important habitats for threatened carnivores and their prey are situated mainly along the junction of BR and NP (Figure 6). Most of these grids are situated in the BR part connecting or buffering the villages situated just outside the Khangchendzonga BR boundary and hence are also very important for regular monitoring. The transition zone of subalpine and alpine area such as dwarf Rhododendron vegetations of *Dzongri*, *Thansing*, upper *Yambong*, *Panchpokhri* and *Thepala* are most important habitats for the threatened carnivores and their prey. A summary of necessary sampling efforts to monitor the populations of different mammal species, their abundances and preferred habitats are presented in Table 3. It should be noted that the recommendation of sampling efforts for species does not of course mean that managers should not try alternate ways of monitoring or a combination of means to achieve the goal of efficient monitoring of population status change of threatened taxa.

CONCLUSION

It is evident that applications of different field methodologies are required to detect and monitor different carnivores and their prey in the Khangchendzonga landscape. Flagship species such as the snow leopard and their major prey blue sheep can be monitored across different landscapes of the Eastern Himalayan region following the monitoring model discussed above. Camera trap studies along with regular scan counts are essential for the proper documentation of the change in the abundance of these species. Already existing abundance estimates or estimates derived from pilot surveys can be used to effectively design monitoring protocols across the protected areas of Nepal, Bhutan and in similar habitats in China. Methods and modes of monitoring can be adapted locally, although scientific rigour should be maintained.

Regular monitoring of the most suitable habitats through patrolling in the alpine and *Krummholdz* zones can effectively reduce the existing harmful anthropogenic activities such as unsupervised livestock grazing,

Table 3. Distribution, abundance, habitat use, habitat suitability and monitoring methods of some mammals in Khangchendzonga NP and BR

Species	Distribution (Watershed)	Abundance/Relative abundance (SE)	Diet/Habitat variables (+ preferred; - avoided)	Suitable habitats	Monitoring
Snow leopard	*Churong, Prek, Lachen, Zemu, Lhonak*	4.77(1.81)/100 km^2 [Density]	Blue sheep, cattle Elevation (+), Alpine (+), Tree cover (-)	*Dzongri-Goechela-Lampokhri, Green lake, Lhonak valley*	Camera trapping for 13 years (10 cameras for 80 days/year) in alpine areas
Red fox	*Churong, Prek, Lachen, Rangyang, Rangit, Zemu, Lhonak*	18.21(6.00)/100 km^2 [Density]	Pika, rodent, beetle Elevation (+), Alpine (+), Tree cover(-)	*Dzongri-Thansing-Lampokhri-Yambong, Aurelungchok, Panchpokhri*	Camera trapping and sign survey in alpine zone
Stone marten	*Churong, Prek, Lachen, Rangyang, Rangit, Zemu*	10.26(4.52)/100 km^2 [Density]	Pika, rodent Elevation (+), Alpine (+),Conifer (+)	*Dzongri-Thansing-Lampokhri-Yambong, Aurelungchok, Panchpokhri*	Camera trapping in alpine and subalpine
Golden cat	*Churong, Prek, Rangit, Rangyang, Zemu, Lachen*	0.41 (0.13)/100 days [Photo-capture rate]	Conifer (+), Broadleaved (+)	*Sachen-Tsokha-Jamling-Yambong, Kasturi*	Camera trapping in subalpine and temperate
Black bear	*Churong, Prek, Rangit, Rangyang, Zemu, Lachen*	0.23 (0.08)/100 days [Photo-capture rate]	Conifer (+), Broadleaved (+)	*Sachen-Tsokha-Jamling-Yambong, Kasturi, Panchpokhri, Yuksam- Nambu*	Camera trapping in subalpine and temperate
YT marten	*Churong, Prek, Rangit, Rangyang, Zemu, Lachen*	33.52(7.80)/100 km^2 [Density]	Rodent, pika Tree cover(+), Conifer (+), Broadleaved (+)	*Sachen-Tsokha-Jamling-Yambong, Kasturi, Panchpokhri, Yuksam-Nambu*	Trail sampling and camera trapping in subalpine and temperate
Leopard cat	*Churong, Prek, Rangit,Lachen*	17.52(5.52)/100 km^2 [Density]	Rodent, pika Broadleaved (+)	*Yuksam-Sachen-Nambu-Melli, Narkhola*	Camera trapping in temperate
Large Indian civet	*Churong, Prek, Rangit*	10.67(3.71)/100 km^2 [Density]	Broadleaved (+)	*Yuksam-Sachen-Nambu-Melli, Narkhola, Lingdem*	Camera trapping in temperate
Masked palm civet	*Churong, Prek, Rangit*	14.03(6.52)/100 km^2 [Density]	Broadleaved (+)	*Yuksam-Sachen-Nambu-Melli, Narkhola, Lingdem*	Camera trapping in temperate
Blue sheep	*Churong, Prek, Lachen, Zemu, Lhonak*	5.25 (1.40)/km^2 [Density]	Elevation (+), Alpine (+), Tree cover(-)	*Dzongri-Goechela-Lampokhri, Green lake, Lhonak valley*	10 years scanning (9-10 surveys/year)
Musk deer	*Churong, Prek, Lachen, Rangyang, Rangit, Zemu*	6.40 (0.40)/ha [Dung density]	Elevation (+), *Krummholdz* (+)	*Dzongri-Thansing-Lampokhri-Yambong, Aurelungchok, Panchpokhri*	Camera trapping and pellet group count

CONTINUED OVERLEAF

Table 3. Distribution, abundance, habitat use, habitat suitability and monitoring methods of some mammals in Khangchendzonga NP and BR (CONTINUED)

Species	Distribution (Watershed)	Abundance/Relative abundance (SE)	Diet/Habitat variables (+ preferred; - avoided)	Suitable habitats	Monitoring
Serow	*Churong, Prek, Rangit, Rangyang, Zemu, Lachen*	8.71 (3.94)/100 km^2 [Density]	Elevation (+), Tree cover(+), Conifer (+), Trekking trail (-)	*Sachen-Tsokha-Jamling-Yambong, Kasturi*	Camera trapping in subalpine and temperate zone, pellet group count
Goral	*Churong, Prek, Rangit, Rangyang, Zemu, Lachen*	21.44 (6.48)/100 km^2 [Density]	Tree cover(+), Broadleaved (+), Trekking trail (-)	*Yuksam-Sachen-Tsokha-Nambu, Tung*	Camera trapping for 8 years (10 cameras for 60 days/year)
Barking deer	*Churong, Prek, Rangit*	16.93 (5.56)/100 km^2 [Density]	Tree cover(+), Broadleaved (+), Trekking Trail (-)	*Yuksam-Sachen-Nambu-Melli, Narkhola*	Camera trapping for 8 years (10 cameras for 60 days/year)
Wild pig	*Churong, Prek, Rangit*	0.30 (0.12)/100 days [Photo-capture rate]	Broadleaved (+)	*Yuksam-Sachen-Nambu-Melli,*	Camera trapping in temperate forests

unsustainable extraction of resources for local use and presence of feral dogs. Strong coalitions between the Forest Department, local NGOs and village representatives are necessary in the western part of the Khangchendzonga NP and BR. Similarly strong associations are needed in the northern part to conserve and monitor carnivores, their prey populations and habitats.

The present study generated baseline information on distribution, abundance, habitat use and co-existence of carnivores and their prey at spatial scale. However, major ecological issues such as diet overlap and niche breadth at dietary scale among these species and pack animals would provide insights into competition if any between wild and domestic ungulates inside the NP and BR. The response of these ungulates to anthropogenic factors such as disturbances due to eco-tourism is another aspect that requires scientific investigation. Camera trap studies in other watersheds (barring *Prek chu*) can help to validate the habitat suitability models prepared in this study and hence can also develop the prediction quality of these models. Implementation of these recommendations as part of a Long-term Monitoring Programme (LTMP) would help the managers in the effective monitoring of mammals in Khangchendzonga NP and BR. The described protocol is also relevant in the development of monitoring in other landscapes of Eastern Himalaya, at least for the flagship species snow leopard and its prey.

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RESUMEN

Durante 2008-2012, pusimos a prueba la aplicabilidad de técnicas de campo relacionadas con la vida silvestre, tales como monitoreo de rastros, recuentos, captura con cámaras trampa y conteo de estiércol en el Parque Nacional Khangchendzonga (PN) y la Reserva de la Biosfera (RB) en Sikkim, India, para desarrollar programas adecuados para el monitoreo de mamíferos. En total, se confirmaron 42 especies de mamíferos en el PN Khangchendzonga y en la RB, 40 de las cuales fueron confirmadas mediante encuentros visuales, imágenes y signos. Se determinó que la captura con cámaras trampa era el método de campo más aplicable para todos los carnívoros y ungulados solitarios. Para las poblaciones del leopardo de las nieves (Panthera uncia), para detectar la disminución anual del 10 por ciento con una eficacia del 70 por ciento, serían necesarios 800 días efectivos de cámara por año durante siete años. Para detectar porcentajes deseados de disminución/aumento anual de poblaciones de mamíferos con una eficacia significativa, el período de esfuerzo y tiempo requerido se estimó en Rs. 3.067.000 (USD51.116) por un período de 10 a 15 años. Se han identificado los hábitats más importantes para los carnívoros amenazados y sus presas en el Khangchendzonga. El monitoreo periódico de los hábitats más adecuados y el patrullaje estricto de la condición de la zona alpina y el Krummholdz podría reducir eficazmente los efectos negativos de las actividades antropogénicas actuales, tales como el pastoreo descontrolado de ganado y la extracción insostenible de los recursos para uso local.

RESUME

Au cours des années 2008-2012, nous avons testé la pertinence des techniques de terrain comme la surveillance des sentiers, l'échantillonnage, le piège photographique et le comptage d'excréments, pour élaborer des programmes de surveillance des animaux sauvages dans le parc national (PN) et la réserve de biosphère (RB) de Khangchendzonga au Sikkim, en Inde. Au total, 42 espèces de mammifères ont été recensées dans le PN et le RB de Khangchendzonga, dont 40 ont été confirmées par des rencontres directes, des photos ou des indices. Le dispositif de piège photographique a été jugé la méthode de terrain la plus appropriée pour tous les carnivores et ongulés solitaires. Pour les populations de léopard des neiges (Panthera uncia), il faudrait 800 jours effectifs d'enregistrement par an pendant sept ans pour détecter une baisse annuelle de 10% avec une efficacité de 70%. Pour détecter les pourcentages désirés de baisse ou d'augmentation annuelles de la population de mammifères avec une efficacité significative, le coût et la période nécessaire ont été estimés à Rs. 3,067,000 (51,116 $ US) pour une période d'environ 10 à 15 ans. Les habitats les plus importants des carnivores menacés et leurs proies dans la Khangchendzonga ont été identifiés. Un suivi régulier de ces habitats et une surveillance rigoureuse des conditions de la zone alpine et du Krummholdz pourront réduire les effets négatifs des activités anthropiques actuelles, telles le pâturage du bétail sans surveillance et l'extraction de ressources non durables par la population locale.