Assessment of large mammals of the Chittagong Hill Tracts of Bangladesh with emphasis on tiger (*Panthera tigris*)

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Statement of the Sources Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other Institutions. Information derived from published or unpublished work of others has been acknowledged in the text and a list of references is given.

Suprio Chakma

Certificate

I certify that the thesis entitled “Assessment of large mammals of the Chittagong Hill Tracts of Bangladesh with emphasis on tiger (*Panthera tigris*)” submitted by Suprio Chakma for the degree of Doctor of Philosophy of the Department of Zoology, University of Dhaka, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of Ph.D. degree.

This work has not been submitted for any degree of any other university.

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Abstract

Biodiversity assessment is the first step of conservation and monitoring of an ecosystem. Scientific information like ecological requirements of a species helps conservation practitioners to monitor the changes over time, but it is almost true that assessment of each and every species in an area is not necessary and impractical. Globally tiger is an endangered species and tiger density strongly correlated with prey densities. The Chittagong Hill Tracts (CHT) of Bangladesh is considered as Tiger Restoration Landscape. Neither tiger nor prey abundance has been assessed for the CHT. The overall goal of this study was to assess the conservation potential of medium (> 5 kg) to large mammals (>20 kg) across the CHT with special emphasis on tiger (*Panthera tigris*).

A total of 3800 km² area has been surveyed from March, 2010 to July 2011.

I have collected presence absence data using signs (tracks, scats, scrapes) survey and analysed using programme PRESENCE by applying occupancy models and figures using programme R. In addition to signs survey camera trap survey was also conducted, and compared the effectiveness of two methods. Relative Abundance Index (RAI) and activity patterns of medium to large mammals were quantified. Potential conservation areas assessed following The Nature Conservancy (TNC) guidelines and finally formulated conservation recommendations.

A total of 20 species of terrestrial mammals was recorded from both sign and camera trap survey. No tiger signs were found except 3 tiger killing records in last 15 years indicating tigers are either extirpated from the CHT or extremely rare and sporadic in the CHT landscapes. The notable carnivores documented are leopard (*Panthera pardus*), dhole (*Cuon alpinus*), clouded leopard (*Neofelis nebulosa*) and golden cat (*Felis temminki*). Gaur (*Bos gaurus*) thought to be an extirpated species for Bangladesh but rediscovered during this study. The other notable ungulates found are sambar deer (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), wild boar (*Sus scrofa*) and red serow (*Capricornis rubidus*). One deer skin was photographed which resembles to Fea muntjac (*Muntiacus feae*). Barking deer (*Muntiacus vaginalis*) occupancy (Ψ) was found 100% (SE = 0.0; 95% CI= 0.99-1) in surveyed area following by wild boar (*Sus scrofa*) 0.81 (SE = 0.08; 95% CI = 0.60-0.92), and sambar deer (*Rusa unicolor*) 0.73 (SE = 0.13; 95% CI = 0.41-0.91). The availability of primary forest (pf) was found to be the most important determinant for the species occupancy. Presence of ungulates in combination with primary forest was found to be the best prediction model for carnivore occupancy (Ψ) and determining probability of detection (p). Signs survey was found useful than camera trap method for short time survey. Relative Abundance Index (RAI) of main tiger prey species in selected grid cells was found higher than other tiger low density places of Southeast Asia. Habitat connectivity, abundance of ungulates, presence of carnivores, and quality of forest all are in stress. Shifting cultivation, hunting and settlement of plane land people were assessed as the high threats. The Kassalong Reserve Forest (KRF) adjacent to Dampa Tiger Reserve (DTR) of India is most potential to restore many large mammals. The study partially fulfilled the Convention on Biological Diversity's (CBD) Aichi Biodiversity Target 2020 and it is hoped that these results will be used for future study and conservation planning in the CHT.

Introduction

Assessing the status and trends of biodiversity is essential for sustainable development strategies at all levels (IUCN 2000). What is the overall status of biodiversity, what rate it is being lost, where it is being lost, and what are the causes of decline? These answers are needed in order to design and implement effective conservation strategies (Baillie *et al*. 2004). However, providing the information is a complex process and requires multiple measures, and it is even more difficult if there is an absence of baseline information or the available information is inadequate. Mammals are among the most studied vertebrate taxa across the world (Mackinnon 2000). Mammals, particularly large carnivores and herbivores, are often regarded as keystone species (Mills *et al*. 1993, Lindenmayer *et al*. 2000, Terborgh *et al*. 2008). Medium and large mammals may also serve as good indicator species of forest integrity because of their critical role to maintain a balanced community structure.

Globally, more than half of all species are facing population decline and about 25% of mammalian species are at risk of extinction (Morrison *et al.* 2007). Tiger (*Panthera tigris*) is the apex predator in Asian terrestrial ecosystem that has been lost from 93% of its former range spread across 13 countries (Sanderson *et al*. 2006, Dinerstein *et al.* 2006). Further assessment suggests that their range has further shrunk by 41% from 1996 to 2006 (Dinerstein *et al*. 2007). Like other large carnivores, tigers interact strongly with other species, mainly large ungulates; and tiger abundance at any place is strongly dependent on prey abundance (Schaller 1967, Johnsingh 1983, Karanth 1995). Thus, extirpation of large carnivores such as tiger (*Panthera tigris*) and leopard

(*Panthera pardus*) led to profound their respective ecosystems (Terborgh *et al*. 2001).

The Chittagong Hill Tracts (CHT) is an area of 13,295 km^2, located between 21°25′-23°45′N and 91°45′ -92°-50′ E. The CHT is a unique area of Bangladesh falls under Indo-Burma biodiversity hotspot (Myers *et al*. 2000) and considered as a Tiger Restoration Landscape (Sanderson *et al*. 2006).

Historically, tigers occurred throughout the CHT landscape, but the current occurrence of tiger is not clear (Khan 2004, Ahmad *et al*. 2009). The medium to large mammal diversity information of the CHT is scattered (Chaudhury 1969, Husain 1974, Khan 1982, 1985, Ahmad 1981, Chowdhury 1984). However, the abundance, spatial distribution, and their status have never been well explored in the CHT. Given the scenario, assessment of medium to large mammals in the CHT is of interest to both wildlife biologists and forest managers. My study addressed this critical need and it was aimed to fill the information gap.

The overall goal of the study was to collect the baseline data to assess future tiger conservation prospects under three specific objectives:

(1) Distribution patterns of medium (>5 kg) to large mammals (>20 kg) in the CHT of Bangladesh;

(2) Estimate relative abundance and activity patterns of medium to large mammals in selected areas of the CHT; and

(3) Setting conservation priorities for medium to large mammals in the CHT.

I have organised the thesis in 5 chapters, which are as follows:

Chapter 1 gives a background of the species tiger (*Panthera tigris*) including tiger morphology, behaviour, ecological requirements, taxonomy, historical and current distribution, population number, conservation history, current threats and challenges throughout the range countries.

Chapter 2 is an overview of the study area, where I have critically reviewed all relevant documents and briefly presented geopolitical to environmental changes over the last 500 years that would provide the necessary understanding about the complex political, socio-economic and cultural differences of the CHT from rest of the Bangladesh. Such information is important to modern conservation practices to integrate and adopt with policies that directly or indirectly linked with the biodiversity. At last, all biodiversity and forest management related policy has been taken into account from the 19^{th} Century and presented chronologically. Both chapters 1 and 2 are devoid of abstract but have their own introduction.

Chapters 3, 4 and 5 are directly related to 3 specific objectives and each chapter deals with one specific study objective. Although all 3 chapters are interlinked with one another, each has its own abstract, introduction, study area, methods, results, discussion and conservation implications.

Finally, all the references used in the thesis are listed in a common list of literature cited, followed by appendices linked to the different chapters. I hope that the study results will be helpful for the researchers to design their study in the future, and guide any biodiversity conservation or forest management planning in the CHT.

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Chapter 1: Tiger conservation

1.1 Introduction

The tiger (*Panthera tigris* Linnaeus 1758) is the largest living cat in the world (Mazák 1981, Sunquist and Sunquist 2009). Globally tiger is classified as an Endangered species (Goodrich *et al.* 2015). The most recent summary of tiger status worldwide suggests that they are now extirpated from 93% of their former range (Dinerstein *et al.* 2006) and the present distribution has been fragmented into about 160 population segments (Dinerstein 1997). Small populations are not viable in the long term and many others are on the verge of extinction because of demographic stochascity and genetic drift (Harmon and Braude 2010). Tiger is a global conservation priority species for its significant roles in the many Asian forest ecosystems. As an apex predator tigers play an important role in forest ecosystem by regulating the number and distribution of prey, which in turn has an impact on forest structure, composition, and regeneration (Ale and Whelan 2008, Wegge *et al.* 2009). The decline of tiger population will reduce ecosystem integrity, ultimately an essential for mankind's own existence.

In 1969, conservationists at the IUCN (The International Conservation Union) meeting in New Delhi, India, focused for the first time on declining tiger numbers. Based on this meeting the Indian government implemented the first state tiger protection project in the world in 1973 first of its kind. In the same year Nepal joined and established the Royal Chitwan National Park as its first national park and launched the tiger ecology project in collaboration with the Smithsonian Institution led by John Seidensticker. Even today most of the scientific knowledge on tiger ecology is based on research conducted in Chitwan National Park (Smith 1984, Smith *et al.* 1987, Smith and McDougal

1991, Smith 1993, Gurung *et al.* 2008) and Nagarahole of India (Karanth 1995, Karanth and Nichols 1998, Karanth and Stith 1999, Karanth and Sunquist 2000) and recent information coming from Russia (Kerley *et al.* 2003, Miquelle *et al.* 2005, Goodrich *et al.* 2008, 2012, Gilbert *et al.* 2014).

In the following decades Nepal increased the tiger landscapes by declaring four more protected areas mainly focusing on protecting tigers. Nepal launched its first tiger Action Plan in 1999 and then updated it again in 2007 (2008-2012). Currently all 13 tiger range countries developed and are updating their own tiger action plans and strategies are: Bangladesh Tiger Action Plan (2009-2017), Tiger Action Plan for the Kingdom of Bhutan (2006-2015), Cambodia Tiger Action Plan (2011-2022), China Tiger Recover Plan (2010-2022), Indian Tiger Action Plan (XII Plan period 2012-13 to 2017-18), Conservation strategy and action plan for the Sumatran tiger Indonesia (2007-2017), National Tiger Action Plan for Lao PDR (2010-2020), National Tiger Action Plan for Malaysia (2008-2020), A National Tiger Action Plan for The Union of Myanmar (2003-2007), Tiger Conservation Action Plan for Nepal 2008-2012 and National Tiger Recovery Program for the period of 2012-2016, Strategy for Conservation of the Amur Tiger in the Russian Federation 2010-2020, Thailand Tiger Action Plan 2010-2020, and National Action Plan on Tiger Conservation in Vietnam (2014-2022).

Wild tiger hunting is legally not allowed throughout their ranges. In Bangladesh tiger shooting and killing has been prohibited since 1973 when the Bangladesh Wildlife (Preservation) ordinance 1973 (President’s Order .23 of 1973) was enacted in 1974 under the name of Bangladesh Wildlife (Preservation) (Amendment) Act, 1974. In general, wild tiger killing and shooting is not allowed in any tiger range countries by law. It is listed in Appendix-1 by the Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) means any trade of tiger and tiger-part is banned. However, formulating laws are not enough to save tigers from their sharp decline. Therefore, to conserve the tiger's population and their ecological needs in the changing world, an understanding of tiger habitat requirements is essential (Seidensticker *et al.*1999). By gaining a better knowledge on tiger ecology we are able to be more certain what conservation efforts should be directed where, in order to save tiger and tiger landscapes for future generations to respect and admire (Kitchener and Yamaguchi 2010). Understanding the magnificent carnivore life and their ecological needs is necessary to understand tiger conservation from both local and global perspective in order to help put in context the conservation action needs for tigers in particular setting link it to current and future conservation.

1.2 Morphology

There are considerable variation observed in tiger size, colouration and markings. In general, males are larger and heavier than the females (Table 1.1) and body sizes variation within species and subspecies follows a latitudinal gradient, rather than being discrete to subspecies (Kitchener and Dugmore 2000, Sunquist 2010). Bengal tiger (*Panthera tigris tigris*) of the Indian sub-continent is the largest among all 5 living subspecies although Amur tiger (*Panthera tigris altica*) have long been thought to be the largest (Slaght *et al.* 2005, Sunquist 2010). Surprisingly, very recent the Bengal tigers in the sundarbans have been reported being the smallest tigers of the world with females' body weights of 75-80kg (Barlow *et al*. 2010).

The tiger is one of the easily recognisable cats for its distinctive and unique coat stripes (Kitchener and Yamaguchi 2010).The hair of the body is short showing a typical dark golden-orange background with black stripes which are more prominent towards the rump and thighs. The hair color and length varies depending on location and season. The tigers found in humid tropical forests are darker than the less humid temperate forest and grassland however, variations within population also observed (Kitchener and Yamaguchi 2010). The tail is elongated with an alternate series of black and yellowish rings that end with black. Belly parts are whitish and also a white spot on the black ear is typically visible. The hair of the cheeks from behind the ears towards the sides of the neck is considerably lengthened in adult males (Blanford 1888). The new borns look like the adults, but they are usually brighter.

The skull is large and heavy, the zygomatic arches (bones on the side of the skull below the orbits) are excessively wide and strong, and the crests for attachment of the muscles are highly developed giving the tiger a powerful bite on a formidable set of canines (Blanford 1888, Van Valkenburgh 1987). Male tiger has longer cranium and relatively greater width across the interorbital region, muzzle, rostrum, zygomatic arch, occipital region and of the upper carnassials (Mazák 2004). The short and thick neck, the broad shoulders, and the strong forelimbs allow them to capture prey five times their own body weight (Sunquist 2010).

1.3 Behaviour, life history characteristics, and ecological needs

Tigers occur in a wide range of habitats such as the tropical forests of Southeast Asia, the dry thorn forest of central India, the tidal mangroves of the Sundarbans and the extreme cold areas of Eastern Russia (Seidensticker *et al.* 1999, Sunquist 2010).

Tigers are territorial and maintain their territory in different ways, but mainly by scent marking and scratching on tree bark up to a considerable height. The territory size of a male tiger is normally three times larger than the female tiger but sometimes it can be seven times larger (McDougal 1977, Sunquist 1981, Smith *et al.* 1987, Karanth and Nichols 2002). The size of female tiger home range in south Asian forests is 10-20 km^2 (Sunquist 1981, Karanth and Sunquist 2000, Barlow 2009), whereas in Russian Far East it is 200-400 km^2 (Miquelle *et al.* 1999).

A female occupies her own territory and starts typically breeding at the age of 3-4 years (Karanth and Chundawat*.* 2002). She continues breeding until her territory is been overtaken by another competitor, which usually happens after about 5 to 7 years (Karanth and Chundawat*.* 2002). The breeding male tenures is usually 2-4 years shorter than the female 6-10 years tenures (Sunquist 1981, Smith 1993). Tiger is usually solitary except female with dependent cubs (Nowell and Jackson 1996). During breeding season female is also accompanied by a male for few days (Schaller 1967, McDougal 1977, Sunquist 1981). The gestation period is 103 days, average litter size is 3, but can go up to 5 (Smith and McDougal 1991, Smith 1993). The inter-birth interval is about 21 months (Smith and McDougal 1991). Cubs stay with their mother until they are nearly full-grown and at about 18-24 months old. After leaving their mother they become floaters or transients (Smith 1993, Karanth and Stith 1999).

Tigers usually follow existing human and animal trails, ridge top and river or stream banks as their travel route and takes advantage of the routes to quick move from one hunting spot to another (Sunquist 1981, Karanth and Nichols 2000). The distances tigers travel daily vary from place to place and correlates with the abundance of prey (Karanth and Sunquist 2000). Males travel more than females and can travel 30 km in a night whereas females travel 10 km to 20 km per day (Matiushkin and Smirnov 1980, Sunquist 1981). The least travel distances per night were 3 km in Nagrahole, India where prey numbers are probably the highest of the any tiger landscape (Karanth and Sunquist 2000).

So far not much is known about tiger dispersal however, floaters are known to travel 100 km or more and often cross the territories of several breeding females while searching for their own. Males dispersed three times farther than females, which travelled 10-33 km (Smith 1993), however, one tiger known to disperse 165 km in the same landscape of in Nepal (Sunquist 1981). During dispersal they are tolerated to some extent by the mother and the male that sired them (Karanth and Chundawat 2002). In this specific phase tigers typically show high mortality rates, suffering from starvation, intra-specific fights and human persecution. In general tigers are good swimmers, and have been recorded to cross a distance over 10 km in the Sundarbans (Chaudhuri and Choudhury 1994). During the hot season tigers can be often observed half-submerged in forest streams and pools. In contrast to other cats tigers are not good climbers and therefore rarely ureascend trees, but they can climb slopping trunks.

Prey densities are an important determinant of tiger densities (Schaller 1967, Sunquist 1981, Karanth and Sunquist 1995). Declining principal prey species ultimately reduce the carrying capacity of tigers in an area or female tiger home range became larger (Karanth and Sunquist 2000). Tigers are usually ambush hunters, mostly takes place in the early evening and early morning, sometimes in the late morning and late afternoon (Karanth and Sunquist 2000). For hunting tigers prefer large ungulate rather than medium-sized prey (Schaller 1967, Johnsingh 1983, Karanth and Sunquist 1995). Tigers prefer to kill their prey in dense to moderate cover to take advantage of the darkness of vegetation (Karanth and Sunquist 2000, Sunquist 2010). In general tigers avoid humans, and are reported to give a warning growl in the case of a contact (Sunquist and Sunquist, 2002). Despite typically avoiding humans man eating behaviour has been reported throughout the tiger's range. They accelerate their attack from distances of 15 to 30 m, they do not chase prey for a long time and rarely pursue for more than 150 m (Karanth and Sunquist 2000, Sunquist 2010).

The orientation of killing varies, depends on prey species, size, hunting location and finally tiger size, age and experience but usually attack from the rear but mainly target the prey's neck (Nowell and Jackson 1996, Sunquist 2010). They usually do not eat the kill at the kill site, generally dragging it a few meters to few kilometres from the site. In case of very large prey like adult gaur which are difficult to drag the tiger may start eating at the kill site before dragging the prey away. Tigers prefer to eat the soft muscles, like rump, first (Schaller 1967). Though tigers are powerful hunters but that does not mean they are able to kill their prey without a struggle. Tigers are often injured by their prey's antlers, horns or tusks, may be kicked and trampled by larger animals and sometimes killed outright (Blanford 1888). The success rates of hunting tigers varies depending on prey grouping pattern, densities and individual skills of tiger (Sunquist 2010). Schaller (1964) recorded a rate of 5% for Kanha, whereas

Thapar (2000) found 10% for Ranthambhore and in Russia it was 38% (Yudakov and Nikolaev 1987, Sunquist 2010).

Tigers can eat 15-18 kg meat at a time (Sunquist 2010) although on average they consume 5-6 kg of meat per day and about 3000 kg per year (Sunquist 1981, Sunquist *et al.* 1999). Usually small prey, such as barking deer *Muntiacus vaginalis*, can be eaten in a single sitting, whereas tigers spend up to week feeding on larger prey animals such as adult gaur *Bos gaurus*, sambar deer *Rusa unicolor* and wild boar *Sus scrofa* (Nowell and Jackson 1996). Larger prey items will be guarded by sitting close to the kill and if the tiger needs to leave to drink the remains will be concealed with vegetation and even rocks. In general, Tigers depend on killing one large prey about once a week or about fifty animals per year to reach their food requirements although a tigress with cubs needs more (Champion 1933, Sunquist 1981, 2010). Seidensteicker (1976) reported that a tigress killed one large prey animal every 5 to 6 days when she was with two 6-10 months old cubs. These findings supported a study in India, where a tigress with her three cubs killed one large prey about every 6 days (Chundawat *et al.* 1999).

1.4 Taxonomy

Within the Tiger (*Panthera tigris*), there are 9 subspecies are in the world of which 3 subspecies became extinct in the mid-to late twentieth century (Seidensticker *et al.* 1999). One subspecies, the South China tiger (*P.t. amoyensis)* exists only in captivity. Eight subspecies have been considered classical subspecies (Mazák 1981; Table 1.1). However, the tiger taxonomy (8 subspecies) is traditional are not based on sound scientific principle most are based on limited numbers of specimens (Kitchener and Yamaguchi 2010). The newly proposed subspecies (Luo *et al.* 2004) the Malay tiger, *P. tigris jacksoni* is still not clear as the cranial comparison study did not find difference and the naming subspecies without designated type specimen does not conform to Article 16.4 of the Fourth Edition (1999) of the International Zoological Nomenclature (Mazák and Groves 2006). The taxonomy is now under review process by the IUCN SSC Cat Specialist Group (Kawanishi 2015)

1.5 Distribution

Once tigers occurred throughout Asia, from eastern Turkey to the Sea of Okhotsk (Belsare 2011), but today they are found in only 7% of this historical range (Figure 1.1). The political boundary of current tiger range is Bangladesh, Bhutan, India, Indonesia, Nepal, Thailand, China, Cambodia, Vietnam, Lao PDR, Malaysia, Myanmar, and Russia (Mazák 1996, Nowell and Jackson 1996). The remaining tiger populations occur in isolated areas known as Tiger Conservation Unit (TCU). There are a total of 160 TCUs in existence but most of these populations (61%) are not viable in the long term (Dinerstein 1997, Wikramanayake *et al.* 1999). Tigers once occurred in almost all corners of Bangladesh but now they are restricted to the Sundarbans with a few anecdotal reports from the CHT (Khan 2004, 2011, Ahmad *et al*. 2009).

1.6 Population

Today the estimated size of the global wild tiger population ranges between 3250 and 3750 (Table 1.2) as compared with 6000 in 1998 and 100,000 at the beginning of the twentieth century (Morell 2007, Seidensticker *et al.* 1999, Seidensticker 2010). In Bangladesh Sundarbans the estimated population is 300 to 500 (Barlow 2009). However, the several studies indicating a sharp decline (Hossain *et al.* 2011, Rahman *et al.* 2012) and the recent camera trap study found similar results estimating 83-130 tigers in the Bangladesh Sundarbans (Dey *et al.* 2015).

1.7 Threats and challenges

There are many factors behind the global decline in tiger numbers and the nature of the threats to tigers differs between landscapes and countries. In general, prey depletion (Karanth and Stith 1999) poaching (Jackson and Kempf 1994) and habitat loss (Schaller 1967, Mountfort 1981, Panwar 1987) are the three major known factors of current decline of wild tiger. Most of the tiger range countries themselves are facing several problems such as human population growth and the loss of large amounts of forest which are converted into cultivated land and human settlements. The small fragmented landscapes are not sufficient for long term survival of the wild tiger. The general loss of forest, forest fragmentation and decreasing forest quality ultimately effect the prey population and lead to a decline in prey numbers. This finally affects the tiger population since there is as a positive correlation between prey densities and tiger densities (Seidensticker and McDougal 1993, Karanth 1995). Shortage of prey increases the chance tiger feeding off livestock and ultimately increases the chance of human-tiger conflict. Even in landscapes where destruction of habitat and decreasing prey numbers are absent or minimal tigers are becoming increasingly rare due to tiger poaching.

Tiger are poached mainly to satisfy the demand for tiger body parts in manufacturing traditional Chinese medicine. Based on the demands for tiger parts an illegal wildlife trade system exists worldwide and Bangladesh is not an exception. Despite the fact that the Chinese government strictly forbade any domestic trade in tiger parts in 1993 the illegal harvesting and trade from other tiger range countries is on-going and even increasing (Tilson *et al.* 2010).

Sea level rise due to climate change may affect the tiger population in the Sundarbans of both Bangladesh and India but its influence on other tiger landscapes is not yet clear. Despite such challenges the remaining habitat of both Bangladesh and India still can support good number of tigers if adequate habitat protection can be given. First, governments have to decide whether to protect the national symbol or not and to keep it needs strong political will. Capacity building in forest department and other law enforcement agencies is required to tackle the current poaching pressure of both tiger and prey.

Most of the tiger range countries are poor and unable to handle the challenges on their own. The cooperation between different government bodies such as forest department, civil administration, police and law enforcement agencies and collaborative support from multiple stakeholders (donors, local and international NGOs) can drive the government towards mainstream tiger conservation and awareness building among general public, particularly the local people who are living in and around tiger habitats. The on-going inter-governmental cooperation between the tiger range countries must continue to accelerate the conservation of tigers.

Figure

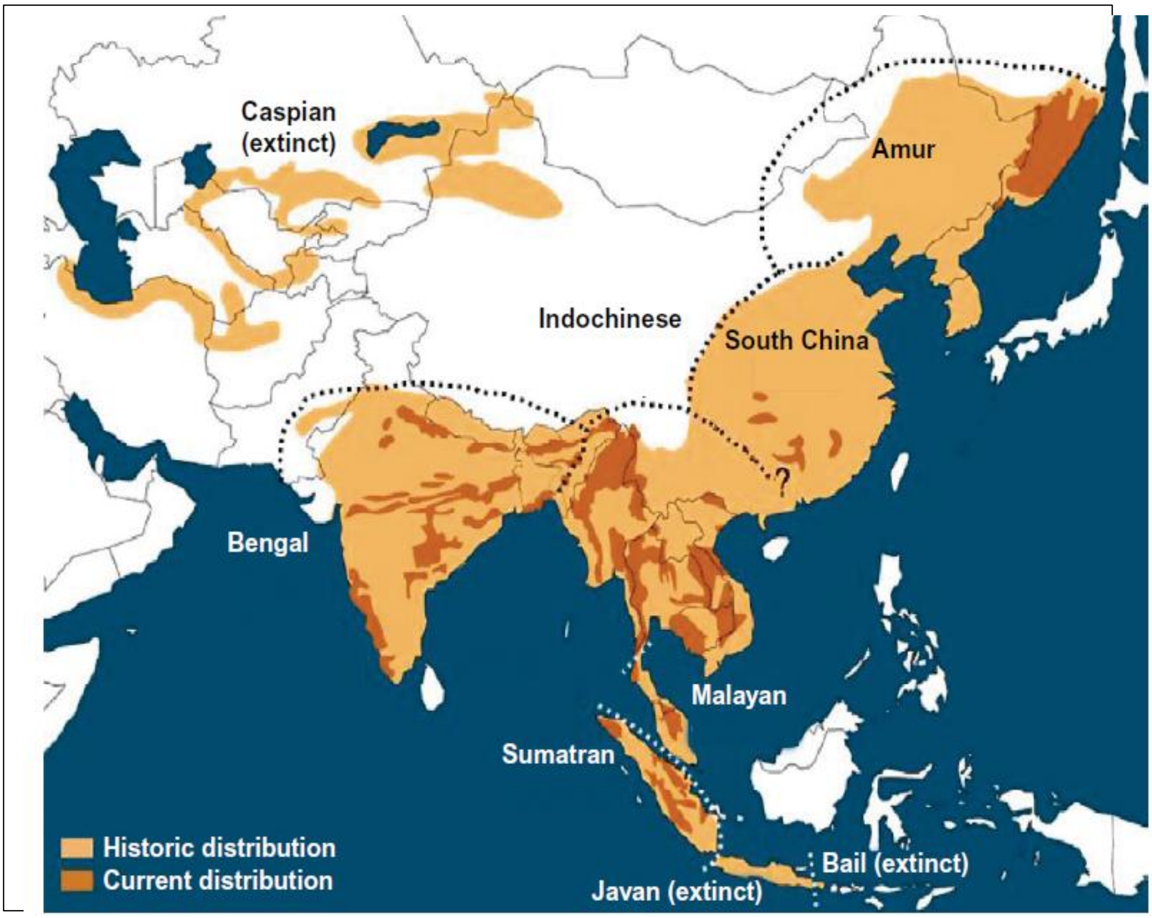

Figure 1.1 Historic and current distribution of tiger subspecies including Malayan tiger. Dotted lines are approximate boundaries between subspecies (modified from Luo *et al*. 2010)

Tables

Table 1.1 Physical feature of the tiger subspecies (from Seidensticker *et al*. 1999; weights from Slaght *et al*. 2005; Bali Tiger taken from Mazák 1981). *Captive tigers

Subspecies	**Physical features**	**Average weight (kg)**	
		Male	Female
Bengal Tiger *Panthera tigris* (Linnaeus 1758)	Reddish-yellow to rust brown, whitish underside, stripes black, ears black and with white spots on outside	221	139
Indo-Chinese Tiger *P. t. corbetti* Mazák 1968	Darker than Bengal Tiger, lighter than South Chinese Tiger	120*	98*
South Chinese Tiger *P. t. amoyensis* Hilzheimer 1905	Reddish-ocher, light belly mane long, mape, mane short	162	93
Amur Tiger *P.t. altaica* (Temminck 1844)	Thick yellowish long coat without red in winter but reddish in summer, belly white extends onto flanks	215	137
Sumatran Tiger *P. t.sumatrae* Pocock 1929	Smaller than Bengal Tiger, stripes closer, cheek hair long, short neck mane	140	86*
Javan Tiger *P. t. sondaica* (Temminck 1844) extinct in 1980	Smaller body size, darker ground colour, greater number of flank strips and stripes are narrower	110*	95*
Caspian Tiger *P. t. virgata* (Illiger 1815) extinct in 1970	Greater numbers of stripes but less wide, longer fur and broader occiput, more brownish on side	156	116
Bali Tiger *P. t. balica* Schwarz 1912 extinct in 1940	One of the smallest tigers	95	72

Table 1.2 Estimated wild tiger population (from Luo *et al.* 2010).

Subspecies	Numbers
Bengal Tiger *Panthera tigris*	1300-2200
Indo-Chinese Tiger *P. t. corbetti*	700-1300
Sumatran Tiger *P. t. sumatrae*	300
Amur Tiger *P.t. altaica*	450
Malayan Tiger *P. tigris jacksoni**	500
South Chinese Tiger *P. t. amoyensis*	extinct in the wild
Total	3250-3750

*Mazak and Groves (2006) found no clear morphological differences between tigers from Peninsular Malaysia *P. tigris jacksoni* and those elsewhere in Indochina *P. t. corbetti*

Chapter 2: The Chittagong Hill Tracts (CHT)

2.1 Introduction

The Chittagong Hill Tracts (CHT) is a unique area in terms of landscape, people and culture compared to the rest of Bangladesh and is well-known for its scenic beauty (Khan *et al*. 2012). It falls under the Indo-Burma hotspot, one of the 25 biodiversity hot-spots of the world (Myers *et al.* 2000). The flora and fauna of the CHT resembles that of Southeast Asia more than of the Indian mainland. The people were once known as Jhumiadue to their special crops growing system on the hill slopes, which is called Jhuming and also known as shifting cultivation. This type of cultivation system is also practiced in other parts of the world including Nepal, India and other south east Asian countries.

Once the CHT was covered with dense forests of valuable trees but now the forest is highly degraded and fragmented and the remaining forest also lost its original form. The causes of deforestation have long been an issue of debate. The traditional shifting cultivation is considered to be reason for the forest degradation (Forestal 1966, Hamid 1974, Farid and Hossain 1988). This cultivation system impact was not adverse in the past when there was less population pressure on land but the impact gradually increases with the increase of local population and state sponsored migration of the lowland people to the CHT (Gain 2002, Knudsen and Khan 2002). Therefore degradation of the CHT forest is not only the result of traditional cultivation practice but also of other factors including inappropriate state policies and programmes (Rasul 2007).

For a long period the CHT was a remote area where only a few routes, including some navigable rivers, offered limited access. In the recent past it was not only a remote but also an access restricted area due to insurgency. Therefore the whole CHT area was unexplored and only a very few publications can be found, most of them addressing human right violation, state policy and social unrest.

After the peace accord between the Bangladesh Government and Parbatya Chattagram Jana Sanghati Samity (PCJSS, the Political party of ethnic people fought for autonomy and the recognition of ethnic identity in the CHT) in 1997 led to the disarmament of Shantibahini the arms wing of PCJSS, The accord is opened the door for researchers and NGO's has resulted many academic thesis and publications in recent years. However, these publications have mainly focused on the ethnic conflict issues (Rahman 2011) shifting cultivation and its impact on the environment and biodiversity (Chowdhury 2001, Rasul *et al.* 2004, Bai 2006, Rasul 2007, Biswas *et al.* 2010). Apart from the recent publications some older reports and books, mainly written by colonial administrators, researchers and travelers, are Buchanan 1798 (van Schendel 1992), Lewin (1869), Hunter *et al.* (1876), Mills (1931) and Hutchinson (1909). Though the old documentation was administrative in purpose but it is also the oldest ethnographic account and has so far remained the main source on the CHT. The first manuscript written by Buchanan (1798) was preserved for a century until unveiled by Willem van Schendel (1992). Books in Bengali are mainly focused on insurgency and few are on traditional life, the history of local inhabitants or a particular ethnic group.

The objective of this chapter is to collate the existing information on CHT in relation to:

(a) geopolitical features, (b) topography, (c) climate, (d) biodiversity, (e) culture, (f) forest management; and (g) use of natural resources.

The information is collected mainly from historical sources such as colonial reports, official documents (i.e. gazetteers and official correspondence), the dairies of colonial administrators, travelers, journals, and other grey literature sources. They were critically examined and then supplemented by information from field visits.

2.2 Geopolitical features

The Chittagong Hill Tracts area was first documented on a Bengal map around 1550 AD by the Portuguese cosmographer João Baptista Lavanha during his attempt of illustrating the text of *The Fourth Decade of Asia* by João de Barros (Boxer 1981, Mathew 1988, van Schendel 2004).Unlike other parts of Bangladesh the early history of Chittagong including the CHT is not fully understood. Historically the present CHT was never ruled by a single ruler until 1860 when British officially brought it under Bengal administrative by declaring a separate district by the Act XXII (Lewin 1869, Roy 2002). Though only 1.5% of total CHT population was Bengali Muslim (census, 1941) but during the independence of India and Pakistan in 1947 the region fell under former East Pakistan (present Bangladesh). At present the CHT includes three separate administrative districts Rangamati, Khagrachari and Bandarban, compromises a total area of 13,295 km^2, approximately 9% of Bangladesh located between 21°25′-23°45′N and 91°45′ -92°-50′ E (Figure 2.1).

2.3 Topography

The CHT is a part of the 1800 km mountain range which runs from the eastern Himalayas in China to western Myanmar (Gain 2000). The CHT borders Myanmar to the southeast, the Indian states of Tripura to the north and Mizoram to the east. The ground configuration of the area is rough, irregular and characterized by longitudinally aligned hill ranges and river valleys. A series of ridges runs more or less in a north to south direction across the CHT the heights of which vary from about 700 m in the north to more than 1000 m in the south found in the Mowdok Mual range on the border of Myanmar in the south (Islam 2003, Islam *et al.* 2007). These hill ranges were formed in the Tertiary period and are the oldest geological formation in Bangladesh (Rashid 1977). The highest peak is Keokradong (21°56′59″N 92°30′51″E) with an altitude of 986 meters point in but some sources claim the Saka Haphong (21°47′18″N 92°36′33″E) is the highest point of the country with an altitude of 1060m, both are located in the region. From these main ridges innumerable spurs branches off to form hills and valleys drained by winding streams.

The CHT can be divided into seven major valleys formed by its principal rivers and their tributaries the Feni, Karnafuli, Chengi, Myani, Kassalong, Sangu, Matamuhuri (Shelley 1992). In total about 1400km of streams and rivers flow over the CHT (Khan *et al.* 2007). Typically rivers in the CHT run from north to south but a few, such as the Sangu and Matamuhuri, ran from the south to the north and then again to the southwest before finally falling into the Bay of Bengal with the exception of the Chengi, Maini and Kassalong rivers flow north to south like other rivers of the country. The Kassalong has a big tributary in the Maini River. The rivers in the CHT form large, somewhat palmate, lowland valleys between the mountain ranges. Almost the whole of the Karnafuli Valley and the lower reaches of its tributaries are today submerged due to the construction of the Kaptai Dam over the river Karnafuli in 1962 (Rashid 1977).

2.4 Climate

The CHT receives a subtropical monsoon characterized by seasonal variation in rainfall, temperatures and humidity, with a long dry and cool season extending from November to May (Chaudhury 1973). April and May are considered to be a pre-monsoon season with high temperatures and the proper monsoon usually starts at the end of May or the beginning of June and continues until September (Lewin 1869, Islam 2003). The prevailing winds are from the south-west between March and May, from the south-east between June and September and from the north-west between October and February. The average temperature varies from 14°C in January to 33°C in April. The maximum highest temperature was recorded at 40.5°C during May 1995 and minimum recorded was 5.5°C in February 1961. The average rainfall is highest in July with 572.6 mm and lowest in January with 5.1 mm (Bangladesh Meteorological Department, Rangamati Station). The humidity is high throughout the year with a peak in July and August. The mean humidity is approximately 78% in Bandarban and 76% in the other two administrative districts. During the last 10 years, the annual precipitation was lowest in 2006 with 22,494 mm and highest in 2004 with 30,611 mm (Bangladesh Meteorological Department).

2.5 Biodiversity

The CHT has the richest biodiversity of any area in Bangladesh. The natural habitat was once made up of semi-evergreen forest dominated by tall trees belonging to *Dipterocarpaceae, Euphorbiaceae, Lauraceae, Leguminacae* and *Rubiaceae* families (Ishaq 1971). However, less disturbed native habitat now only exists as scattered patches of primary forest in the northernmost and southernmost parts of the area both areas are remote and difficult to access. Areas of degraded forests are largely made up of shrubs and bushes and consist mainly of different weeds and tall grass species including Sun grass (*Imperata cylindrical*) and exotic Asamlata (*Eupatorium odoratum*). The notable plant species once found are hardly seen particularly has timber value (Table 2.1). Once abundant bamboo species such as Kaliseri (*Teinospachyum dulloca*), once dominated in the Gangaram area of the Kassalong Reserve Forest but are now hardly seen probably the species is sensitive with the change of soil composition (physiochemical or mineralogical) because of top soil erosion for habitat degradation and other anthropological stress.

Notable mammals previously reported from the CHT are elephant *Elephas maximus*, tiger *Panthera tigris*, leopard *Panthera pardus*, asiatic black bear *Ursus thibetanus*, sun bear *Helarctos malayanus* dhole *Cuon alpinus*, gaur *Bos gaurus*, sambar deer *Rusa unicolor*, hog deer *Hyelaphus porcinus* and barking deer *Muntiacus vaginalis*, hoolock gibbon *Hoolock* . The mammalian faunal diversity of CHT is likely as rich as it has been historically. However, some well-known species of animals which once had a wide distribution are now either extirpated or edge of extirpated due to hunting and habitat lost. The CHT is home to the richest avifauna of the country and is the only area to support the species of birds typically found in tropical evergreen forests in addition to species found in open and cultivated areas. To date there has not been an extensive faunal survey in the CHT except for a few anecdotal observations from colonial civil servants and few limited observational reports without any specific study (Table 2.3).

2.6 People and Culture

The oldest census report in the CHT came in 1871 where the total population was 63,054 and 61,957 (98.26%) was the ethnic and rest (1.74%) was Bengali both Hindu and Muslim. The plain land (Bengali) population gradually increased and they are now about the half (47.1%) of the total CHT population (Figure 2.3).The original inhabitants of the CHT belong to 11 different ethnic groups: Bawm, Chak/Sak, Chakma, Khumi, Khyang, Lusai, Marma, Mro, Pankhua, Tanchangya, and Tripura. Chakma is the largest ethnic group with approximately 422,905 individuals, about 26% of the total CHT and about 50% among the ethnic population of the CHT. The total population in the CHT is 1,598,231 which is about 1% of the National population (BBS 2011).

The livelihood of most ethnic groups in CHT is traditionally based on Jhum or shifting cultivation for growing crops such as rice, but most of the Chakma and Marma, who are riverside dwellers, have now changed towards plough cultivation. The people of the CHT have had a long economic relationship with mainstream Bengali people and now most of the ethnic groups have adopted with mainstream Bengali culture. However, distinct cultural identities including unique languages and dialects, both in written and oral forms, are still maintained and more remote areas are considerably less integrated with mainstream Bengali culture. Whilst local languages and dialects are still prevalent they are not officially used in the education system.

The dominant religion of the indigenous people in the CHT is Buddhism, practiced by the Chakmas, Marmas, Tanchangya and partially by the Mros, Lusais, Pankhos and Bawams. Insignificant numbers of Chakmas are Christian and very recently many Mros and Tripuras (mostly reang clans) have converted to Christianity under the influences of missionaries. The Tripura largely adhere to Hinduism whilst the Mros are animist although a few of them have converted to Buddhism, Christianity and Krama, a set of religious teachings developed by Menley Mro during the mid-1990s. The Bengalis are predominantly Muslims with some Hindus. All ethnic communities are traditionally patrilineal with the property transmitted from father to son but recently many families have begun giving property to daughters as well. All ethnic groups have their own social and administrative structure, starting from village level. The village head (Karbari) is usually appointed by the villagers themselves and is responsible for all internal matters relating his village. The British restructured the old system and introduced a headman in charge of a Mauza, a territorial unit of jurisdiction consisting of a number of villages. The headman was responsible for revenue collection, allocation of land and conservation of natural resources and also dealt with other unresolved matters brought to their attention by Karbari or villagers. At the highest level is the chief or Raja (king) who has authority over a territory or circle consisting of several Mauzas and collects revenue from the headmen (Ishaq 1971, Roy 2000).

2.7 Forest Management

The official management of the forest and forest parts started in 1865 after a forest inspection by the Inspector General Sir D. Brandis (Chaudhury 1973). The Chittagong forest division was created in 1872 and was the first division to be created in present Bangladesh. In 1871 most of the CHT area (9123 km^2)

was declared as governmental forest and the CHT forest division separated from Chittagong in 1909 (see Appendix A).

Declaring the CHT as government forest opened the way for the exploitation of the forest and even a few years ago the sole objective of forest management was to collect revenue by extracting the natural resources without any concern of wildlife and conservation. Management plans were just an annual basis guideline for determining the quantities and locations of tree cutting with some basic plans on reforestation to cover the cleared forest. Today forest management activities themselves have not changed much although the objectives have changed.

There are three different forest types in the CHT being managed by the Forest Department under the Ministry of Environment of Forest (MoEF): protected areas (PAs) cover 498.82 km^2 (3.75%) of CHT, reserve forests (RFs) cover 3221.94 km^2 (24.43%) and unclassed state forest (USFs) cover rest of the area (partially managed by MoEF). The other areas of forest are not categorized under these three categories and are considered as private forests. The USFs are a residual category of partly forested lands, under the control of district collectorates under the Ministry of Land (Roy 2002).

Currently the CHT forest is managed by nine forest divisions under two circle offices under two Conservator of Forests (Figure 2.4). At present the forest management is almost limited to plantation forestry which is directly monitored from the Planning Division located in Chittagong. Forest management for wildlife protection is not yet functional despite concerns for wildlife protection being raised in 1966 when a World Wildlife Fund (WWF) expedition report prompted the Chief Secretary of the Agriculture Department to issue a letter to the Chief Conservator of Forests (CCF) concerning the indiscriminate and illicit shooting of animals in the CHT (Mountford and Poore 1968). A National park (Kaptai) and two Wildlife Sanctuaries (Pablakhali and Sangu) have also been established but the three PAs are not directly controlled by the Wildlife and Nature Conservation Circle.

The national forest policy was formulated in 1994 but the objectives are still more commercial than conservation oriented encouraging rubber and other rapid growing tree plantations and supplying raw materials for the paper industry from reserve forests. There was an attempt to practice social forestry as is done in other parts of the country but this failed due to disagreements between the local people and the government regarding land ownership. In addition to government management of forests, the ethnic groups have their own management practices known as village common forest and many forest regulations conflict with traditional management systems. Forest Department does not have sufficient capacity to adequately regulate the existing illegal extraction and logging.

2.8 Human use

The utilization of natural resources is part of the daily livelihood of communities in the CHT and many of the resources used by ethnic communities are renewable. Besides that non-renewable resources have also been reported in various places in the CHT but adequate information is not available. Extensive geological surveys have never been completed and a feasibility study has not been done on existing resources such as limestone, coal and gas. The Semutang situated in Khagrachari district is the only gas field in the CHT and produced over 12.17 million standard cubic feet (MMSCF) per day in April, 2012 and production fell down to 7.10 MMSCF in June 2013 (BAPEX 2013). The renewable resources used by the people can be classified into 3 categories:

2.8.1 Land-based resources

Land is the sole means of livelihood and agriculture is the main occupation of the majority of the people in the CHT. The traditional economy is mostly land-based agriculture or jhuming. According to Forestal (1966) only 3.07% of land is suitable for all types of agriculture or plough cultivation (Table 2.2). The percentage is actually less because the reserve forests were not included within the total area in Forestal's study. Due to the scarcity of suitable plough land the hill slopes is the main sources for cultivation have been using for traditional Jhum cultivation. At present, people would prefer to use plough cultivation but the scarcity of suitable land for ploughing forces them to continue traditional jhumming. The social and economic transformation in the CHT is clearly illustrated by the changing mode of traditional systems. A growing section of ethnic population has now taken non-traditional economic activities and grows market-oriented crops including agro-forestry and horticulture (Roy 2002). The infrastructure development such as road construction and increasing availability of modern transport have made it easy to shift people from one place to another ultimately increases the rate of extraction of forest resources. Other gross factors which are directly influencing the changes of forest resource use patterns are: raising the water level of the Kaptai reservoir, state sponsored settlement of plains people, population growth, insurgency and dislocation though factors are interlinked with each another. People got settled in the reserved areas and started cultivation in their own way. So the CHT land use patterns are now different to those assessed by Forestal due to many factors. All factors made difficult to assess exactly how much land is being used for cultivation including horticulture, agro-forestry, settlement and other purposes. No contemporary reports are available on land use system in the CHT but there is no doubt it is not same as the categorized by Forestal in 1966.

2.8.2 Forest-based resources

Forestry has been considered as the largest sector of the economy in the CHT with more than three quarters of land suitable for forestry (Forestal 1966). There are not many differences between land-based and forest based resources traditionally used by ethnic people for their livelihood. Ethnic life and culture cannot be imagined without forests and they traditionally consider forest as common property. Bamboo is the prime forest resource and forms an integral part of ethnic life and livelihood. In his account of ethnic life in the CHT Lewin (1869) states: "*The bamboo is literally his staff of life. He builds his house of the bamboo, he fertilizes his fields with its ashes; of its stem he makes vessels in which to carry water; with two bits of bamboo he can produce fire; its young and succulent shoots provide a dainty dinner dish; and he weaves his sleeping mat of fine slips thereof. The instruments with which his women weave their cotton are of bamboo. He makes drinking cups of it, and his head at night rests on bamboo pillow; his forts are built of it; he catches fish, makes baskets and stools, and thatches his house with the help of the bamboo. He smokes from a pipe of bamboo; and from bamboo ashes he obtains potash. Finally his funeral pile is lighted with bamboo.*" Even today not much has changed from the life illustrated by Lewin more than 150 years ago.

Traditionally people have been exploring the forest resources in harmony with the nature and they collect forest resources for their daily needs not for cash earning. However, increased population pressure has caused over harvesting of forest resources and has created scarcity of forest products. Therefore, the people of the CHT have been forced to change their traditional attitude to forest resources and their livelihood. In contrast to their traditions and due to economic hardship, the ethnic people now extract forest resources and sell them in order to support themselves. Hunting and gathering wild animals was common practice for all communities but, due to the rarity and scarcity of animals, this practice is now restricted to remote areas. In remote areas people's protein requirements come directly from wild sources either by fishing nearby streams, hunting wild animals or rearing poultry. Apart from some urban areas (district headquarters) a significant proportion of daily vegetables and firewood comes directly from forest. Besides local use the CHT forest also supplies timber and other non-timber forest products to other districts of the country. The CHT supplies about 40% of the commercial timber production of the country (Gain 2002). Karnafulli Paper Mill started production in 1953 and is the only mill in the CHT that requires large amounts of forest resources, in particular bamboo and wooden logs which are the raw material for making the pulp. There are thousands of timber based small–scale cottage industries in the CHT that demand high quantities of commercial wood supplied from both private and state owned forest. About 35% of the rattan supplied to the rattan based furniture makers in the Chittagong area comes directly from the natural forests of the CHT (Miah and Rahman 2002).

2.8.3 Water-based resources

Bangladesh is a land of rivers and wetlands. The people's livelihood is highly connected with the country's rivers and wetlands. In the CHT rivers also played an important role for human life although solely river-based livelihoods have never been observed. Water-based livelihood in the CHT started after the creation of the Kaptai Dam. The dam created a large lake, the area of which varies between 268 km^2 in May and a maximum of 742 km^2 in October (BBS, 2004). Thousands of people's livelihoods now depend on the Kaptai Lake, most from directly fishing the lake, and a significant proportion of Bangladesh's inland open water fish production comes from the Kaptai Lake. These fishermen are mostly from Bengali communities, however, ethnic people are also involved with about 750 (25%) of the 3000 registered fishermen from ethnic communities (Rafi and Chowdhury 2001, Islam *et al*. 2007). At present the average annual production of fist is more than 7,000 metric tons (Mahmood and Hai 2003)

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Figures

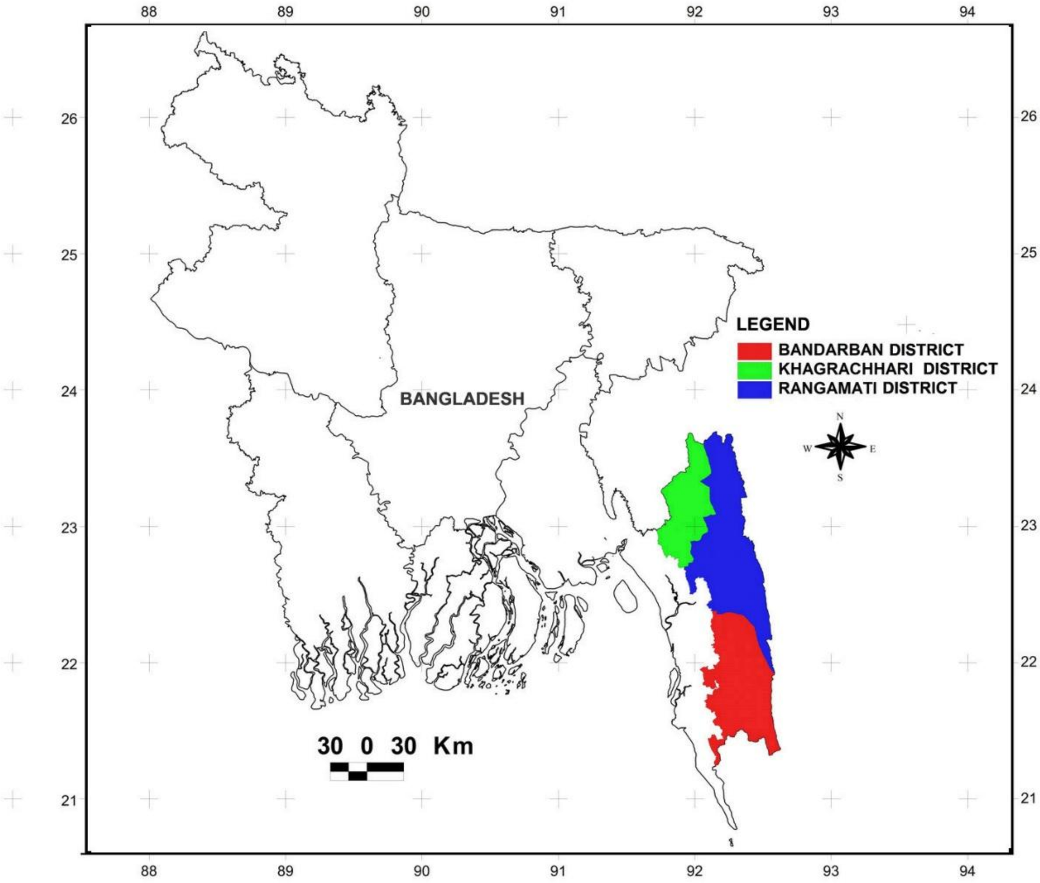

Figure 2.1 Map of the CHT of Bangladesh

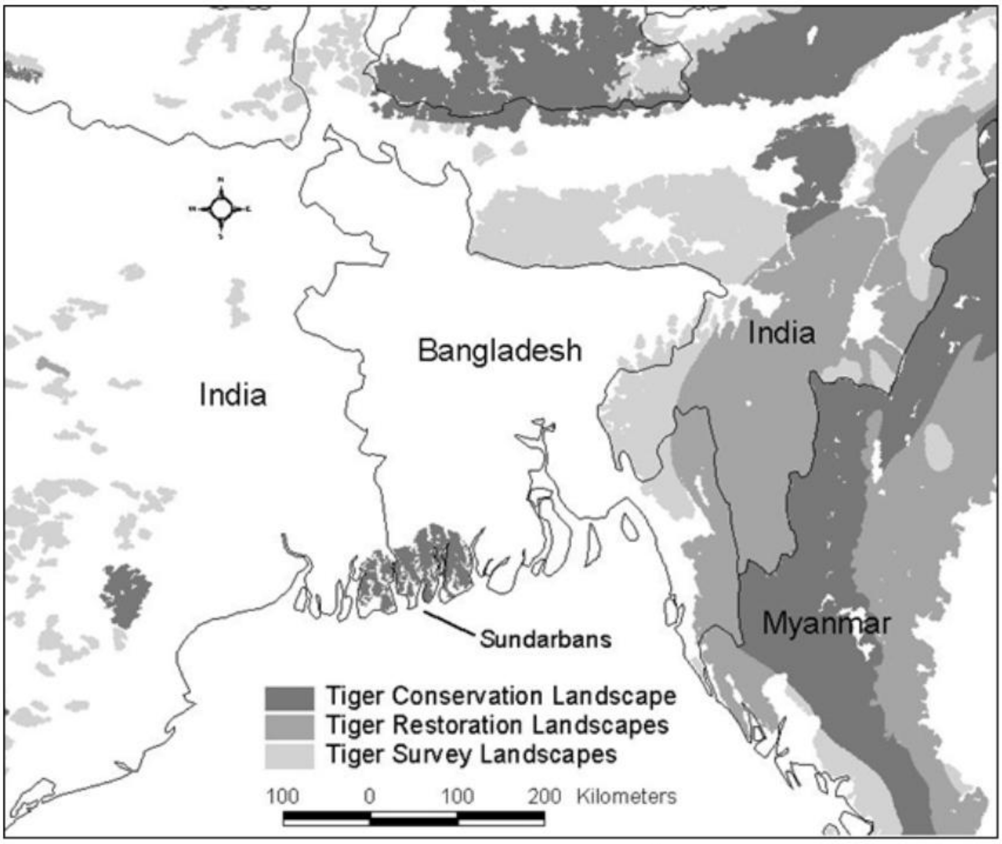

Figure 2.2 Map of different Tiger Landscapes of Bangladesh (from Sanderson *et al*. 2006)

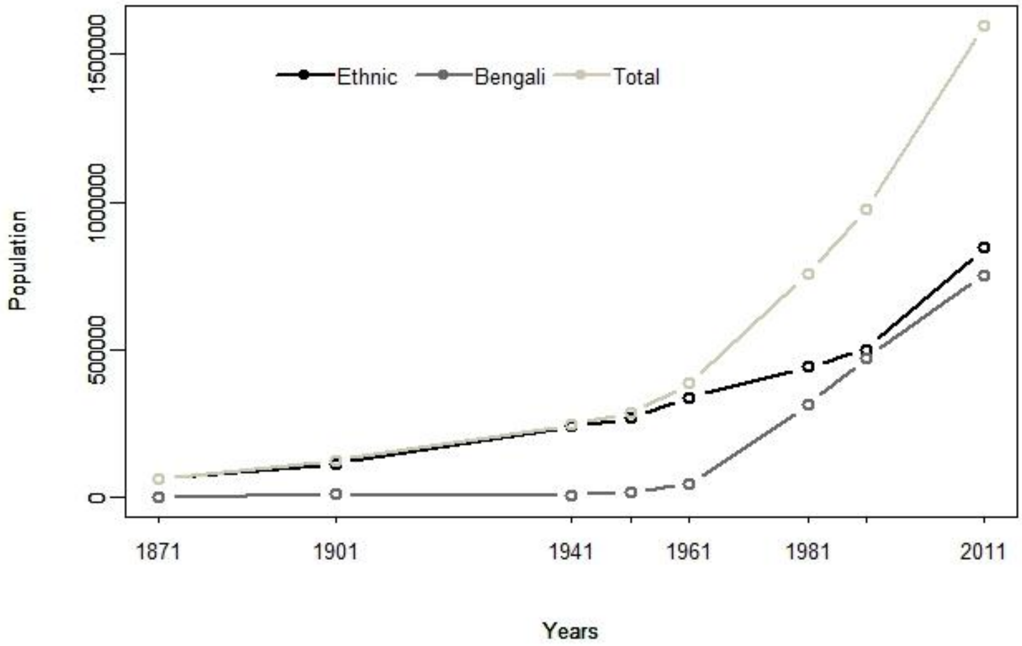

Figure 2.3 Population growth in the CHT (1871-2011)

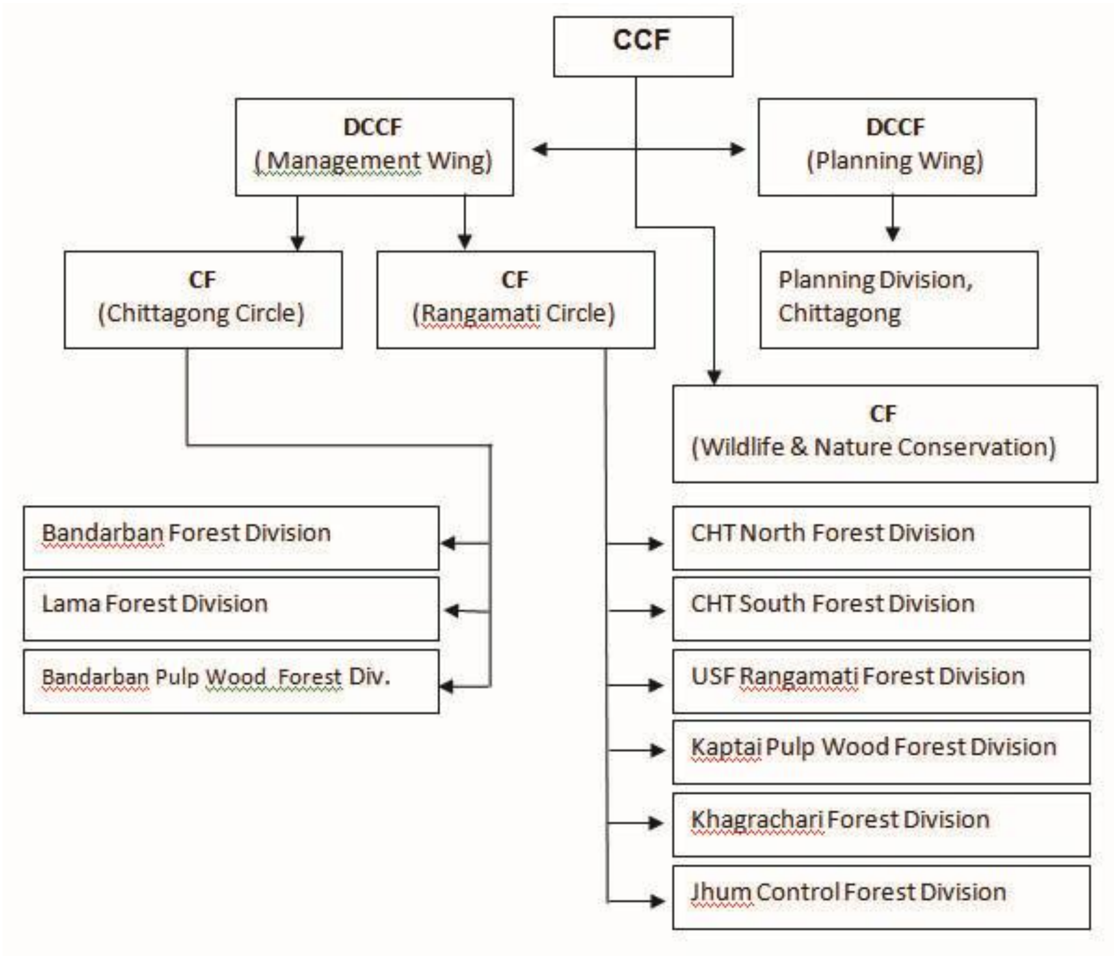

Figure 2.4 Forest Department administration in the CHT

Tables

Table 2.1 Notable plant species of the CHT (from Ishaq 1971)

Local (Bangla) name	**Scientific name**
Banderhola	*Duabanga sonneralisides*
Batna	*Quercus spp.*
Chalmugra	*Taraktogenes kurzii*
Chalta	*Dillenia indica*
Champa	*Michelia champaca*
Chapalish	*Artocarpus chapalisha*
Chikrassi	*Chickrassia tabularis*
Civit	*Swintonia floribunda*
Chundul	*Tetrameles nudiflora*
Daki jam	*Syzygium grande*
Garjan	*Dipterocarpus* spp.
Gamari	*Gmelina arborea*
Jarul	*Lagerstroemia speciosa*
Kadam	*Anthocephalus kadam*
Koroi	*Albizia* spp.
Nageswar	*Mesua ferrea*
Arsol	*Vitex* spp.
Bohal	*Cordia myxa*
Bohera	*Terminalia belerica*
Boilam	*Anisoptera glabra*
Gutgutya	*Protium serratum*
Haritaki	*Terminalia chebula*
Ranghat	*Adina cordifolia*
Shilbhadi	*Garuga pinnata*
Simul	*Salmalia* spp.
Telsur	*Hopea odorata*
Udal	*Firmiana colorata*

Table 2.1 (Continued)

Local (Bangla) name	**Scientific name**
Gallak	*Calamus flagellum*
Kerak	*Calamus latifolius*
Muli	*Melocanna bambusoides*
Dholu	*Schizostachyum dullon*
Mitinga	*Bambusa tulda*
Orah	*Dendrocalamus longispathus*
Kaliseri	*Gigantochloa andamanica*

Table 2.2 Classification of Land in the CHT and Landuse potential by Forestal (1966) (excluded the area of Reserved Forests cover about 3237.49 km²).

Classification	Land Type	Total Area		Landuse potential
		km²	Percentage	
Type A	Plainland	309.45 km²	3.07%	All types of agriculture, mostly paddy and crops
Type B	Gentle hill slope	274.66 km²	2.72%	Terrace cultivation, both for crops and horticulture
Type C	Hill Slope	1483.66 km²	14.71%	Mostly for horticulture and partly for forestry
Type D	Hills	7353.11 km²	72.91	Only for forestry and not suitable for any type of agriculture
Type E	Hill tops	129.60 km²	1.18%	Forestry and agriculture only after deep terracing
		2.64 km²	0.03	Settlement
		532.72 km²	5.28	Water bodies
	Total	10085.84 km²	100	

Table 2.3 Sources where partially discussed about the CHT flora and fauna

Year	Author(s)	Title/Subject	Note
1798	Buchanan (Hamilton)	His Journey to Chittagong,the Chittagong Hill Tracts, Noakhali, and Comilla	First document mentioned on CHT wildlife
1869	Lewin	The Hill Tracts of Chittagong and the Dwellers Therein	Ethnology, mentioned many lage mammal species
1882	Dr. Emil Riebeck	The Chittagong hill-tribes : results of a journey made in the year 1882	Ethnology; translated by A.H. Keane
1875	Hooker and Thomson	Flora Indica Vol. 1	
1876	Hunther WW	A statistical account of Bengal, vol 6	listed major plant and animals
1879	Pollok	Sports in British Burmah, Assam, and the Cassyah and Jyntiah Hills	
1879	Sanderson	Thirteen Years Among the Wild Beasts of India	Described modes of elephant capturing in CHT
1885	Blanford	The Zoology of Dr. Riebeck's “Chittagong Hill Tribes” —The Gayal and Gaur	
1896	Clay	Leaves from a Diary in Lower Bengal	
1903	Prain	Bengal Plants Vol 1-2	
1906	Hutchinson	An Account of the Chittagong Hill Tracts	
1909	Hutchinson	Eastern Bengal and Assam District Gazetteers: Chittagong Hill Tracts	
1925	Haining	List of Plants of Chittagong Collectorate and Hill Tracts	
1958	Bessaignet	Tribesmen of the Chittagong Hill Tracts	Ethnography
1967	Husain	Expedition to Chittagong Hil Tracts (Bandarban Subdivision), 1965	
1967	Husain	On the occurrence of some birds of Chittagong hill Tracts	
1967	Rashid	Systematic list of the birds of East Pakistan	General checklist
1969	Chaudhury	Wildlife of Chittagong Hill Tracts-A list of mammals and Birds	The year of publication need to confirm
1970	Chaudhury	List of Wildlife of Chittagong Hill Tracts- Mammals and birds	The year of publication need to confirm
1969	Mountfort and Hosking	The vanishing Jungle	WWF expedition
1969	Husain	Field notes on the birds of the Chittagong Hill Tract	
1971	Ishaq	Bangladesh District Gazetteers: Chittagong hill tracts	
1973	Choudhury	Forest management Plan	listed 228 major plants and 88 mammals
1975	Husain	Birds of the Pablakhali Wildlife Sanctuary (The Chittagong Hill Tracts)	

1976	Husain and Haque	Further addition to the list of birds of Pablakhali Wildlife Sanctuary	
1977	Husain	The White-winged Wood Duck	
1982	Husain and Haque	The White-winged Wood Duck project Report	The last sighting report of White-winged duck
1969	Khan and Banu	Angiosperm flora of CHT	
1981	Ahamad	With the wild animals of Bengal	Hunting experiences
1982	Gittins and Akond	What survives in Bangladesh?	
1982	Khan	Wildlife of Bangladesh-A Checklist	
1984	Khan	The endangered mammals of Bangladesh	County checklist
1988	Sarker and Sarker	Wildlife of Bangladesh: A Systematic List with Status, Distribution, and Habitat	
1989	Rahman	Fishes	All bangladesh
1991	Halder *et al.*	Fishes	Kaptai Reservoir
1998	Uddin *et al.*	Plant	study conducted in very small area
2003	Asmat *et al.*	Amphibians	
2006	Islam *et al.*	Conservation of the Hoolock Gibbon (*Hoolock hillock*) of Bangladesh	Distribution of Gibbon in CHT and other areas
2007	Chakma	Fishes; 71 species of fish including 5 exotic and 2 species of prawn	Kaptai Lake
2007	Asmat and Hannan	Checklist	
2007	Mujaffar *et al.*	Hoollock Gibbon	
2008	Mahony and Reza	Herpetofaunal collection from the Chittagong Hill Tracts	
2008	Khan	Protected areas of Bangladesh: A guide to wildlife	General country checklist with many photographs
2009	Rasul	Land use environment and development experiences from the CHT of Bangladesh	Very comprehensive work (Ph.D. Thesis)
2009	Uddin *et al.* (eds.)	Encyclopedia of Flora and Fauna of Bangladesh Vol 27 Mammals	Multivolume edited by many person
2013	Ahmed *et al*.	Biodiversity of hillstream fishes in Bangladesh	Listed most of the species found in upstream
2013	Islam *et al.*	Bear	

Chapter 3: Distribution patterns of medium to large mammals in the Chittagong Hill Tracts (CHT) of Bangladesh

3.1 Abstract

Medium to large animals are vital for any large carnivore conservation, and their spatial distribution and abundance information is crutial to assess any species or group to evaluate the trend and initiate any conservation measure and effectiveness. I have conducted a survey on medium to large mammals distribution applying the track and sign survey and estimated their occupancy. I modeled the species occurrence in relation to ecological and human made covariance's using programme PRESENCE. A total of 13 species of carnivores and 5 species of Artiodactyls recorded from track survey. Gaur *Bos gaurus* thought an extirpated species of Bangladesh has rediscovered. Barking deer *Muntiacus vaginalis* was found the most widely distributed species and 100% occupancy in surveyed area folllowed by wild boar *Sus scrofa* (0.81, SE = 0.08; CI = 0.60-0.92) and sambar deer *Rusa unicolor* (0.73, SE = 0.13, CI = 0.41-0.91). Among the large carnivores asiatic black bear *Ursus thibetanus* was found highest (0.62, SE = 0.18; CI = 0.26-0.88) followed by golden cat *Felis temminki* (0.59, SE = 0.15; CI= 0.29-0.83), leopard *Panthera pardus* (0.46, SE = 0.18; CI= 0.16-0.79) and dhole *Cuon alpinus* (0.45, SE = 0.16; CI = 0.18-0.75). No tiger *Panthera tigris* signs were found except a few killing reports in last ten years. The availability of primary forest was found important for the occurrence of medium to large mammal species. Presence of barking deer and sambar deer along with primary forest was found important factor of predicting occupancy of leopard *Panthera pardus*. Although the occupancy estimated only for the area where survey conducted and was not extrapolated to the rest of the CHT but these results could be a base line data for future study.

3.2 Introduction

Mammals are one of the important ecological components of all terrestrial ecosystems (Cole and Wilson 1996). Conservation of large mammals such as tiger is a global priority due to the critical roles they play in maintaining a functional ecosystem. Studies from a widely various types of ecosystems all agree that the conservation of tigers will lead to conservation of all the attributes of a healthy ecosystem (Steneck 2005). Large mammals are sensitive (Sodhi *et al.* 2010) often to first species to disappear upon human disturbance (Morrison *et al.* 2007). Large carnivore species, such as the tiger (*Panthera tigris*), often function as indicator and keystone species (Mills *et al.* 1993), and thereby maintain the stability and biodiversity in an ecosystem (Terborgh 1988). Despites large carnivores large bodied ungulates are among major ecological drivers shaping the structure and functioning the terrestrial ecosystem (Danell *et al.* 2006, Terborgh *et al.* 2008). However, in recent years, tiger population and their sympatric predators such as leopards (*Panthera pardus*) and dholes (*Cuon alpinus*) have been declining from many Asian forests due to prey depletion, poaching and habitat loss; thus assessment of status and distribution of medium (>5 kg) to large mammal (>20 kg) species in an area is necessary to gain an understanding of the health of the ecosystem and crucial for the development and implementation of any conservation management decisions (Brashares *et al.* 2001, Parks and Harcourt 2002). However, such information are not available for the CHT, the important landscape of Bangladesh considering both cultural and biological diversity. Moreover, the available informationis not reliable to any current management decision because these either not based on scientific study or outdated. Further the CHT is also expected an important corridor from zoogeographical point of view as it falls under two bioregions: Indian Subcontinent Bioregion and Indo-China Bioregion (Wikramanayake *et al.* 2002). Thus, baseline information on faunal distribution and abundance in the CHT is highly important to understand the current status of medium to large mammals and their conservation potential including tigers.

Many large mammal species names are found in historical books and reports such as sumatran rhinoceros (*Dicherorhinus sumatrensis*), elephants (*Elephas maximus*), tigers (*Panthera tigris*) and sambar deer (*Rusa unicolor*) rather than providing general mammal diversity list and spatial distribution. The first concern about the wildlife declining in the CHT came from the WWF's first expedition report led by Mountfort (1968). The first scientific paper on the mammals diversity in the CHT was published by Chaudhury (1969) has been cited in many books and reports mentioning different years (Harvey 1990, Sarker and Sarker 1988, Islam and Islam 1997, Khan *et al.* 2000, Nishat *et al.* 2002, Khan 2005). Besides Chaudhury (1969), Husain (1974), Chowdhury (1984) and Khan (1982, 1985) also mentioned many mammals species occurrence without any spatial and specific reference. Ahmad (1981) had associated with the CHT forests for long time from 1930 to 1958 who has narrated his encountering experiences with many large mammals such as the elephant, tiger, leopard, wild goat (serow), and bison (gaur). The partial assessments of mammal species conducted in the CHT were restricted to elephants (Aziz 2002, IUCN-Bangladesh 2004), and other primates (Gittins 1980, Islam *et al.* 2006). Thus despite anecdotal reports, and grey literature the general knowledge on the CHT mammal species is still sparse and majorly limited to the country checklist which offers no information on spatial distribution (Khan 1982, 1987, Sarker and Sarker 1984, 1988, Khan 2008).

So far it is known that two species of rhinoceros, Javan (*Rhinoceros sundaicus*) and Sumatran (*Dicerorhinus sumatrensis*) went extinct from the CHT, a third species, the Asian one-horned rhinoceros (*Rhinoceros unicornis*) may have existed in the north-western and south-eastern parts of the CHT as its range included neighboring Tripura (Hunter *et al*. 1876, Gupta 2000) of India and Arakan of Myanmar (Pollok 1879, Baker 1887). However, the Arakan record of one-horned rhinoceros is doubtful probably a misidentification (Rookmaaker 1980). The last Sumatran Rhinoceros has been reported being killed near Cox's Bazar in 1967 (Cubitt and Mountfort 1985, Choudhury 1997). The last sightings of rhinoceros were an encounter reported by bamboo collectors in the Kassalong Reserve Forest of Rangamati in the late seventies (Singh Chakma, pers. comm.) and recent (Choudhury 2013) claims of foot print sighting by woodcutters in the upper Sijak area is doubtful. In addition to the rhinoceros species, the Banteng (*Bos javanicus*) known to occur in the CHT (Jerdon 1874) went extinct around 1940's (Husain 1974, Gittins and Akonda 1982, Asmat 2001). The only obligatory aquatic mammal species occurring in the CHT is the Ganges river dolphin (*Platanista gangetica*) which is now restricted to the Karnafuli River downstream of the Kaptai Dam (Smith *et al.* 2001). The population of Ganges river dolphins in the Sangu River uses the CHT administrative boundary only during the monsoon when water level rises. The river dolphin was not a rare species in the Kaptai lake when it was created (1962) but in recent years no sightings of dolphins have been reported in the upstream of the Karnafuli River or Kaptai lake. The last dead dolphin was found in Kaptai lake in 1993 near Tabalchari of Rangamati (pers. obs., photo seen). The only bird is known to extinct from the CHT is pink-headed duck (*Rhodonessa caryophyllacea*) probably a globally extinct species. The white-winged duck (*Cairina scutulata*) a globally Critically Endangered species probably locally extirpated as there is no confirmed sighting report since 1982 (Siddiqui *et al*. 2008)

The Bengal tiger (*Panthera tigris tigris*), the largest predator in Bangladesh, occurred in 11 of the 17 civil administrative districts of Eastern Bengal (which came to form Bangladesh) until the 1930s (Mitra 1957). Today encounters with tigers in Bangladesh are only reported in the Sundarbans, the largest mangrove forest in the world, leading to the assumption that tigers are extirpated in all other remaining forests in Bangladesh, including the CHT. Yet clear information on the status of the tiger in the CHT is lacking and local people from the CHT area are still convinced that tigers can be found there (Khan 2004b, 2011, Ahmad 2009).

Small tiger populations can recover rapidly from low numbers with appropriate management actions. However, the presence and abundance of tigers and other predators in any area is strongly linked to prey species abundance so in order to recover sufficient populations of prey species or large-ungulates are needed (Smith *et al.* 1987, Karanth and Nichols 1992, Karanth *et al.* 2004, Linkie *et al.* 2006). The loss of prey increases the risk of tiger populations going extinct, by reducing the carrying capacity of breeding female tigers and reducing cub survival (Karanth and Stith 1999). So, a baseline data of both tiger and tiger preys in the CHT is highly necessary to understand the conservation potential of tiger in this area.

Rapid assessments to determine the presence of wildlife by observing their natural signs, such as spoor and scat are widely used (Liebenberg 1990). The sign survey has been applied for a variety of species and been used as a tool for detection and occupancy purposes (Karanth *et al.* 2009, Hines 2010, Karanth *et al.* 2011). Track data survey are common and broadly used and has been applied for large carnivores and ungulates occurrence in Asia (Karanth and Nichols 2002, Karanth *et al.* 2009, Gopalaswamy *et al.* 2012).

The reliability of detecting large mammals via signs depends on the detectability of signs, the substrates in the study areas, and the skill of the observer (Wemmer *et al.*1996). Pawed-mammal signs may not be detectable during the dry season or after heavy rainfall, and in places where leaf litter is dense or on rock or other hard substrates but the great advantages of sign survey are without special equipment multiple species data can be gathered from large geographical area in the same time with low cost (Heinemeyer *et al.* 2008).

To gather base line data on mammals distribution in the CHT a track survey was conducted in 2010-2011 and the data analyzed using occupancy modeling in order to estimate the present geographical ranges of medium to large mammal species in the CHT. Species occurrence in relationship to associated ecological and social covariates was modeled to elucidate observed species distribution patterns.

The specific aim of this study was to assess the current status and spatial distribution of medium and large mammal species in the CHT, with a special focus on tigers and their prey.

3.3 Methods

3.3.1 Study area

The CHT (details in Chapter 2) areas where the study was conducted is characterized by remote, less human habitation and more forest covers than the other areas of the CHT and can be divided into the CHT north and CHT south. Three main reserve forests, Kassalong Reserve Forest (KRF), Rainkyong Reserve Forest (RRF) and Sangu Reserve Forest (SRF) fall under the study areas however, the study also conducted outside the reserve forests (Fig 3.1). The northern CHT where KRF is situated, observed dense forest canopy and less-disturbed forest compared to rest of the two reserve forests. Chakma and Tripura communities with a few Pankua community residing inside the KRF and RRF whereas SRF is the home to Marma, Tripura, Mro, Chak, Bawm, Khumi and Tanchangya communities. Now Bengali settlers from the plain land are also living inside the SRF.

3.3.2 Field survey protocols

3.3.2.1 Survey design, grid cell selection

The total area was split into 100 km^2 (10 x 10 km) grid cells. This was based on the potential size of a female tiger's home range in rugged, hilly terrain given the size of female tiger home ranges in similar landscapes in Thailand (Steinmetz *et al*. 2009). Grid cells selected for the sign survey were characterized by >50% hill forest cover based on a Forest Department GIS map of land cover. The study focuses on forest parts which were chosen under the assumption that they would offer a high chance of presence of large mammals considering the low chance of tiger occurrence in low quality habitats (Smith *et al.* 1998). A total of 30 grid cells were selected under this criterion (Fig. 3.1).

Grid cells were also selected which were not covered by the previous criterion (>50% hill forest cover) but were located adjacent to the Northern Forest Complex-Namdapha-Royal Manas, being a Level 1 Tiger Conservation Landscape (TCL) in Myanmar (Sanderson *et al.* 2006). Here 8 grid cells were selected under this criterion, summing up to a total of 38 grid cells for the survey (Fig. 3.1).

3.3.2.2 Survey training and team formation

Sign surveys are commonly used for animal studies and are effective tools to determine the presence of an animal by observing natural signs such as footprints, scat, scratches (Leibenberg 1990). Under certain conditions, they can also be used to estimate spatial distribution patterns of animal species. Though track sign survey has a long history but it is sometimes challenging because the shape and size of animal signs of individuals of the same species may vary depending on the substrate, sex and age (Murie 1975, Karanth and Niichols 2002, Kimberly *et al*. 2008). Karanth and Nichols (2002) illustrated tiger and their major preys track shape but not size and how differences on different substrates. To overcome this uncertainty a standard track identification tool was created following Karanth and Nichols (2002), Parr *et al.* (2003), Francis and Barrett (2008) and outlined by Wildlife Conservation Society, developed for Southeast Asian mammals (Appendix B).

To form the survey team, experienced trackers from the local villages were identified and those with additional geographical and local cultural knowledge of the CHT were finally selected for training. Five trackers were trained for two days on skills such as basic GPS operation, navigating map, recognition different animal signs using track identification tool, first aid and safety, and data collection. Different animal species and their signs were observed in Dulahazara Safari Park in Cox's Bazar to maximize the identification skills and to assure consistency in data collection. Observers worked together for the first week of the field work then formed two teams. Each survey team consisted of one team leader and two trackers but finally only one team was functional throughout the survey due to trackers unavailability throughout the survey period. Occasionally additional members, mainly experienced hunters were added as required. In most cases the surveyed grid cells were far from roads where motor vehicles can reach. The only way to reach by backpack tracking and the areas which had a navigable water route a small canoe and additional man power were hired to carry the all essential field materials and to guide the survey team because it is very unusual to get a tracker who keeps geographical knowledge for an area far from where he lives.

3.3.2.3 Trail selection and data collection

The survey was conducted in the dry season (March-May and October-November, 2010 and March 2011) to assure a high sign detection probability, because rainfall is known to decompose tracks at a fast rate. The existing trail created by either humans or animals are used for survey transect as tigers usually follow existing trails and thereby leave their signs (Sunquist 1981, Karanth and Nichols 2002, O'Brien *et al.* 2003). A total of 15 km long transect consisting of 15 segments (1 km each) within each grid cell were surveyed. However, it was not always possible to complete the 15 km long transect in a single continuous segment because of limited accessibility for rough terrain. In these instances the survey was continued immediately in the next direction depending on potential habitat and other field demands like distance of probable night halt place and direction and distance of next grid cell will be surveyed.

Surveys were conducted during daylight, from the morning to the evening by walking slowly at a speed of 2-3 km/hr along the transect line. To avoid spatial bias and in order to save time, data collection was started wherever the team entered a grid cell. Signs were carefully searched for within a detectable distance defined as1 m of either side of the transect line. Whenever footprints were not clearly identifiable on the transect the team followed the track until species identification was possible. In case of any confusion of animal sign identification, note was taken, the sign was photographed and measurements were taken for further analysis to mitigate the risk of false identification. In case of similar tracks of two different species (for example Dhole and domestic dog, domestic cattle and wild gaur) I have followed some basic consideration to determine the species like: dole sign usually found far from human habitation and domestic dog sign often found with human signs. Gaur foot print is much bigger than domestic cow and forest users or local (if any) were interviewed whether they keep any domestic Gaur (*Bos frontalis*) or cow in nearby area. Each type of sign detection recorded only once to each 1 km trail segment using standard '1' (detection) and '0' (non-detection) histories required for occupancy analysis (Mackenzie *et al.* 2006, Hines *et al.* 2010). The segment length 1 km instead of 100 m used by Karanth *et al.* (2011) because of very low encounter rate of sign. Each grid cell has surveyed within <12-24 h, reasonably met the 'closure' assumption (MacKenzie *et al*. 2006). Primates were not targeted species, however, primates data also opportunistically collected whenever signs observed, sighting and hearing call (Table 3.1).

3.3.2.4 Covariates

Though the size of grid cells was determined by the estimated home range size of a female tiger it was assumed the home range of other medium-large mammals might be much less so, habitat and other covariates observed data were collected following similar detection non-detection histories (Appendix C).The covariates or factors data used for analysis are:

pf = primary forest observed at least 2 hectors (eye estimate) near the trail segments.

sf = secondary forest observed along the trail segments

sc = shifting cultivation observed along the trail segments

ho = house observed along the trail segments

vi = village observed along the trail segments (≥5 houses in a single place considered a village)

ls = livestock detected along the trail segments

In addition to above covariates detection history of major ungulate prey were also used as covariates for determining predator occupancy and detation.

wb = wild boar

sd = sambar deer

bd = barking deer

3.3.3 Data Analysis

3.3.3.1 Relative abundance and building occupancy model structure

Presence absence of signs were used to estimate relative abundance of detected species by a simple percentage equation.

$$P_s = \frac{n}{N} \times 100$$

Here,

P_s = percentage of detected sign of targeted species.

n= no of segment detected sign of targeted species.

N= total number of surveyed segment (here it is 570).

The programme PRESENCE version 4.2 (Hines 2006) was used for occupancy modeling (Mackenzie *et al.*2006). The programme also provides the naïve estimate of occupancy using a simple formula

ψ = x/s,

where, x the number of occupied sites and s is the total number of cells or sites surveyed.

This occupancy model has two components:

ψ is the probability that a study site or cell is occupied by a target species.

p is the probability of detecting a target species presence in a replicate sample (here 1 km segment).

The detection probability again has two components: Pr (present at survey cell) and Pr (detection│present at survey cell). The goal of site occupancy modeling is to account for the difference between *occupancy* and *detection*; it is important to consider a species may be present on a site but not detected during the survey (false absence). Any detection indicates a species is present, but non-detection does not necessarily mean the species is absent (Mackenzie *et al*. 2002).

In single-species, single-season occupancy models, there are two stochastic processes that are occurring at a site that could affect whether or not a species is detected. The first is that a species is either occupied (ψ) or unoccupied (1 – ψ). Repeated surveys of a site lead to a detection history composed of 0s (for absences) and 1s (for presences), such that a detection history of h_i= 01011 means that the cell is occupied at site *i* and that the species was not detected in survey 1, detected in survey 2, not detected in survey 3, and detected in survey 4 and survey 5.

This detection history can be expressed in the following probability statement:

Pr (h_i = 01011) = ψ(1-p1)p2(1-p3)p4p5.

At sites where the species was never detected, there are two possibilities for why the species was never detected at the site or cell: either (1) the cell was occupied by the species and the species was not detected in any of the five surveys or (2) the cell was unoccupied by the species. Both of these possibilities must be incorporated into the probability statement, which becomes

$$\Pr(hj = 00000) = \Psi \prod_{j=1}^{5} (1 - Pj) + (1 - \Psi)$$

The first term is the species was occupied but not detected in 5 surveys and the second term, (1- ψ) corresponding the sample unit was not occupied.

In general multiple surveys in a short time period are recommended for single season occupancy surveys and surveys must be independent from each other (MacKenzie *et al.* 2002, 2006) although this is not always possible due to logistical constraints (Hines *et al.* 2010, Karanth *et al.* 2011). If surveys are conducted along trails nearby transects have a much higher probability of the same species being present compared to transects conducted further away. A species might walk and the ending of trail segment and appear again in another starting trail segment. Therefore, the model developed by Hines *et al.* (2010) which takes sample correlation into account using a first-order Markov process (Gillespis 1992) to be the most appropriate. The Hines *et al.* (2010) model structure is

$[\Psi(.), \theta_0(.), \theta_1(.), p(.)]$

or

$[\Psi(.), \theta(.), \theta'(.), p(.)]$

There are two parameters added in this model where,

θ_0 = probability that the species is present locally, given the species was not present in the previous sample, and

θ_1 = probability that a species is present locally, given it was present at the previous sample. The above detection history with new model would be:

$Pr(h_i = 01011) = \psi[(1-\theta_0)\theta_0+\theta_0(1-p_1)\theta_1]\ p_2[(1-\theta_1)\theta_0+\theta_1(1-p_3)\theta_1]\ p_4\theta_1 p_5$

and

$Pr\ (h_i = 0000)= (1- \psi) + \psi\ [\theta_1(1-p1)(\theta_2'(1-p2)(\theta_3'(1-p3)(\theta_4'(1-p4)+(1-\theta_4'))$

$+(1-\theta_3')(\theta_4(1-p4)+(1-\theta_4)))+(1-\theta_2')(\theta_3(1-p3)(\theta_4'(1-p4)+(1-\theta_4'))+(1-\theta_3)(\theta_4(1-$

$p4)+(1-\theta_4))))+(1-\theta_1)(\theta_2(1-p2)(\theta_3'(1-p3)(\theta_4'(1-p4)+(1-\theta_4'))+(1-\theta_3')(\theta_4(1-p4)+(1-$

$\theta_4)))$

$+(1-\theta_2')(\theta_3(1-p3)(\theta_4'(1-p4)+(1-\theta_4'))+(1-\theta_3)(\theta_4(1-p4)+(1-\theta_4))))]$

Here, $(1 - \psi)$, corresponds to the probability that the sample unit is not occupied.

For example, a detection history of a species sign, h_j for cell j, could be as follows: h_j = 01011. The history means a species signs were detected only 2nd, 4th and 5th but not detected 1st and 3rd spatial replicates in a survey with k = 5 replicates conducted in a cell j. Hence, there is uncertainty about the non-detection due to non-detection of sign, given species presence, or was due to species not being present on those replicates. To calculate an unbiased estimate of occupancy, both possibility counted for. The general computing expression for probabilities associated with such detection histories,

P_j = Pr (h_j), is described as: (detection at a segment | sample unit occupied and species present on segment.);

Ψ = Pr (sample unit occupied)

θ_0 = Pr (species present on segment t| sample unit occupied and species not present on previous segment *t*-1)

θ_1 = Pr (species present on segment t| sample unit occupied and species present on previous segment *t*-1)

p_t = Pr (detecting species present on segment t| sample unit occupied and present on segment *t*)

The log likelihood under this model is-

$$L(\Psi, \theta_0, \theta_{1,} p_t | \mathrm{h}_{1,} \mathrm{h}_2, \ldots\ldots \mathrm{h}_\mathrm{s} = \prod_{\mathrm{j}=1}^{\mathrm{s}} \mathrm{Pr(hj)}$$

The expression of for Pr(h_j) can be written as

Pr(h_j) = φ ρ , where

φ = [1- φ φ];

$\rho = \begin{bmatrix} X \\ Y \end{bmatrix}$ = Pr (detection of target species sign | true occupancy state of target species)

X = 1 if target species sign is detected, 0 otherwise;

Y = Pr (detection history of target species signs | presence of target species) .

Here my analysis was a "Custom w/spatial correlation" model in which species occupancy (ψ) and detection probability (p) was constant across sites,

ψ (.),θ(.),θ'(.),p(.),π(.) or, psi(.),thta0(.),thta1(.),p(.),pi(.).

Here, sites refers to grid cells. Of the two model types, the type was used assumes that the species was not locally present before the first sample (first θ is θ_0).

3.3.3.2 Covariates determinants of focal species occupancy

I aimed to identify models that best explained each species observed (detected) distribution, and to determine the role of different covariates. Occupancy and detection probability usually not constant (Royle 2006). Occupancy and detection probabilities as functions of covariates using logit link functions (MacKenzie *et al.* 2006) where the probability of a site occupancy can be expressed as

$$\text{Logit}(\Psi_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots\dots\dots + \beta_u x_{iu}$$

which is a linear function of the u covariates associated with site I ($x_{i1} + x_{i2} + \dots + x_{iu}$), and with the intercept term β_0 and u regression coefficients for each covariate that need to be estimated (MacKenzie *et al.* 2006).

Besides, target species occupancy rate ψ, I was also interested to determine covariates influencing this site level species presence that means it was assumed that some of the covariates may also contribute to the variation in target species abundance and thereby influence sign detection probability *p* (Royle and Nichols 2003). Furthermore, it is expected that other factors influenced the detectability of target species signs.

I first ran the "single species single season custom model, ψ(.),p(.) (MacKenzie *et al*. 2002) and "Custom w/spatial correlation" model, ψ (.),θ(.),θ´(.),p(.),π(.) or, psi(.),thta0 (.),thta1(.),p(.),pi(.). (Hines *et al*. 2010) to compare the overall occupancy rate. For model selection procedure of covariates roles for both in determining probability of occupancy and probability of detecting a species I have used global model (model with the greatest number of parameters) based on MacKenzie *et al*. (2006) and Karanth *et al*. (2011) using all 9 covariates for the species predates on ungulates and 6 covariates for other species. The global model used for carnivores is:

Ψ(pf+sf+sc+ho+vi+ls+bd+sd+wb),θ(.),θ´(.),p(pf+sf+sc+ho+vi+ls+bd+sd+wb),π(.)

And for general:

Ψ(pf+sf+sc+ho+vi+ls),θ(.),θ´(.),p(pf+sf+sc+ho+vi+ls),π(.)

Multiple models were run for each species using covariates to determine which combination of covariates would have the best fit. Models include roles of covariates on probabilities of both occupancy and detection, then on occupancy and on detection. Normally model with the lowest Akaiki's Information Criterion (AIC) value was accepted as having the best fit, but in situation where multiple models had AIC< 2 averaged models on the basis that models had strong support. Models with an AIC of >2 were excluded as having lower, little or no support (Burnham and Anderson, 2002).

3.4 Results

3.4.1 Relative abundance Signs survey and occupancy estimation

Data were collected from a total transect length of 570 km (15 km × 38 grid cells) over a time period of 6 months (March-May and November-December, 2010 and April, 2011). At least 20 species of medium-large mammals (few are identified only genus level; Table 3.1) could be detected via track survey in the study area (excluded family Mustelidae). Hereby, no tiger signs were detected in the whole area. The largest detected mammal and ungulate was the elephant (*Elephas maximus)*, and largest carnivore was asiatic black bear (*Ursus thibetanus*).

Among the recorded species barking deer relative abundance were found highest which is 35.43% (recorded from 202 segments out of 570 km or segments) followed by wild boar 23.33%, sambar 14.56%, leopard cat 8.42%, dhole 7.01%, black bear 3.86%, elephant 3.16%, common leopard 2.80%, red serow 1.23%, binturong 0.70% and gaur 0.53%.

Among the carnivores the highest naïve occupancy was Golden cat (0.42) detected 16 grid cells out of 38 followed the asiatic black bear (0.39) and dhole (0.34) (Table 3.1 and 3.2). The largest felid was the leopard (*Panthera pardus*) detected in 9 grid cells (naïve occupancy 0.23). Few species grouped were amalgamated due to lack of confidence in distinguishing them in the field particularly using scats. For example jungle cat (*Felis chaus*) detected in many grid cells but were not analysed due to lack of confidence in distinguishing their scat in the field. The himalayan porcupine (*Hystrix brachyura*) and asiatic brush-tailed porcupine (*Atherurus macrourus*) have both been recorded in track surveys and can be distinguished by footprints but were not consistently distinguished when recorded earlier stage of survey. Same results are also applicable for civets. Prime tiger prey, gaur *(Bos gaurus)* was detected in 3 grid cells, red serows (*Capricornis rubidus)* in 6 grid cells, the sambar deer (*Rusa unicolor*) in 23 grid cells, wild boar (*Sus scrofa*) in 29 grid cells and the barking deer (*Muntiacus vaginalis*) in 36 grid cells . Another predator species detected and recorded is dhole (*Cuon alpinus*) in 13 grid cells (Table 3.1). Overall the most abundant species (naïve occupancy) was the barking deer with 0.94, followed by wild boar (0.76) and sambar deer with (0.58) naïve occupancy. The estimated occupancy ($\widehat{\Psi}$) of barking deer is highest with 100% occupancy (SE. ± 0.0; 95% CI=0.99-1) followed by wild boar 81% (SE± 0.08; 95% CI= 0.60-0.92), sambar deer 73% (SE± 0.13; 95% CI= 0.41-0.91), Asiatic black bear 61% (SE± 0.62; 95% CI= 0.26-0.88), golden cat 59% (SE± 0.15; 95% CI= 0.29-0.83), leopard 46% (SE± 0.18; 95% CI= 0.16-0.79) and dhole 45% (SE± 0.16; 95% CI= 0.18-0.75). The detection probability p was highest for the barking deer (0.67) and the lowest is red serow (0.09) (Table 3.2).

3.4.2 Covariates determinants of focal species occupancy (Model Selection)

Primary forest (pf) appeared to be the most important covariates to determining probability of occupancy for asiatic black bear and sambar deer when models run using same number of covariates both for occupancy and detection probability (Table 3.3). Presence of sambar deer or ungulates combination with primary forest and secondary forest were found best fit to determining probability of detecting both leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) . In case of ungulates it was primary forest and secondary forest for sambar however roles of shifting cultivation found important covariates to determinant barking deer sign detection (Table 3.4). Covariates either primary forest or secondary forest or combination of both model found best fit in determining probability of ungulate signs detection and ungulate occupancy but not strong support to carnivores where presence of prey species (particularly sambar deer) including livestock was related with carnivore occupancy (Table 3.5). The beta (β) coefficients values for different covariates are listed in Table 3.6 where primary forest was found most important in determinant of species occupancy indicated by positive β values. Barking deer was found more adaptable with different types of habitats:. primary forest found very positive some degree of positive with degraded habitat like shifting cultivation area and even with scattered houses but negatively response with the village. However, secondary forest were found negative with barking deer occupancy (Table 3.6).

3.5 Discussion

3.5.1 Methods

3.5.1.1 Data collection

The survey track segments or presence absence data were not collected from continuous trail due to survey constrain including topographical and other survey constrain in most of the grid cells and were combination of two or more segments probably some sort of violation of the spatial autocorrelation assumption. While the forest cover was not homogenous and habitat highly fragmented in few grid cells It was very difficult to follow the trail. As the existing trail used by local people often runs through highly degraded habitat where probably mammals usually do not use the trail but use habitat 50 to 100 m far from the trail probably affect the segment level detection of animal signs but the chance is less in grid cell level occupancy.

Weather condition might have affected the detection probability of specific species during the sign surveys. While the survey was conducted during the dry season, the trails appeared sometimes being too hard to keep suitable footprints of low weight animals such as jackals or clouded leopards leading to lower abundance calculations for these species.

3.5.2 Data analysis and results

3.5.2.1 Relative abundance Signs survey and occupancy estimation

As mentioned earlier, sometimes data were not collected from continuous trail but when considered a continuous segment then the segment level dependency was not adjusted. The adjusted estimate could be a little different from the current estimate. The naïve occupancy provided the distribution maps of the medium to large mammals of CHT and the estimated occupancy provided only for the area surveyed and I did not extrapolate to the grid cells where survey was not conducted. Assuming both occupancy and detection probability relate human population density in an area that data (human population) are not available at cell level so, it was not possible to draw the probability occupancy map for whole CHT landscape. So naïve occupancy maps provided here are not representing the “true” occupancy of the sites as not detection does not mean absence of animal (MacKenzie *et al.* 2006). Grid cells with less than 50% forest cover also sometimes mislead the natural forest cover as the existing forest cover map does not differentiate the plantation forestry and trees planted in and around the villages. At least 2 grid cells were included in survey where the vegetation dominated by teak (*Tectona grandis*) and rubber (*Hevea* *brasiliensis*) plantation. Sometimes existing trail or trails we used do not represent the whole grid cells that possible to give over or underestimate the real scenario of particular area. For example, we have not detected any elephant track in grid cell 38 and adjacent the 38 grid cells because our trail ended before the area where elephant used to visit but elephants do not cross certain areas presumably due to anthropogenic disturbances or topological barriers and therefore couldn't be detected by the track survey that certainly affect the occupancy estimation.

As predicted the primary hill forest is the crucial part for the occurrence and distribution pattern of most mammal species. The gaur taught being an extirpated species from Bangladesh was detected in surveyed cells (Table 3.1) with primary forest dominant habitat and found primary forest and secondary forest influence to predict their occupancy (Table 3.3). Barking deer the most abundance species found showed preference in degraded habitat like shifting cultivation (Table 3.3) or in combination with diverse habitat types (Table 3.5) means the species has great tolerance and found all type of covariates representing habitats. Red serow can be found in degraded habitat adjacent villages and houses where hill slope is rocky and very steep (Table 3.5). Ungulates (sambar deer and barking deer) are very important for both leopard and dholes occupancy and livestock also found an important covariates in determining both occupancy and probability of detection for dhole (Table 3.3). The pack of dhole track only recorded from the forest without human habitation or very low. The leopard tracks were low compare to the forest cover and prey level in Grid Cell 1 - 6. These cells are continuous with good amount of forest cover and level of prey (field obs.). Though tiger and leopard both are sympatric but tigers chase out the leopards where prey are less. So, leopard population remain less where tiger survive with low prey density. The low detection of leopard is probably for the chase out scenario in recently past. Hypothesizing the landscape is now empty tiger and leopard probably in restocking stage can be increase in future if sufficient level of prey exist. Hunting probably one of the most important factors for ungulate and their predator occupancy which was not able to quantify in this study. Further studies required to understand the leopard rarity and hunting effect to ungulates and their predators.

The mammal assessment revealed the presence of 18 medium to large mammal species, yet no signs of tiger presence could be revealed. This leads to the assumption that tiger is extirpated in the CHT, although prey animals species, such as sambar deer and barking deer show good abundance in remote places where survey has conducted. The occurrence and relative high abundance of prey animal reflects the status of the habitat quality being still potentiality although within the area ungulates showed a clear preference for primary forest patches with low human population. Thus the lack of tiger detection can't not be explained solely by habitat degradation and fragmentation or food scarcity. Therefore, intensive tiger poaching activities or disease need to be considered as another cause of the extirpation which would match the observations from other tiger range countries. Tiger poaching is driven in part by the traditional Asian medicine trade and is documented as the most important threat to tiger populations in nearly all the landscapes where they occur (Nowell 2000, Newman 2004, Sanderson *et al*. 2006, Nowell and Ling 2007). Recently Verheij *et al*. (2010) showed that tiger poaching and an increasing illegal trade in tiger parts is greatly contributing to the current rapid worldwide decline of tigers in the wild. Evidences from the Sundarban tiger population in Bangladesh revealed that tiger poaching is most likely responsible for a steep decline of 69% in relative tiger abundance over the last 5 years (Rahman *et al*. 2012), matching the assumption that tiger poaching has also caused the extinction of the tiger population in the CHT being a much easier accessible area than the swamps of the mangrove forest in the south.

As the study mainly focused on medium-large mammals and conducted in well-forested area. So, this result may not providing all medium to large mammals information particularly the species prefer open area or extreme rare animals. For example golden jackal (*Canis aureus*), hog deer (*Hyelaphus porcinus*), hog badger (*Arctonyx collaris*) and sun bear (*Helarctos malayanus*) were not detected in this survey but all the species have confirmed recent record. Marbled cat (*Pardofelis marmorata*) and clouded leopard (*Neofelis nebulosa*) track either not detected due to rarity or misindentified as golden cat due to lack of experience on their track size and pattern. All previous record of hog deer are from Khagrachari district where there is no good hill forest patches existing and the area was not covered in the survey as all none of grid cell fall under the selection criteria. However, further research needs to understand the historical trends, driver factors of changes of medium to large mammal population in the CHT.

3.6 Conservation implications

Although tiger seem to be extirpated from the CHT, typical tiger prey species are still showing fare abundances in remaining forest patches. Here habitat quality and habitat loss seem to be the key factors ultimately affecting the current occupancy of mammals species in the CHT. It is well known that prey animal densities, especially ungulates, highly dependent on the habitat type and quality and changes in prey densities reflect typically changes in habitat quality, such as level of degradation and fragmentation. Indeed with this study I revealed that most medium to large mammal species showed a clear preference for primary forest patches assumed for less disturbed. In order to protect the existing mammal fauna and probably allow the tiger to reappear through corridors via Myanmar or India immediate habitat protection and management strategies need to be developed and strongly implemented.

The northern part of the CHT (grid cells 1-6) is characterized by a comparatively good forest cover, less human population and highest abundance of vital tiger prey species although hunting is not uncommon. Furthermore, it connects directly with an Indian tiger reserve, named Dampa, which offers the excellent perspectives to reintroduce tigers by protecting habitat and increasing prey level in both the sites. But it only possible by awaring local people to reduce prey hunting and increasing law enforcement activities to stop wildlife poaching. These conservation actions would allow the tiger to reoccupy the CHT, sourced by the Indian population.

Though the habitat in south-eastern part of the CHT is medium to highly degraded, it is still characterized by a low human population density, and adjacent to a larger tiger conservation landscape (TCL). This makes it another potential area for tiger conservation actions by increasing the TCL into the CHT of Bangladesh and protecting and regenerating the habitat and mitigating hunting pressure by awaring forest inhabitants.

Figures

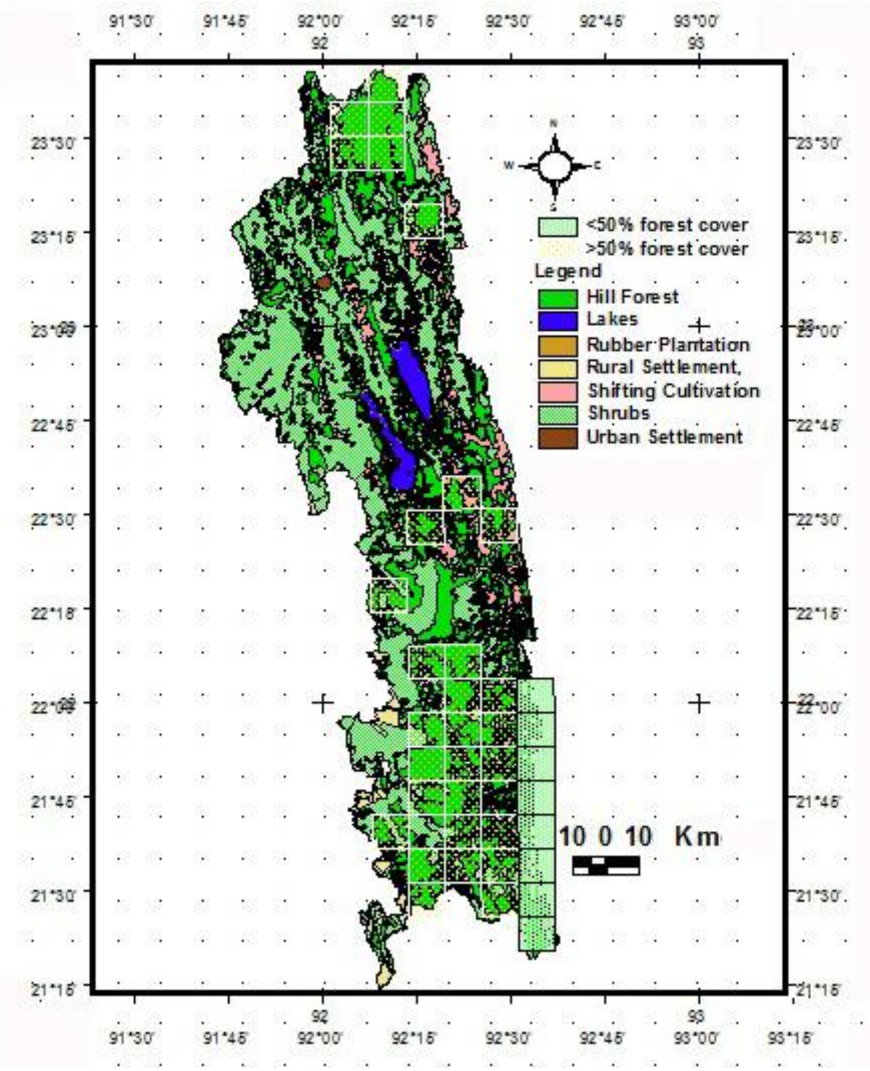

Figure 3.1 Map of surveyed grid cells

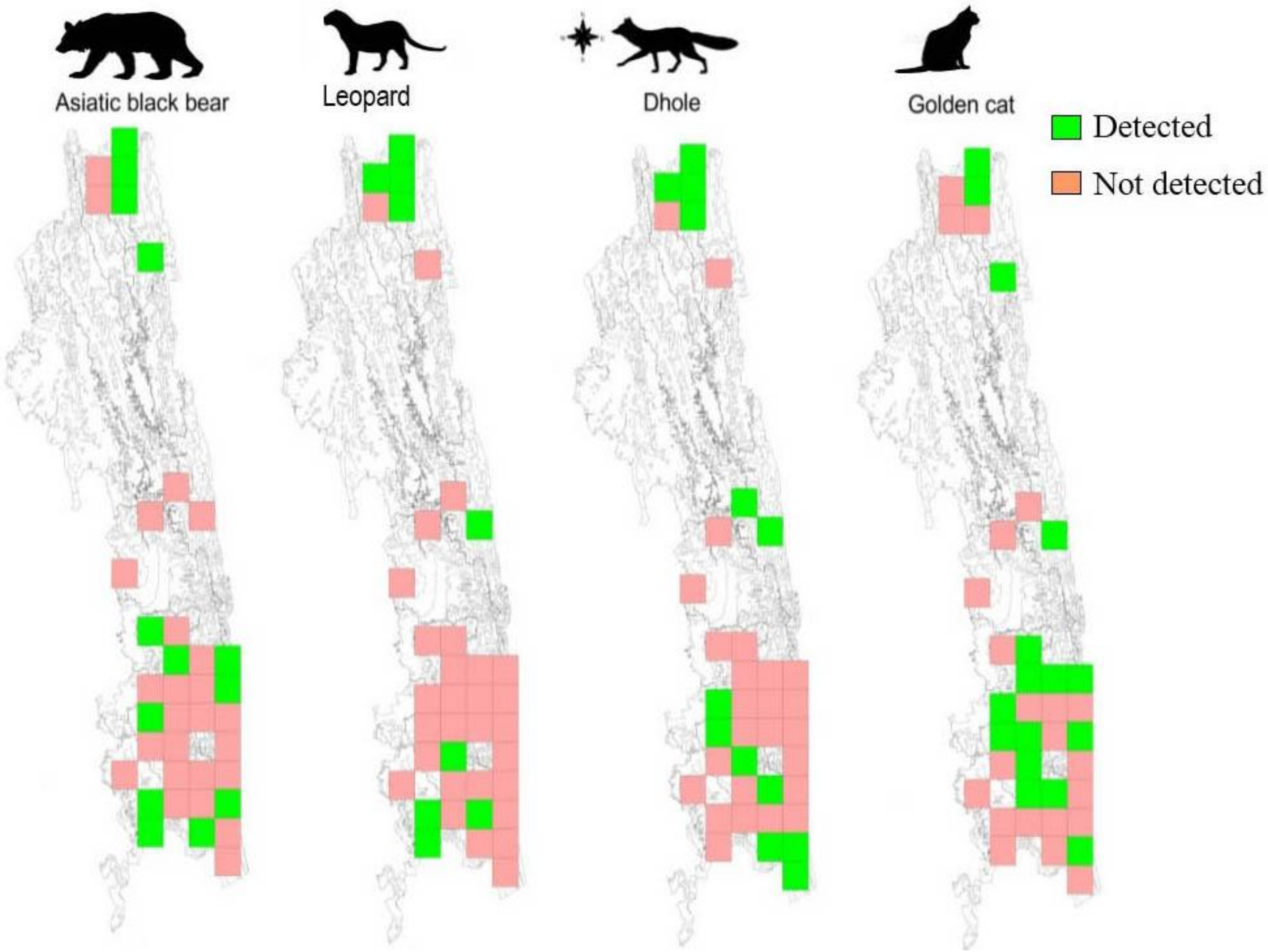

Figure 3.2 Naïve Occupancy map of selected mammal species

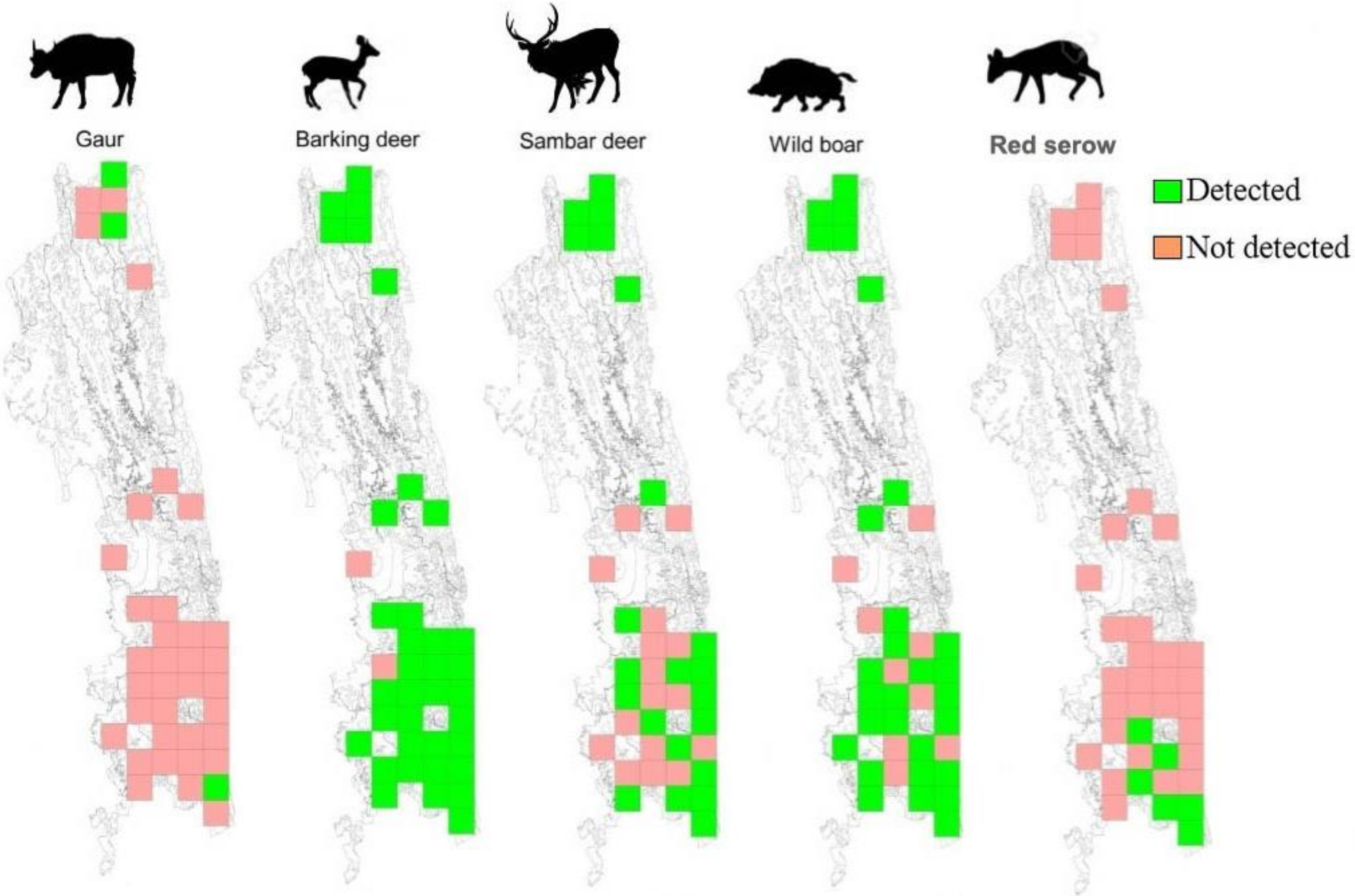

Figure 3.2 (Continued)

Tables

Table 3.1 Species recorded by track survey in different grid cells

			Grid Cells																		
Order	Family	English name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Artiodactyla	Bovidae	Gaur	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bovidae	Red serow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cervidae	Sambar deer	+	+	+	+	+	+	+	-	-	-	+	-	-	-	+	-	+	+	-
	Cervidae	Barking deer	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	+	+	+	+
	Suidae	Wild boar	+	+	+	+	+	+	+	+	-	-	-	+	+	-	+	-	+	+	+
Proboscidea	Elephanitidae	Elephant	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Carnivora	Canidae	Dhole	+	+	+	-	+	-	+	-	+	-	-	-	-	-	+	-	-	+	-
	Felidae	Leopard	+	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
	Felidae	Clouded leopard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Felidae	Jungle cat*	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+
	Felidae	Golden cat	+	-	+	-	-	+	-	-	+	-	-	+	-	+	+	+	-	+	+
	Felidae	Leopard cat	+	+	+	-	+	-	-	-	-	-	-	+	-	-	+	-	-	+	-
	Felidae	Fishing cat	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mustelidae	Yellow-throated marten	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mustelidae	Otter**	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
	Ursidae	Asiatic black bear	+	-	+	-	+	+	-	-	+	-	+	-	+	-	-	-	-	+	-
	Viverridae	Binturong	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Viverridae	Civet** (3 species)	+	+	+	-	+	-	-	+	-	-	-	-	+	-	-	-	-	+	-
Rodentia	Hystricidae	Porcupine* (2species)	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Primates	Cercopithecidae	Rhesus macaque***	+	+	+	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-
	Cercopithecidae	Pig-tailed macaque***	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cercopithecidae	Phaery's leaf monkey***	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	Cercopithecidae	Capped langur***	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	Hylobatidae	Hoolock gibbon***	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-

Table 3.1 (Continued)

Order	Family	English name	Grid Cells																		
Order	Family	English name	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Artiodactyla	Bovidae	Gaur	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
	Bovidae	Red serow	–	–	+	–	–	+	–	+	–	–	+	–	–	–	–	–	–	+	+
	Cervidae	Sambar deer	–	–	+	–	–	+	–	–	–	+	+	+	+	+	+	–	+	+	+
	Cervidae	Barking deer	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Suidae	Wild boar	–	+	+	+	–	+	+	–	+	+	+	+	+	+	+	–	+	+	+
Proboscidea	Elephanitidae	Elephant	–	+	–	+	–	–	+	–	–	+	–	–	–	–	–	–	–	–	–
Carnivora	Canidae	Dhole	–	–	+	–	–	+	–	–	–	–	+	–	–	–	–	–	–	+	+
	Felidae	Leopard	–	–	+	–	–	–	+	–	+	+	–	–	–	–	–	–	–	–	–
	Felidae	Clouded leopard	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–
	Felidae	Jungle cat*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Felidae	Golden cat	–	–	+	–	+	+	–	–	–	–	–	+	–	+	–	–	–	+	–
	Felidae	Leopard cat	–	–	–	–	–	–	+	–	–	+	+	+	+	+	–	–	–	–	–
	Felidae	Fishing cat	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–	–
	Mustelidae	Yellow-throated marten	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
	Mustelidae	Otter**	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
	Ursidae	Asiatic black bear	–	–	–	–	–	–	+	–	–	+	+	+	+	–	–	–	+	–	+
	Viverridae	Binturong	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Viverridae	Civet** (3 species)	–	–	+	–	–	+	–	+	+	–	+	–	–	–	–	–	–	+	+
Rodentia	Hystricidae	Porcupine** (2 species)	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Primates	Cercopithecidae	Rhesus macaque***	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–	–	–	–
	Cercopithecidae	Pig-tailed macaque***	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	+	+
	Cercopithecidae	Phaery's leaf monkey***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Cercopithecidae	Capped langur***	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–
	Hylobatidae	Hoolock gibbon***	–	–	–	–	–	–	+	–	–	+	+	–	–	+	–	+	+	+	+

*Few Identifications are doubtful and probably civet sp. ** Not identified at species level; ***Not terrestrial and opportunistically recorded

Table 3.2 Naïve occupancy (Ψ), detection probability (P) and estimated occupancy ($\hat{\Psi}$) of focal mammal species

Species	Ψ	**p**	Std.err	($\widehat{\Psi}$)	Std.err	95% conf. interval	
Asiatic black bear *Ursus thibetanus*	0.394	0.207	0.613	0.626	0.180	0.269	0.884
Leopard *Panthera pardus*	0.263	0.104	0.046	0.464	0.187	0.164	0.791
Golden cat *Felis temminki*	0.421	0.428	0.211	0.590	0.154	0.292	0.834
Dhole *Cuon alpinus*	0.342	0.143	0.140	0.451	0.165	0.182	0.752
Gaur *Bos gaurus**	0.078	-	-	-	-	-	-
Barking deer *Muntiacus vaginalis*	0.948	0.670	0.249	1	0	0.999	1
Sambar deer *Rusa unicolor*	0.589	0.248	0.024	0.739	0.136	0.414	0.919
Wild boar *Sus scrofa*	0.763	0.467	0.067	0.817	0.080	0.609	0.927
Red serow *Capricornis rubidus**	0.157	0.096	-0.031	-	-	-	-

*data are inadequate to get a proper estimate of occupancy due to very low probability of detection

Table 3.3 Best models for predicting occupancy for each species in the CHT (roles of covariates in determining both occupancy and probability of detection).

Species	Top-ranked models with lowest AIC	AIC	∆AIC	AIC wgt	Model Likelihood	no.Par.	-2log(L)
Asiatic black bear	psi(pf),thta0(.),thta1(.),p(pf),pi(.)	152.46	0	0.3401	1	7	138.46
Ursus thibetanus	Psi(.),thta0(.),thta1(.),p(.),pi(.)	152.72	0.26	0.2986	0.8781	5	142.72
	psi(pf+sf+sc+ho+vi),thta0(.),thta1(.),p(pf+sf+sc+ho+vi),pi(.)	154.26	1.8	0.1383	0.4066	15	124.26
Leopard	psi(bd+sd+pf),thta0(.),thta1(.),p(bd+sd+pf),pi(.)	108.05	0	0.2515	1	10	88.05
Panthera pardus	psi(sd+pf),thta0(.),thta1(.),p(sd+pf),pi(.)	108.52	0.47	0.1988	0.7906	9	90.52
	psi(sd+wb+pf),thta0(.),thta1(.),p(sd+wb+pf),pi(.)	108.91	0.86	0.1636	0.6505	10	88.91
Golden cat	psi(pf+sf+sc+ho+vi),thta0(.),thta1(.),p(pf+sf+sc+ho+vi),pi(.)	227.99	0	0.3632	1	15	197.99
Felis temminki	psi(pf+sf+sc+ho),thta0(.),thta1(.),p(pf+sf+sc+ho),pi(.)	228.31	0.32	0.3095	0.8521	13	202.31
	psi(pf+sf+sc+ho+vi+ls),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	230.47	2.48	0.1051	0.2894	17	196.47
Dhole	psi(pf+ho+ls),thta0(.),thta1(.),p(pf+ho+ls),pi(.)	206.55	0	0.6647	1	11	184.55
Cuon alpinus	psi(pf+ls),thta0(.),thta1(.),p(pf+ls),pi(.)	209.06	2.51	0.1895	0.2851	9	191.06
	psi(pf+sc+ho+ls),thta0(.),thta1(.),p(pf+sc+ho+ls),pi(.)	210.92	4.37	0.0748	0.1125	13	184.92

Table 3.3 (Continued)

Species	Top-ranked models with lowest AIC	AIC	∆AIC	AIC wgt	Model Likelihood	no.Par.	-2log(L)
Gaur	psi(pf+sf),thta0(.),thta1(.),p(pf+sf),pi(.)	39.31	0	0.7421	1	9	21.31
Bos gaurus	psi(pf),thta0(.),thta1(.),p(pf),pi(.)	43.49	4.18	0.0918	0.1237	7	29.49
	psi(pf+sf+sc),thta0(.),thta1(.),p(pf+sf+sc),pi(.)	44.04	4.73	0.0697	0.0939	11	22.04
Barking deer	psi(sc),thta0(.),thta1(.),p(sc),pi(.)	649.48	0	0.3145	1	7	635.48
Muntiacus vaginalis	psi(pf+sc),thta0(.),thta1(.),p(pf+sc),pi(.)	649.57	0.09	0.3006	0.956	9	631.57
	psi(sc+ho),thta0(.),thta1(.),p(sc+ho),pi(.)	649.87	0.39	0.2588	0.8228	9	631.87
Sambar deer	psi(pf),thta0(.),thta1(.),p(pf),pi(.)	389.61	0	0.2065	1	7	375.61
Rusa unicolor	psi(pf+sf),thta0(.),thta1(.),p(pf+sf),pi(.)	389.79	0.18	0.1887	0.9139	9	371.79
	psi(pf+sf+ho),thta0(.),thta1(.),p(pf+sf+ho),pi(.)	390.05	0.44	0.1657	0.8025	11	368.05
Wild boar	psi(pf+sf+sc+ho+vi),thta0(.),thta1(.),p(pf+sf+sc+ho+vi),pi(.)	494.91	0	0.3785	1	15	464.91
Sus scrofa	psi(pf+sf+sc),thta0(.),thta1(.),p(pf+sf+sc),pi(.)	495.58	0.67	0.2707	0.7153	11	473.58
	psi(pf+sf+sc+ho+vi+ls),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	496.06	1.15	0.213	0.5627	17	462.06

Table 3.3 (Continued)

Species	Top-ranked models with lowest AIC	AIC	∆AIC	AIC wgt	Model Likelihood	no.Par.	-2log(L)
Red serow	psi(.),thta0(.),thta1(.),p(.),pi(.)	75.55	0	0.3222	1	5	65.55
Capricornis	psi(pf),thta0(.),thta1(.),p(pf),pi(.)	75.63	0.08	0.3096	0.9608	7	61.63
rubidus	psi(pf+sf),thta0(.),thta1(.),p(pf+sf),pi(.)	77.45	1.90	0.1246	0.3867	9	59.45

Note- pf=primary forest, sf=secondary forest, sc=shifting cultivation, ho=house, vi=village, ls=livestock, bd=barking deer, sd=sambar deer, wb=wild boar.

Table 3.4 Model selection results; roles of covariates in determining probability of detecting sign p of species in the CHT

Species	**Model**	**AIC**	**∆AIC**	**AIC wgt**	**Model Likelihood**	**no.Par.**	**-2log(L)**
Asiatic black bear	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf),pi(.)	151.91	0	0.2863	1	12	127.91
Ursus thibetanus	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf),pi(.)	152.09	0.18	0.2617	0.9139	13	126.09
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf+sc),pi(.)	152.15	0.24	0.2539	0.8869	13	126.15
	psi,th0(.),th1(.),p(.),pi(.)	152.72	0.81	0.191	0.667	5	142.72
Leopard	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),pi(pf+sd),pi(.)	99.4	0	0.3206	1	15	69.4
Panthera pardus	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),pi(pf+bd+wb),pi(.)	100.55	1.15	0.1804	0.5627	16	68.55
	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),pi(pf+bd),pi(.)	100.57	1.17	0.1786	0.5571	15	70.57
	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),pi(pf+bd+sd),pi(.)	101.14	1.74	0.1343	0.419	16	69.14
Dhole	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),p(sd),pi(.)	207.96	0	0.3785	1	15	177.96
Cuon alpinus	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),p(pf+sf+sd),pi(.)	209.68	1.72	0.1601	0.4232	17	175.68
	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),p(sf+sd),pi(.)	210.09	2.13	0.1305	0.3447	16	178.09
	psi(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0(.),th1(.),p(bd),pi(.)	211.05	3.09	0.0807	0.2133	15	181.05

Table 3.4 (Continued)

Species	Top-ranked models with lowest AIC	AIC	∆AIC	AIC wgt	Model Likelihood	no.Par.	-2log(L)
Golden cat	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf+sc+ho+ls),pi(.)	214.6	0	0.9334	1	15	184.6
Felis temminki	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf+sc+ho+vi+ls),pi(.)	220.49	5.89	0.0491	0.0526	16	188.49
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(ho),pi(.)	223.34	8.74	0.0118	0.0127	12	199.34
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf+sc+ho),pi(.)	225.08	10.48	0.0049	0.0053	14	197.08
Gaur	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf),pi(.)	45.31	0	0.1311	1	12	21.31
Bos gaurus	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sc),pi(.)	45.31	0	0.1311	1	12	21.31
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(ls),pi(.)	45.31	0	0.1311	1	12	21.31
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(ho),pi(.)	45.42	0.11	0.1241	0.9465	12	21.42
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf),pi(.)	45.76	0.45	0.1047	0.7985	12	21.76
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf),pi(.)	46.34	1.03	0.0784	0.5975	13	20.34
	psi,th0(.),th1.(),p(.),pi(.)	47.03	1.72	0.0555	0.4232	5	37.03
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+ho),pi(.)	47.31	2	0.0482	0.3679	13	21.31

Table 3.4 (Continued)

Species	Top-ranked models with lowest AIC	AIC	∆AIC	AIC wgt	Model Likelihood	no.Par.	-2log(L)
Barking deer	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sc+ho+vi),pi(.)	595.18	0	0.427	1	14	567.18
Muntiacus vaginalis	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sc+ho+vi+ls),pi(.)	597.11	1.93	0.1627	0.381	15	567.11
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sc+ho),pi(.)	597.18	2	0.1571	0.3679	13	571.18
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sc),th0pi(.)	597.77	2.59	0.1169	0.2739	12	573.77
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	600	4.82	0.0383	0.0898	17	566
Sambar deer	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf),pi(.)	344.09	0	0.2563	1	12	320.09
Rusa unicolor	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf),pi(.)	344.72	0.63	0.1871	0.7298	12	320.72
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf),pi(.)	344.81	0.72	0.1788	0.6977	13	318.81
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sc+ho+vi+ls),pi(.)	345.12	1.03	0.1531	0.5975	15	315.12
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf+sc+ho+ls),pi(.)	345.15	1.06	0.1509	0.5886	15	315.15
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf+sc),pi(.)	346.58	2.49	0.0738	0.2879	14	318.58

Table 3.4 (Continued)

Species	Top-ranked models with lowest AIC	AIC	∆AIC	AIC wgt	Model Likelihood	no.Par.	-2log(L)
Wild boar	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf+sc),pi(.)	487.82	0	0.2752	1	13	461.82
Sus scrofa	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf),pi(.)	488.39	0.57	0.2069	0.752	12	464.39
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sc),pi(.)	488.62	0.8	0.1845	0.6703	13	462.62
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf),pi(.)	489.32	1.5	0.13	0.4724	13	463.32
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	489.43	1.61	0.123	0.4471	17	455.43
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf),pi(.)	490.89	3.07	0.0593	0.2155	12	466.89
Red serow	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(),p(sc+ho),pi(.)	73.02	0	0.3472	1	13	47.02
Capricornis rubidus	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(vi),pi(.)	74.48	1.46	0.1673	0.4819	12	50.48
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(ho),pi(.)	74.88	1.86	0.137	0.3946	12	50.88
	psi,th0(.),th1(.),p(.),pi(.)	75.55	2.53	0.098	0.2822	5	65.55
	psi(pf+sf+sc+ho+vi+ls),th0(.),th1(.),p(sf),pi(.)	75.98	2.96	0.079	0.2276	12	51.98

Table 3.5 Model selection results; role of covariates in determining probability of species occupancy Ψ in the CHT

Species	**Top-ranked models with lowest AIC**	**AIC**	**∆AIC**	**AIC wgt**	**Model Likelihood**	**no.Par**	**-2log(L)**
Asiatic black bear	psi(sf),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	197.73	0	0.2085	1	12	173.73
Ursus thibetanus	psi(pf),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	198.12	0.39	0.1716	0.8228	12	174.12
	psi(sc),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	198.88	1.28	0.1173	0.5627	12	174.88
	psi(ho),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	199.01	1.3	0.1088	0.5222	12	175.01
Leopard	psi(sf+ls),thta0(.),thta1(.),p(bd+sd+wb+pf+sf+sc+ho+vi+ls),pi(.)	118.41	0	0.4929	1	16	86.41
Panthera pardus	psi(pf+ls+bd),thta0(.),thta1(.),p(bd+sd+wb+pf+sf+sc+ho+vi+ls),pi(.)	119.89	1.48	0.2352	0.4771	17	85.89
	psi(sf+ls+bd+sd),thta0(.),thta1(.),p(bd+sd+wb+pf+sf+sc+ho+vi+ls),pi(.)	121.89	3.48	0.0865	0.1755	18	85.89
Golden cat	psi(sf+sc+ho),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	213.86	0	0.5537	1	14	185.86
Felis temminki	psi(sc+ho),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	214.92	1.06	0.3259	0.5886	13	188.92
	psi(pf+sc+ho),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	216.92	3.061	0.1199	0.2165	14	188.192
Dhole	psi(pf+sd),th0(),th1(),p(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0pi()	211.65	0	0.4933	1	16	179.65
Cuon alpinus	psi(pf+sf+sd),th0(),th1(),p(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0pi()	212.12	0.47	0.39	0.7906	17	178.12
	psi(pf+bd),th0(),th1(),p(pf+sf+sc+ho+vi+ls+bd+sd+wb),th0pi()	215.81	4.16	0.0616	0.1249	16	183.81

Table 3.5 (Continued)

Species	**Top-ranked models with lowest AIC**	**AIC**	**∆AIC**	**AIC wgt**	**Model Likelihood**	**no.Par**	**-2log(L)**
Gaur	psi(pf),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	42.09	0	0.4701	1	12	18.09
Bos gaurus	psi(.),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	43.31	1.22	0.2554	0.5434	11	21.31
	psi(sf),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	45.31	3.22	0.094	0.1999	12	21.31
Barking deer	psi(pf+sf+sc+ho+vi),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	598.01	0	0.6596	1	16	566.01
Muntiacus vaginalis	psi(pf+sf+sc+ho+vi+ls),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	600	1.99	0.2439	0.3697	17	566
	psi(pf),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	604.09	6.08	0.0316	0.0478	12	580.09
Sambar deer	psi(pf),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	377.3	0	0.3894	1	12	353.30
Rusa unicolor	psi(pf+sf),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	378.99	1.69	0.1673	0.4296	13	352.99
	psi(.),thta0(.),thta1(.),p(pf+sf+sc+ho+vi+ls),pi(.)	379.41	2.11	0.1356	0.3482	11	357.41
Wild boar	psi(sf),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	482.55	0	0.4415	1	12	458.55
Sus scrofa	psi(pf+sf),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	483.66	1.11	0.2534	0.5741	13	457.66
	psi(sf+sc),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	484.48	1.93	0.1682	0.381	13	458.48
Red serow	psi(vi),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	73.76	0	0.3078	1	12	49.76
Capricornis rubidus	psi(pf),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	74.71	0.95	0.1914	0.6219	12	50.71
	psi(ho+vi),th0(),th1(),p(pf+sf+sc+ho+vi+ls),th0pi()	74.81	1.05	0.1821	0.5916	13	48.81

Table 3.6 Estimated beta (β) coefficient for covariates determining probability of species occupancy Ψ in the CHT (see table 3.5).

Covariates considered primary forest (pf), secondary forest (sf), shifting cultivation (sc), house (ho), village (vi), livestock (ls), barking deer (bd), sambar deer (sd) and wild boar (wb).

Species	pf	sf	sc	ho	vi	ls	bd	sd	wb
Black bear	-	-0.070(0.044)	-	-	-	-	-	-	-
	0.411 (0.153)	-	-	-	-	-	-	-	-
	-	-	0.594 (0.281)	-	-	-	-	-	-
	-	-	-	0.612(0.354)	-	-	-	-	-
Leopard	-	-41.105(0.074)	-	-	-	16.334(0.056)	-	-	-
	0.626(0.194)	-	-	-	-	11.055(0.035)	0.226(0.265)	-	-
	-	--24.682	-	-	-	10.391	0.782	0.762	-
Golden cat	-	0.109(0.064)	0.137(0.012)	-0.411 (0.121)	-	-	-	-	-
			0.222 (0.002)	-0.395(0.034)	-	-	-	-	-
	0.062 (0.018)		0.104(0.102)	-0.394(0.032)	-	-	-	-	-
Dhole	0.120 (0.073)	-	-	-	-	-	-	0.658 (0.054)	-
	0.086(0.068)	0.144 (0.052)	-	-	-	-	-	1.021 (0.054)	-
	-0.463 (0.220)	-	-	-	-	-	1.124(0.333)	-	-
Gaur	42.721(0.467)	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
		2.921(0.095)	-	-	-	-	-	-	-
Barking deer	0.288(0.062)	-0.008(0.047)	0.226(0.082)	0.120(0.054)	-0.176(0.111)	-0.085(0.053)	-	-	-
	0.285(0.075)	-0.081(0.051)	0.222(0.099)	0.120(0.054)	-0.175(0.112)	-0.087(0.059)	-	-	-
	0.175(0.060)	-	-	-	-	-	-	-	-
Sambar deer	0.190(0.073)	-	-	-	-	-	-	-	-
	-	-0.067 (0.034)	-	-	-	-	-	-	-
	0.142 (0.052)	-0.037(0.081)	-	-	-	-	-	-	-

Wild boar	-	-0.083(0.034)	-	-	-	-	-	-	-	-
	2.161(0.76)	0.032 (0.003)	-	-	-	-	-	-	-	-
	-	-0.091(0.032)	0.018 (0.011)	-	-	-	-	-	-	-
Red serow	-	-	-	-	-0.161 (0.012)	-	-	-	-	-
	-0.225 (0.015)	-	-	-	-	-	-	-	-	-
	-	-	-	-0.900 (0.008)	-0.803 (0.023)	-	-	-	-	-

Chapter 4: Assessing the potential of using camera traps for estimating relative abundance and activity patterns of medium to large mammals in selected areas of the CHT

4.1 Abstract

Animal behaviour is an integral part of biological science that can assist in the conservation of biodiversity and can help limit the impact of human on the nature. Baseline information is crucial to understand the biodiversity changes over time and to take any management action. In 2011 a survey was conducted to estimate the Relative Abundance Index (RAI) and activity patterns of medium to large mammal species in two selected areas of the Chittagong Hill Tracts (CHT) in Bangladesh. The survey used camera traps to validate the results of track surveys which had previously been carried out in the same areas. The study revealed that track surveys were more effective than camera trapping in order to conduct rapid mammal assessments in the study area. However, the trap survey effort was not sufficient to document all medium to large mammal species. Despite the limitation of survey effort the study recorded 16 species of mammals, and 4 species of birds and included the first photographic record of a brush-tailed porcupine, *Atherurus macrourus* in Bangladesh after 50 years of previous record. The RAI of medium to large mammals found higher than the similar degraded habitat of many Southeast Asian countries where tigers are still found. Activity patterns showed exclusively nocturnal activities for the crestless porcupine, *Hystrix brachyura* brush-tailed porcupine *Atherurus macrourus* and palm civet, *Paradoxurus hermaphrodites.* The study partially fulfilled the Convention on Biological Diversity's (CBD) Aichi Biodiversity Target, 2020 and it is hoped that these results will be used for future study and conservation planning in the CHT.

4.2 Introduction

Tropical rainforests are incredibly diverse habitats home to large numbers of species from a variety of taxa (Terborgh 1992). However, many species found in tropical rainforests naturally occur at low population densities. This is typically due to their specific habitat requirements, particularly limitations in the spatial and temporal distribution of food resources (Eisenberg 1981). Existing at low population densities makes species particularly vulnerable to environmental perturbations and disturbance from human activities (Purvis *et al.* 2000). Across the globe mankind's activities threaten species with extinction (Robinson and Bennett 2000, Duckworth *et al.* 2012) and gathering information is important for conservation (McNeely *et al.*1990) and is the key in order to address the threat of loss in biodiversity and extinction of species (Sanderson *et al.* 2006).

There are many different techniques to survey a single or a group of species. Surveying terrestrial mammals by identifying their spoor, and in particular their tracks, is probably the oldest but robust study method and is therefore still being used by researchers today (Bider 1968, Lyra-Jorge *et al.* 2008). Track and sign surveys are widely used to collect baseline information on the mammal diversity in an area although additional techniques are usually required to collect detailed information on the population size or when studying rare or less studied species (Heinemeyer *et al.* 2008).

Camera trapping has long been used for detecting and monitoring tigers (Karanth 1995, Karanth and Nichols 1998, O'Brien *et al.* 2003, Barlow *et al.* 2009) and other carnivores with unique spot or stripes pattern such as snow leopard *Panthera uncia* (Jackson *et al.* 2006), pumas *concolor* (Kelly *et al.* 2008) and jaguars *Panthera onca* (Maffei *et al.* 2002, Wallace *et al.* 2003, Kelly

2003, Silver *et al.* 2004). This method is increasingly being used for a variety of taxa around the world (Carbone *et al.* 2001, Jackson *et al.* 2006, Linkie *et al.* 2007). Despite the abundant use of camera trapping in carnivore studies the technique is also efficient for inventories of their prey and other mammals (O'Brien *et al.* 2003, Chiang 2007, Datta *et al.* 2008, Johnson *et al*. 2006, Jenks *et al.* 2011). However, as with track surveys failure to a photograph of a species does not necessarily mean that the species is absent but may suggest that it is rare (MacKenzie *et al.* 2004, Sanderson and Trolle 2005). Camera trapping is an effective and reliable method that in support of the general signs survey results and to collect additional information that sometimes not possible from sole study method like track and signs survey.

However, short periods of camera trapping are not sufficient to study population abundance but the photos collected may still provide large amounts of useful data (Jenks *et al.* 2011). In such circumstances the Relative Abundance Index (RAI) is frequently used in a regression equation to estimate the population density of large carnivores and their prey species (Carbone *et al.* 2001, O'Brien *et al.* 2003, Kawanishi and Sunquist 2004, Johnson *et al*. 2006, Jenks *et al.* 2011).

Data generated by camera trapping is superior to human observations (Griffith and van Schaik 1993) as it allows researchers to concurrently quantify activity patterns of target species (Bridge *et al.* 2004, Dillon and Kelly 2007). Mammal activity patterns from camera traps have been reported for many south-east Asian countries (van Schaik and Griffiths 1996, Grassman *et al.* 2006, Kitamura *et al.* 2010, Gray and Phan 2011). However, information from throughout their distributional range is important to understand and improve earlier is crucial for prioritizing the conservation of rare and threatened species and for planning and evaluating management strategies (Nowell and Jackson 1996, Tobler *et al*. 2008).

The aim of the camera trap survey was (1) to extend the knowledge of mammal diversity in the CHT and thereby (2) to verify the results from a previously conducted signs survey; and (3) to assess activity pattern for selected mammals captured by camera trap.

4.3 Methods

4.3.1 Study area

The study took place in the Chittagong Hill Tracts. Two areas herein Grid Cells from the earlier signs survey (see Chapter 3) were selected (Figure 4.1): The first area is Grid Cell 1 (23° 38′ N, 92° 33′ E) and the second is Grid Cell 37 (21° 28′ N, 92° 33′ E).

4.3.2 Grid cells selection

A base line survey for medium-large mammals was conducted prior to the camera trapping, using track sign detection to determine either the absence or presence of species in the area (see Chapter 3). The main objective of the base line signs survey was to determine whether tigers are still present in the area. Since no tiger signs could been detected, two of the 38 signs surveyed grid cells were selected for camera trapping to verify the previous results. Since tiger presence is positively correlated with their prey species (Karanth 1995) so, firstly I have selected the area (grid cells) on the basis of the presence of potential prey species. The species used as selection criteria were barking deer (*Muntiacus vaginalis*), wild boar (*Sus scrofa*), sambar deer (*Rusa unicolor*), and gaur (*Bos gaurus*) as these are the prey species available to tigers in the CHT though gaur is very close to being locally extirpated. Elephants (*Elephus maximus*) is the largest mammal found in the CHT but the species excluded from the selection criteria because they are not a regular prey species for tigers. In addition to the four prey species two species of carnivores, leopard (*Panthera pardus*) and dhole (*Cuon alpinus*), were also taken into account in the selection criteria due to their dependency upon similar prey species and their known sympatric with tigers across their ranges. Therefore a total of six species, four species of artiodactyl and two species of carnivore were considered to select grid cells for camera trapping.

Secondly, whole transect length (15 km) used for signs survey (see Chapter 3) have divided into 3 segments (5 km × 3) then detection of any of six species in a segment was given 1 point up to a maximum of 3 points per species per grid cell. This meant a maximum of 18 points if all six species were detected in all 3 segments of transect (Figure 4.2). The sum scores of the 6 selected species was used to rank the grid cells with only 6 grid cells out of 38 receiving a score >10, maximum of 14 (Figure 4.3). Though the score was equal for Grid Cell 1 and Grid Cell 2 but Grid Cell 1 was finally selected for camera trapping because Grid Cell 1 had less human disturbance than the Grid Cell 2 (field obs.). Grid Cell 1 is in the northern part of the CHT in close proximity to the Kassalong Reserve Forest (KRF), an area of 1607.78 km^2 which lies at the border of the Indian states of Mizoram and Tripura and is therefore directly adjacent to the Dampa Tiger Reserve of Mizoram. Grid Cell 37 is part of Sangu Reserve Forest (SRF), an area of 338.36 km^2 located in south of the CHT (Figure 4.1) which is contiguous with Matamuhuri Reserve Forest, an area of 406.57 km^2. These are jointly known as the Sangu-Matamuhuri Reserve Forest. However, I have used only Sangu Reserve Forest (SRF) throughout the chapters. The eastern border of the Sangu Reserve Forest sharing border with Myanmar meant this forest is contiguous with the Northern Forest Complex-Namdapha-Royal Manas one of the priority Tiger Conservation Landscapes (Sanderson *et al.* 2006).

Grid Cell 1 is mainly dominated by Dhalu bamboo (*Teinostachyum dulloca*) mixed with a diverse community of tree species, such as Garjan (*Dipterocarpus* sp.), Champa Phul (*Michelia* sp.), and Chundul (*Tetrameles nudiflora*). The sources of the Kassalong River and notable streams, such as the Ahazachara, Nava, and Bangchei, flow from this area. Upstream of the Bangchei area is flat with high proportions of clay soils whereas downstream the area is characterised by rough, generally inaccessible terrain. No human settlements were observed within the grid cell, but each year between a few hundred to a thousand people from the surrounding area enter to collect bamboo to supply to the Karnafuli paper mill.

Gird Cell 37 lies in the Sangu Reserve Forest from where the Sangu River flows and the area only being accessible by canoe. The Lungchei and Yangbong are notable streams which have their sources in the grid cell before they flow into the Sangu River. The original vegetation is characterised by high semi-evergreen forest, however, extensive shifting cultivation and logging have resulted the change in the vegetation community dominated by shrubs with scatter bamboo forest patches especially eastern bank of the river. The notable tree species in remaining forest parts are Champa (*Michelia* spp.), Garjan (*Dipterocarpus* spp.), Civit (*Swintonia floribunda*), Telsur (*Hopea odorata*), Boilam (*Anisoptera scaphula*) and Dumur (*Ficus* spp.). Various cane and palm species as well as stands of bamboo can also be found. There are many villages of the Mro community situated within the forest but they are not usually visible from the riverside. During the dry season hundreds of people enter the area to collect timber, bamboo, and rattan.

4.3.3 Validating presence/absence species data collected from previous signs survey

Passive infrared camera traps (Bushnell 119456C and Bushnell 119405) were used to verify the indirect evidence of the presence of the medium and large mammals identified during the prior track survey. To increase the capture likelihood of this camera traps were set up non-randomly (O'Brien *et al.* 2003) along animal trails, stream beds, at saltlicks and other sites animals were likely to pass or visit. Camera were placed before the monsoon from March-June, 2011 and traps were at least 50 m distance from highly degraded and disturbed areas large mammals were likely to avoid with a minimum distance of 200 m and maximum 1 km between trap locations. However, on three occasions cameras were deployed outside or in adjacent grid cells due to a lack of suitable sites in Grid Cell 37.

Each camera trap unit was programmed to delay sequential photographs by 2 seconds but 3 units were programmed with a 30 minutes delay to prolong battery life predicting false photo capture like to receive direct sunlight due to less forest canopy. Both camera models offer video, a good option for observing animal activity without causing any disturbance, so five units were programmed to capture 10 seconds of video when triggered. Camera placement and height varied depending on location but was usually between 50 and 100 cm above the ground and tilted downward towards the animal trail they overlooked. This placement allowed each camera to monitor a conical area at least 5 m in front of it and tilting the cameras downwards reduced the chance of a false exposure caused by moving leaves and branches in the canopy above. The final act in setting up a camera trap was to test it worked by crawling in front of it. Cameras were supposed to stay at one location for a long period, but some of them needed to be relocated during study because either the better location found or they were under risk of getting stolen by forest users.

All cameras were active 24 hours a day and each photograph was stamped with time and date. The location of each camera trap was recorded using a handheld GPS (Garmin GPS 60), with Universal Transverse Marcator (UTM) datum allowing the straight line distances from one camera unit to another to be calculated. In some locations there was no GPS signal due to the rugged terrain and dense forest canopy. In these instances an approximate position was calculated by recording GPS coordinates as soon as GPS signal became available and using the position of streams and other notable landmarks in the paper map was carried. Fifteen cameras were set in for 223 days in Grid Cell1 and14 cameras were set for 164 days in Grid Cell 37 resulting in a total trapping effort of 387 days. The minimum distance between two camera traps was 217 m and the maximum 1480 m (mean = 388.48 m).

The species recorded by the camera traps were identified using Prater (1990), Menon (2003) and Parr *et al.* (2003). Photographs which were not clear were enhanced by adjusting brightness and contrast using Adobe Photoshop CS (version 8.0). Finally, mammals detected by both the track survey and the camera survey were listed in a table to compare the effectiveness of the two methods when used as techniques for rapidly assessing the mammal diversity of an area (Table 4.1). Primate species recorded either visual or call were also listed but were not used in validation analysis.

4.3.4 Evaluating relative abundance of mammals

Relative Abundance Indices (RAI) were used to evaluate the mammals abundance. RAI, defined as the number of independent photo captures per 100 trap nights (O'Brien *et al.* 2003). A calculation of population densities was not possible due to the limitation of sample sizes, which need to be more than 1000 trap nights in order to get robust estimates (Carbone *et al.* 2001).

Photographs were defined as independent according to O'Brien *et al.* (2003): (1) consecutive photographs of individuals of same species taken more than 0.5 hour apart, (2) non-consecutive photos of individuals of same species, (3) different identifiable individuals or species though they appeared in a single exposure or photographs were taken within 0.5 hour (Chiang 2007) except dependent young in a group. Only independent photos were considered from total number of photos (Table 4.2) as valid for the calculating of RAI. In order to calculate the RAI for each species at each grid cell, all detections for each species were summed for all camera trap days/nights. The RAI was calculated for each species and each grid cell as the number of photo captures per 100 trap days (Table 4.3).

4.3.5 Determining activity pattern of mammals

Data from the camera trapping were also used to analyse species activity levels and behaviour to maximize the information on especially rare nocturnal mammal species in the CHT. Photographs captured by the camera traps were categorized into two hours intervals based on time printed. Species with ≥5 encounters were calculated based upon the time imprinted on each video and photograph then categorized into two hours intervals with percentage of used to calculate whether the species were nocturnal, diurnal and cathermeral (Table 4.4). A species categorized as nocturnal when >80% of encounters during dark phase or 1800-0600 hours, diurnal when >80% of encounters during light phase or 0600-1800 hours or cathemeral (neither nocturnal nor diurnal, active at any time of night or day; van Schaik and Griffiths 1996, Grassman *et al.* 2006).

4.4 Results

4.4.1 Validating presence/absence species data collected from previous signs survey

In all surveyed area (all 38 grid cells) a total of 20 medium to large terrestrial mammal species were recorded from both track and camera trap survey where the number is 17 species in Grid Cell 1, and 13 species in Grid Cell 37 (Table 4.1). Out of 17 species 15 (88%) were recorded in signs survey and only 10 (58%) species were captured in camera trap. However, in Grid Cell 37 out of 13 species 9 (69%) were recorded in signs survey and 10 (77%) were captured in camera trap (Table 4.1). A total of 474 photographs of 17 species were captured from both grid cells (Table 4.2).

4.4.2 Evaluating relative abundance of mammals

A total of 20 species were recorded from 474 photographs of 142 independent captured from 387 camera trap nights. From 20 species 16 were mammals and 4 were birds (Table 4.2).The most photograph captured species was sambar deer with a total of 164 photographs of 8 independent followed by wild boar with 84 photographs of 23 independent, Asian elephant with 67 photographs of 20 independent and barking deer with 56 photographs of 27 independent (Table 4.2).

In Grid Cell 1, most frequently trapped (RAI = captured/100 trap nights) mammal species were elephants (8.97), followed by crestless porcupine (8.52) and wild boar (7.62). In Grid Cell 37 the most commonly trapped species were barking deer (9.76), followed by wild boar (3.05), palm civet (3.05) and crestless porcupine (2.44). The RAI of barking deer found higher in grid cell 37 but the other important tiger prey species sambar deer and wild boar RAI were higher in grid cell-1 (Figure 4.4). The selected two grid cells RAI comparison was found better than the many Southeast Asian countries conducted in similar degraded habitat (Table 4.3)

4.4.3 Determining activity pattern of mammals

Eight species were considered to activity patterns analysis. No diurnal animal was found but 3 species had fully nocturnal activity patterns (Table 4.4). Other 5 species showed cathermeral activity patterns. Among them barking deer showed more cathermeral activity whereas sambar deer found almost nocturnal (87%). The only animal elephant was found more active at daytime (75%) followed by wild boar (65%) and barking deer (52%) (Table 4.4).

4.5 Discussion

4.5.1 Validating presence/absence species data collected from previous signs survey

This study shows that signs (mainly track) surveys are a more efficient method of rapidly assessing mammalian diversity than camera trapping. However, additional logistical and statistical factors must be taken into account when choosing between these two methods. Track surveys require observers to have considerable experience in identifying the spoor of local animals. Any differences in observer skill may bias the result. Additionally observers' detection and identification skills may improve over the duration of the survey, but will do so at different rates, adding an element of temporal variation to the probability of detection, both at the level of the observer and the study as a whole.

The low number of species detected by the track survey in Grid Cell 37 compared to Grid Cell 1 can be explained by the hard, rocky ground surface in the area as this meant light weight animals left no tracks or hard to detect. When using camera traps the probability of detection is not affected by ground surface making a comparison between the two methods may be invalid in some circumstances. The main tiger prey species are large mammals heavy enough to leave tracks even on hard ground. As this survey focused on these species the effect of a difference in substrate between grid cells will be minimal. However, this limitation is ignorable because this study is neither estimating the relative abundance from the track surveys nor estimating the population by camera trapping.

The absolute abundance and total species occurrence could not be determined by the camera trap survey. Survey effort was not sufficient due to the limited number of camera traps and a number of malfunctioning camera trap units. Deploying more cameras within a sample unit can increase the probability of detection and also decrease the effect of data lost due to individual camera malfunctions (Kays and Slauson 2008). The poor validating performance (58% and 77%) of the camera trap survey probably results from inadequate sampling effort (164 and 223 days) but this was unavoidable due to logistical constraints. Carbone *et al.* (2001) recommend a trapping effort of more than 1000 days to confirm the presence or absence of rare species (Carbone *et al.* 2001). Costs associated with remote camera surveys will decrease in the future as purchasing camera equipment is one-time investment. Further long term camera trap study with more robust statistical methods is required to draw firm conclusions on the abundance of mammals in the CHT but these results highlight the conservation importance of this landscape for populations of several mammal species.

4.5.2 Evaluating relative abundance of mammals

Short periods of camera trapping are unlikely to document all animal species or individuals in an area, particularly those which occur at low densities. Whilst camera trapping did not record any tigers it was captured many common tiger prey species, such as sambar, barking deer, and wild boar. The Relative Abundance Index comparison result (Table 4.3) might be an indication that tigers disappeared from the area a number of years ago, resulting in an increase in prey populations. This would be similar to other areas where the top predators disappeared (Beschta and Ripple 2009). Also, the higher RAI for ungulates and other smaller predator species might indicates immediate release due to the disappearance of apex predators but need further studies to draw any firm conclusion. Beside that, RAI of this study derived only from two selected GCs (GC 1 and 37) those were based on best wildlife abundant areas meant that the other cells are likely to have lower RAI base on the relatively much lower track sign encountered there.

Therefore, the results of increased prey and smaller predator cannot be extrapolated for the whole of the CHT because camera trapping only occurred in the two grid cells which were chosen due to the high occurrence of prey animals during the signs survey. A direct comparison of RAIs between study sites was hampered due to the differences of capture probabilities at different camera sites and insufficient sample size.

Under certain condition indices can provide information on relative differences in abundance or density (Williams *et al*., 2002, O'Brien, 2011). However, use of such index to infer about population as a measure of abundance or density have limitations to provide valid comparision across time, space, species or other dimention of interest (Sollmann *et al*. 2013). Index derived from camera trapping cannot deal with imperfect and variable detection and it can be led to bias in RAI ratios towards the more detectable species (Sollmann *et al*. 2013). So, use of, RAI as a measure of animal abundance, comparision between sites or any monitoring purpose caution should be taken (Sollman *et al*. 2013).

Furthermore the period and area covered (36.5 km²) were not sufficient to document all medium-large mammals including gaur, leopard and asiatic black bear though their presence is doubtless due to the records from the track survey. The positive RAI of sambar deer, barking deer and wild boar, all of which are common tiger prey species, indicates that if the ongoing threats of habitat loss and hunting (of both tigers and their prey) can be controlled then there is a chance to restore the tigers in the CHT. However, before any tiger reintroduction efforts can be considered a rigorous monitoring system must be developed and implemented. A general mammal monitoring system for the CHT is also needed to follow the population trend of those globally threatened species which do still occur in the CHT and could be identified via the camera trapping. The study showed that camera trapping can be highly effective for detecting rare, cryptic species like clouded leopard, binturong, and red serow and dholes were detected by camera trap many are considered critically endangered in Bangladesh (IUCN-Bangladesh 2000). Whilst no evidence was found to suggest the presence of tigers in the CHT there are claims of tiger sightings in 2010 in the Kassalong Reserve Forest and confirmed reports of two tigers killed in between 2000 and 2005 in the same area. There is another tiger sighting report from Grid Cell 9 in 2009. The information was cross checked during the signs survey in the Grid Cell 31 adjacent to India and Myanmar border and found similar report in support of sighting in the same year. An interview was conducted over the survey period with a local villager in Dolu Para (village) who claimed to have killed a tiger in 2006 in Remakri Khal (Grid Cell 34, Figure 4.1). The villager used poison injected into a cow killed by the same tiger (pers. comm). Khan (2011) also reported a tiger killed in 2011 near the same area where a tiger was killed in 2006. In Grid Cell 37 no reports were found on tigers for the past 10 years but according to forest users there were pugmark sighting report in nearby grid cell (38) about 5 years ago. A local hunter who has been living in the area for 40 years told that once tigers were common in the area but their numbers suddenly dropped and then disappeared when people from Myanmar introduced traps about 20 years ago. The presence of tigers in the CHT is not clear but it is assumed that all occurrences in the southern CHT are itinerant tigers crossing from Myanmar. It is unlikely tigers are resident in adjacent habitat on the southern Mizoram of the Indian side of the border (adjacent to Bangladesh-India-Myanmar border point) because habitat there is even more degraded than in Bangladesh (field obs.). However, both Bangladesh and Mizoram state sites have good forest cover at northern side. The Dampa Tiger Reserve situated in north-western Mizoram of India contiguous within the KRF of Bangladesh may support resident tigers. No hog deer were detected by either the track or camera trap survey but there are observational reports (Khan 2004) and a few live animals were collected from the local people by forest department, all from degraded habitat in the Khagrachari district. There are no reports from primary forest areas where the survey conducted. It is not clear the historical abundance of hog deer in the CHT but according to older people the species was rare even when other animals including tiger were widespread. One deer skin photographed (Appendix G) from Grid Cell 17 was likely as Fea deer (*Muntiacus feae*) found in China, Lao PDR, Vietnam, Thailand and Myanmar (Steinmetz, R. per. comm.).

4.5.3 Determining Activity pattern

The activity periods of ungulates were similar to those reported across Southeast Asia (Johnson *et al.* 2006, Gray and Phan 2011, Jenks *et al.* 2011). Two porcupine species crestless porcupine (*Hystrix brachyura*) and brush-tailed porcupine (*Atherurus macrourus*) were captured at the same camera location at similar times but on different days, suggesting the two species are sympatric. Crestless porcupine was observed mating in front of camera at 00.35 am. Leopard cats are predominantly nocturnal species may be active at day (Paar *et al.* 2003). Similar results were found in the study as photos were captured both day and night. Red serow probably a nocturnal species was photographed on a single occasion at dawn. Inside the forest it remained dark up to an hour after the sun has risen and red serow stayed active during this period. The camera traps also documented hunters from the nearby village so it is not clear whether animals were very wary and sensitive to foreign objects or if they had left the area because of the presence of hunters. A wild boar was photographed foraging in the daytime with more than 8 dependent young and a mother binturong was captured at night with her baby. The survey yielded preliminary information on presence, distribution, and activity pattern that will serve as guidance and baseline data for future research in the CHT.

4.6 Conservation implications

The results showed that the two reserved forests, the Kassalong Reserve Forest and Sangu Reserve Forest support a greater level of diversity than the protected areas in the CHT. Apart Sangu the existing protected areas in the CHT are Pablakhali Wildlife Sanctuary (PWS), and Kaptai National Park (KNP). The Pablakhali Wildlife Sanctuary did not fall in surveyed grid cells because the area does not fulfil the grid cell survey criteria as the protected area has <50% forest coverage (see chapter 3) .Only 3.60% of the CHT land has been brought under protected area network and many areas remain paper parks because of a lack of ground implementation of current forest and wildlife Acts. The human population is very low in both study grid cells an opportunity to protect the area by relocating inside households outside the area by creating buffer zone with proper management plan, transparency and agreement. The gaur was thought to be extinct in Bangladesh (IUCN-Bangladesh 2000, Asmat 2001) but has since been rediscovered in both northern and southern parts of the CHT means immediate conservation management programme needs for the specis. Though Grid Cell 1 is part of the roughly 700 km^2 of KRF present forest covers a very small area. The recent discovery of a small tiger population in the Dampa Tiger Reserved of Mizoram of India studied by Aaranyak and WWF India (The Telegraph, 2012), in an area of approximately 550 km^2 contiguous with KRF raises the issue of transboundary tigers (see chapter 5). There should be talks between officials in Bangladesh and India on the issue of transboundary tigers as has been done for tigers in the Sundarbans. This would bring the opportunity to merge both landscapes, create a corridor for wildlife to move through and create a larger area more suitable for viable populations of tigers and other large carnivores. India has already taken a few conservation steps to increase the Dampa Tiger Reserve area including the resettlement of villagers. This expertise can be used by Bangladesh if required. A joint monitoring system can be developed to evaluate the actions and their effectiveness across the area. Local participatory and action oriented research should start in the CHT to increase the numbers of prey species and pave the way for the reintroduction of tigers into the landscape. Erecting a fence along the Indo-Bangladesh and/or Bangladesh-Myanmar border would have an impact on the movement of wildlife especially species which require large areas like tigers and elephant. International workshops are needed to elaborate plans and agreements between Bangladesh and Myanmar on wildlife movement, particularly of migratory species, as has been done between Bangladesh and India in the Sundarbans. The CHT is generally categorized as a Tiger Restoration Landscape and here specifically the SRF (Grid Cell-37) is classified as a level 1 (high priority) Tiger Conservation Landscape particularly the Northern Forest Complex-Namdapha-Royal Manas between India and Myanmar (Sanderson *et al.* 2006) offers an excellent opportunity to increase the tiger conservation landscape size in Bangladesh by establishing a transboundary protected area.

Figures

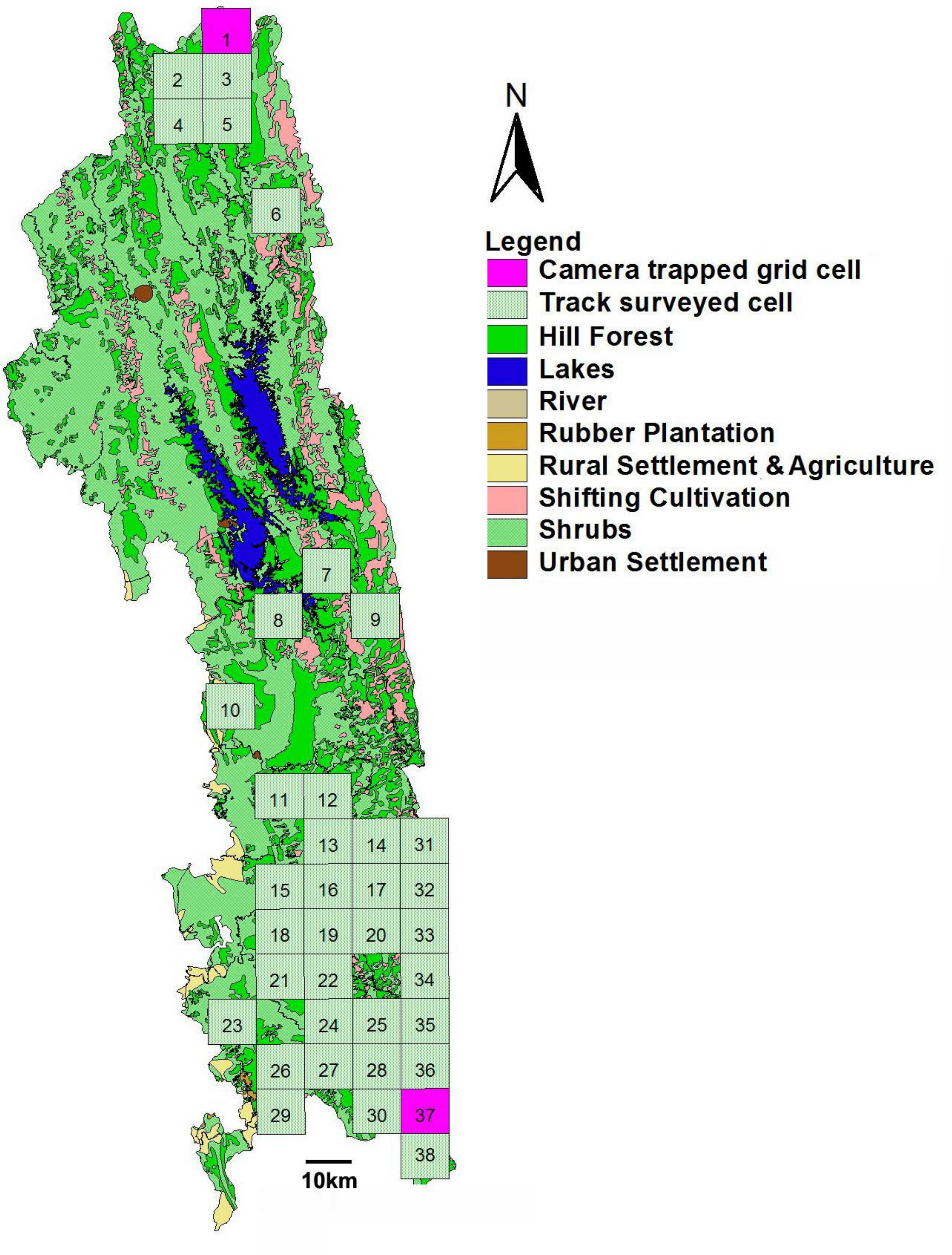

Figure 4.1 Map of the total surveyed and camera deployed grid cells.

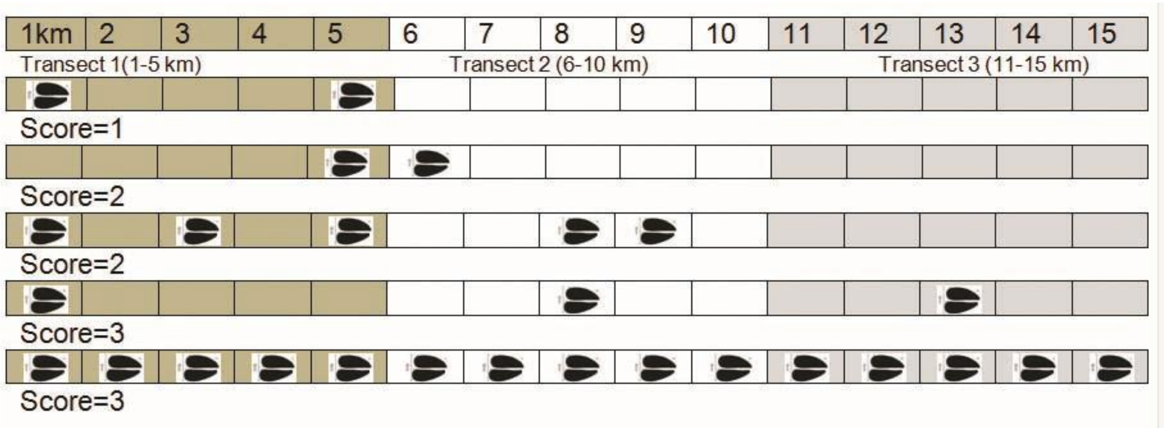

Figure 4.2 Scoring used to ranking the grid cells.

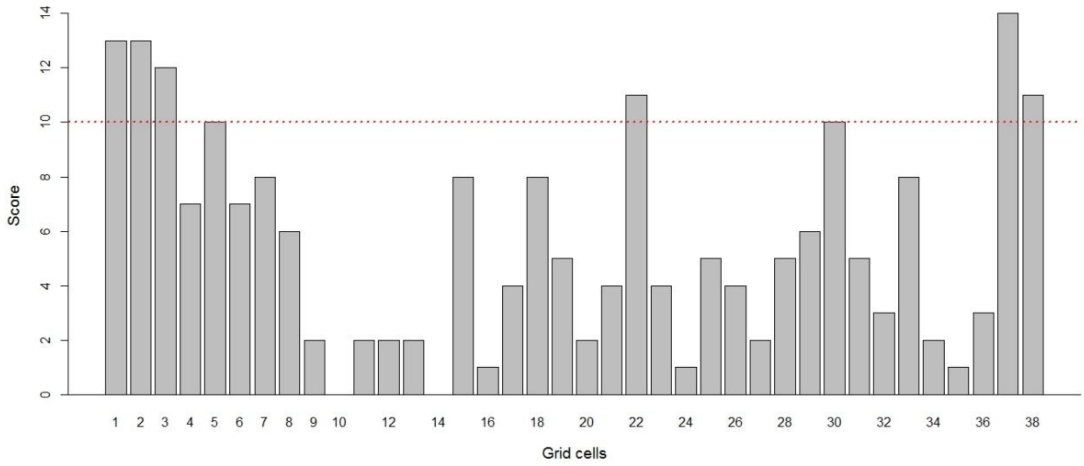

Figure 4.3 Individual score of surveyed grid cells.

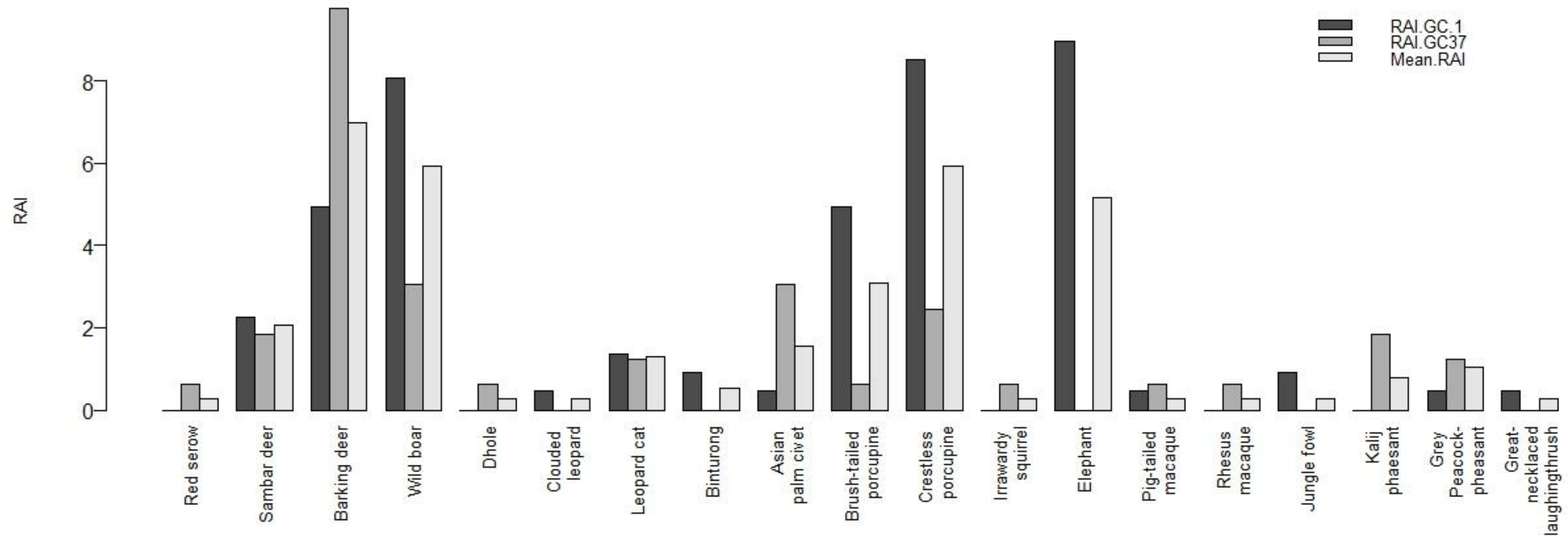

Figure 4.4 Comparison of RAI between grid cell 1 (GC 1) and grid cell 37 (GC 37)

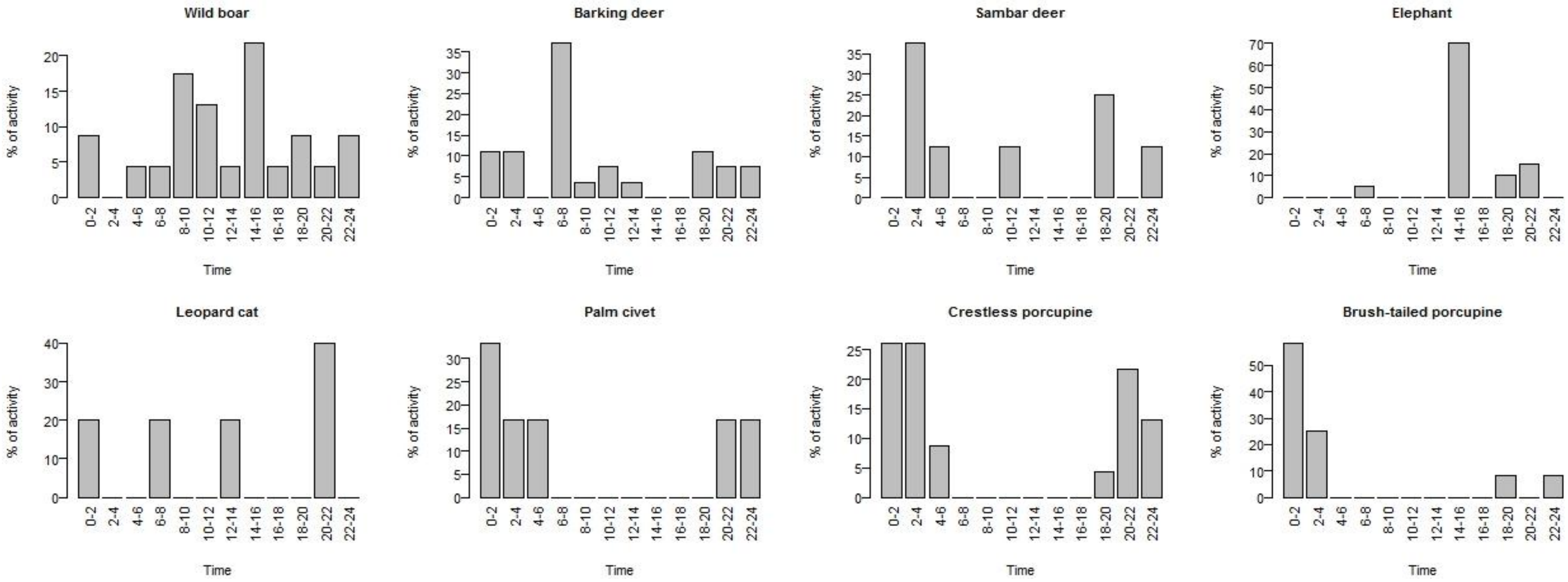

Figure 4.5 Activity time of animals.

Tables

Table 4.1 List of mammals recorded from both signs and camera trap survey.

Order/Family	Common name	Scientific name	Species detected (all GCs)	GC 1		GC 37	
				Method		Method	
				Signs	Camera	Signs	Camera
Artiodactyla							
Bovidae	Gaur	*Bos gaurus*	+	+	-	+	-
Bovidae	Red serow	*Capricornis rubidus*	+	-	-	+	+
Cervidae	Sambar deer	*Rusa unicolor*	+	+	+	+	+
Cervidae	Barking deer	*Muntiacus vaginalis*	+	+	+	+	+
Suidae	Wild boar	*Sus scrofa*	+	+	+	+	+
Carnivora							
Canidae	Dhole	*Cuon alpines*	+	+	-	+	+
Felidae	Leopard cat	*Felis bengalensis*	+	+	+	-	+
Felidae	Jungle cat	*Felis chaus*	+	+	-	+	-
Felidae	Golden cat	*Felis temminkii*	+	-	-	-	-

Table 4.1 (Continued)				GC 1		GC 37	
			Species detected (All GCs)	**Method**		**Method**	
Order/Family	**Common name**	**Scientific name**		**Signs**	**Camera**	**Signs**	**Camera**
Felidae	Fishing cat	*Prionailurus viverinnus*	+	-	-	-	+
Felidae	Clouded leopard	*Neofelis nebulosa*	+	-	**+**	-	-
Felidae	Leopard	*Panthera pardus*	+	+	-	-	-
Ursidae	Asiatic black bear	*Ursus thibetanus*	+	+	-	-	-
Viverridae	Binturong	*Arctonyx binturong*	+	+	+	-	-
Viverridae	Large indian civet	*Viverra zibetha*	+	+	-	+	-
Viverridae	Small indian civet	*Viverricula indica*	+	+	-	-	-
Viverridae	Palm civet	*Paradoxurus hermaphroditus*	+	-	+	-	+
Rodentia							
Hystricidae	Brush-tailed porcupine	*Atherurus macrourus*	+	+	+	-	+
Hystricidae	Crestless porcupine	*Hystrix brachyura*	+	+	+	**+**	**+**

Table 4.1 (Continued)				GC 1		GC 37	
			Species detected (All GCs)	**Method**		**Method**	
				Signs	**Camera**	**Signs**	**Camera**
Proboscidae							
Elephantidae	Asian elephant	*Elephas maximus*	+	+	+	-	-
Primates							
Cercopithecidae	Pig-tailed macaque	*Mecaca leonia**	+	-	+	-	-
Cercopithecidae	Rhesus macaque	*Macaca mulatta**	+	+	-	-	+
Colobidae	Phayre's langur	*Trachypithecus phayrei**	+	-	-	-	-
Colobidae	Capped langur	*Trachypithecus pileatus**	+	-	-	-	-
Hylobatidae	Hoolock gibbon	*Hoolock hoolock**	+	-	-	-	-
		Total	**25**	**16**	**11**	**9**	**11**

* Primates not considered as terrestrial but opportunistically recorded either visual or call.

Table 4.2 List of species, number of photographs and number of independent photo captured from two grid cells.

MAMMALS			GC 1		GC 37		
Order	Common name	Scientific name	Total photos	Independent	Total photos	Independent	**Total**
Artiodactyla	Red serow	*Capricornis rubidus*	0	0	2	1	2
Artiodactyla	Sambar deer	*Rusa unicolor*	34	5	130	3	164
Artiodactyla	Barking deer	*Muntiacus vaginalis*	19	11	37	16	56
Artiodactyla	Wild boar	*Sus scrofa*	64	18	20	5	84
Carnivora	Dhole	*Cuon alpines*	0	0	1	1	1
Carnivora	Leopard cat	*Felis bengalensis*	3	3	3	2	6
Carnivora	Clouded leopard	*Neofelis nebulosa*	1	1	0	0	1
Carnivora	Fishing cat	*Prionailurus viverrinus*	0	0	1	1	1
Carnivora	Binturong	*Arctonyx binturong*	1	2	0	0	1
Carnivora	Palm civet	*Paradoxurus hermaphroditus*	1	1	22	5	23
Rodentia	Brush-tailed porcupine	*Atherurus macrourus*	9	11	1	1	10
Rodentia	Crestless porcupine	*Hystrix brachyura*	25	19	4	4	29

Table 4.2 (Continued)

MAMMALS			GC 1		GC 37		
Order	Common name	Scientific name	Total photos	Independent	Total photos	Independent	**Total**
Rodentia	Irrawaddy squirrel	*Callosciurusn pygerythrus*	0	0	2	1	2
Proboscidae	Asian elephant	*Elephas maximus*	67	20	0	0	67
Primates	Pig-tailed macaque	*Mecaca leonia*	3	1	0	0	3
Primates	Rhesus macaque	*Macaca mulatta*	0	0	1	1	1
BIRDS							
Galliformes	Jungle fowl	*Gallus*	6	2	8	2	14
Galliformes	Kalij pheasant	*Lophura leucomelanos*	2	0	4	3	6
Galliformes	Grey peacock- pheasant	*Polyplectron bicalcaratum*	1	1	0	0	1
Passeriformes	Greater-necklaced laughingthrush	*Garrulax pectorallis*	2	1	0	0	2
		Total	**238**	**96**	**236**	**46**	**474**

Table 4.3 Comparison of Relative Abundance Index (RAI-Independent photos per 100 trap nights) of mammals species in CHT (selected areas), Bangladesh and other South-east Asian countries. ** main tiger prey

Bangladesh		Cambodia	Thailand	Lao PDR
Common name	This study	Gray & Phan 2011	Jenks *et al.* 2011	Johnson *et al.* 2006
Red serow	0.26	-	0.06	0.29
Sambar deer**	2.07	-	1.85	0.25
Barking deer**	6.98	6.74	1.11	2.77
Wild boar**	5.94	5.70	0.78	0.40
Dhole	0.26	0.63	0.02	-
Clouded leopard	0.26	0.04	0.06	-
Leopard cat	1.29	0.77	0.12	-
Binturong	0.52	-	0.15	-
Asian palm civet	1.55	0.85	0.08	-
Brush-tailed porcupine	3.10	1.32	-	1.79
Crestless Porcupine	5.94	-	0.75	-
Elephant	5.17	3.10	0.42	-
Pig-tailed macaque	0.26	0.37	0.58	4.26

Table 4.4 Activity periods of mammals of the CHT resulted from camera-trapping data

Common Name	Scientific Name	Total	Diurnal	Nocturnal	% Nocturnal activity
Wild boar	*Sus scrofa*	23	15	8	35 C
Barking deer	*Muntiacus vaginalis*	27	14	13	48 C
Sambar deer	*Rusa unicolor*	8	1	7	87 C
Elephant	*Elephas maximus*	20	15	5	25 C
Leopard cat	*Felis bengalensis*	5	2	3	60 C
Palm civet	*Paradoxurus hermaphroditus*	6	0	6	100 N
Crestless porcupine	*Hystrix brachyura*	23	0	23	100 N
Brush-tailed porcupine	*Atherurus macrourus*	12	0	12	100 N

Abbreviations used: N= nocturnal, C= cathermeral.

Chapter 5: Setting conservation priorities for medium to large mammals in the CHT

5.1 Abstract

Medium to large mammals in tropical forests are facing different level of threats throughout the globe. A major goal of conservation practitioners is to identify biodiversity significant areas and then strategically bring them under an effective management system. The priority areas selection at local scale is important considering of selection for conservation actions. This study evaluated the priority areas in the Chittagong Hill Tracts (CHT) are potential for medium to large mammals conservation following The Nature Conservancy's (TNC) Conservation Planning Handbook. Stress predicted in next 10 years, identified the threats and their current rating for the targets. However, I did not put any desire rating because it was not the objective of this study and there are no immediate plans to reduce the threats. I identified a total of 5 areas or targets, 7 key ecological attributes, and 15 threats. Habitat connectivity, abundance of ungulates, presence of carnivores, and quality of forest all are in stress and were ranked high. Shifting cultivation, hunting and settlement of plain land people were assessed high threats. This result can be useful as it obviated any source of record of baseline data for future conservation planning.

5.2 Introduction

Setting conservation priority areas combining by the biodiversity hotspot concept tools (Myers 1988, Myers *et al*. 2000) is globally accepted (Gerlech 2008). However, setting priorities for biodiversity conservation is a complex issue (Margules and Pressey 2000). The International Union for Conservation of Nature's (IUCN) definition of a protected area is as follows: "A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values." Establishing protected areas or reserves is one of the most effective ways to maintain wildlife populations (Bruner *et al.* 2001, Peres 2005), particularly large mammals. However, a rapid growth of protected areas is insufficient to stop the steep rate of biodiversity loss (Mora and Sale 2011). Long-term survival of large mammals, such as top predators and their prime preys, will only be protected if these reserves are effectively protected and well-connected because many large carnivores and ungulates are intolerance of human persecution and habitat alteration (Newmark 1987, Marsden *et al.* 2005, Chetkiewicz *et al.* 2006).

Priority protected areas at the regional level have already been identified (Rodrigues *et al.* 2004) but the global budget on biodiversity protection is insufficient to ensure effective management of all these areas. Resources must therefore be wisely allocated through sound planning and priority setting (Joseph *et al.* 2009, Metcalf and Wallace 2013). Additionally, biodiversity rich areas often occur in tropical countries where biodiversity faces the gravest threats to their natural resources and countries have very limited resources.

Bangladesh is no exception. Bangladesh is a signatory of Convention of Biological Diversity (CBD) where countries need information to assess the status of biodiversity, identify threats to biodiversity, to assess and implication of biodiversity changes for human wellbeing and to determine priorities for conservation and sustainable use (Aichi Biodiversity Targets 2020, Target 19: Knowledge, Science and Technology). Thus, there is an urgent need to conduct further prioritization studies at the local level within Bangladesh as part of a global solution to biodiversity loss and to meet the Aichi Targets-2020.

At the country scale of conservation planning, the process is selecting candidate areas where to work. If, the decision has already been made to work at a particular site or target, then the driving question becomes site management issues, such as how to protect the biodiversity contained in that site (Rao *et al.*2007). There are many ways to select the priority areas in local level depending on target objectives. In Bangladesh two landscapes are considered as important for tigers: the Sundarbans and Chittagong Hill Tracts (CHT). The Bangladesh Tiger Action Plan (BTAP) 2009-2017 was formulated to guide the practitioners to tiger conservation (Ahmad *et al.* 2009) and the threats to the Sundarbans have already assessed (Aziz *et al.* 2013). As per the BTAP recommendations, a survey conducted to carry out occupancy and abundance survey of tiger and prey in Chittagong Hill Tracts (CHT). The results of this survey can be found in Chapters 3 and 4. This chapter is focused on selecting conservation sites within the CHT and therefore aimed -

(1) to select the medium-large mammal’s conservation potential area (hereafter Key Biodiversity Area); and

(2) to identify the threats and their assessment (current rating).

5.3 Methods

5.3.1 Study area

The CHT is an area of 13,295 km^2, which comprises approximately 10% of Bangladesh located between 21°25′-23°45′N and 91°45′ -92°-50′ E with three separate administrative districts: Rangamati, Khagrachari and Bandarban (see Chapter 2). The CHT is a part of the 1800 km mountain range that runs from the eastern Himalayas in China to western Myanmar (Gain 2000). It is included in the Indo-Burma hotspot as one of the twenty five biodiversity hotspots in the world (Myers *et al*. 2000).

5.3.2 Priority setting

The priority setting methods used here are adapted from The Nature Conservancy's Conservation Planning Handbook (TNC 2007) and Conservation Action Planning Workbook (version: CAP_v6b). The TNC planning software now merged with another software known as MIRADI (www.miradi.org) an Adaptive Management Software for Conservation Projects. The data used in CAP Workbook are mainly based on field experiences gathered from recent field study described in Chapters 3 and 4.

5.3.3 Defining project scope and focal conservation targets

The scope is "the place where the biodiversity of interest to the project is located". It can include one or more "conservation areas or areas of biodiversity significance" as identified through an assessment (TNC 2007). In this case, I considered the CHT landscape as it has been identified as both a tiger survey and restoration landscape (Sanderson *et al.* 2006). The focal conservation targets are the basis for setting goals (TNC 2007). Here focal conservation targets are selected using the following two criteria:

(1) the area where many endangered animals occurred or potential for conservation; and

(2) the area already has some degrees of legal protection such as wildlife sanctuary, national park and reserve forest in the CHT landscape. Smaller fragments habitats were not considered suitable for long-term medium to large mammal conservation because fragmented gaps are generally not feasibly restorable.

5.3.4 Assessing viability of conservation targets

Populations of top carnivores like tigers and leopards are dependent on principal prey population (Karanth and Sunquist 2000) and need large areas and habitat connectivity for long-term survival. Considering medium to large mammal conservation potential in my project scope, I considered all categories and several Key Ecological Attributes (KEAs) under each category, although one target need not to have all three types of categories (TNC 2007). A KEA is a critical component of a conservation target. If that missing or altered, would lead to the loss of that target over time (TNC 2007). KEAs are selected following one or more rationales and each KEA is measurable by one or more indicators (Table 5.4). An indicator is information that meets the criteria of being: measurable, precise, consistent and sensitive. One indicator was selected for each KEA based on existing knowledge, the measurability of the state of that KEA, and the rating value and current state set based on existing knowledge (Table 5.4). Here, the second value (desired rating) is not set until a project will be targeted to achieve the desired state. The current KEA rating will instead provide the source of baseline data for any future study and assess the changing of each KEA over time.

5.3.5 Stress and source of stress ranking

Among the two threats ranking methodologies used, the stress and source of stress of ranking known as standard threat ranking method. In general, stresses are equivalent to a degraded or altered KEA (TNC 2007) directly or indirectly resulted from human activities (eg. habitat loss). In this case the conservation targets were predicted to be altered within next 10 years. The severity and scope (Box 1) for each stress were decided based on field experiences and existing knowledge. Source of stress known as direct threats is the proximate activities or processes that directly have caused, are causing, or may cause stresses and thus destruction, degradation and/or impairment of focal conservation targets (TNC 2007). Threats were listed that were likely to affect the targets directly after reviewing available information in different publications and consulting with persons who have experience about the CHT. For the direct threats and common taxonomy the IUCN-CMP classification were followed, which are also integrated with CAP workbook. (http://www.conservationmeasures.org/initiatives/threats-actions-taxonomies/threats-taxonomy). The CAP workbook calculated the overall threat ranks. The contribution and irreversibility (Box 1) of each source of stress were defined based on existing information. In many sources of stress (threats) the information was lacking or insufficient so assumptions were made, based upon our recent field experience.

Box 1: Definition and rating criteria for Stresses and Source of Stresses

Severity- The level of damage to the focal target that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the current situation).

• Very High: The threat is likely to destroy or reduce the current state of target 71-100%.

• High: The threat is likely to destroy or reduce the current state of target 41-70%.

• Medium: The threat is likely to destroy or reduce the current state of target 21-40%.

• Low: The threat is likely to destroy or reduce the current state of target 1-20%.

Scope- The geographic scope of impact on the conservation target at the site that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

• Very High: The threat is likely to be pervasive in its scope and affect the target (71-100%) of the target's occurrences at the site.

• High: The threat is likely to be widespread in its scope and affect the target (41-70%) of the target's occurrences at the site.

• Medium: The threat is likely to be localized in its scope and affect the (21-41%) conservation target at some of the target's locations at the site.

• Low: The threat is likely to be very localized in its scope and affect (1-20%) the conservation target at a limited portion of the target's location at the site.

Contribution- The expected contribution of the threat, acting alone, to the full expression of a stress under current circumstances (i.e., given the continuation of the existing conservation situation).

• Very High: The source is a very large (71-100%) contributor of the particular stress.

• High: The source is a large (41-70%) contributor of the particular stress.

• Medium: The source is a moderate (21-40%) contributor of the particular stress.

• Low: The source is a low (1-20%) contributor of the particular stress.

Irreversibility- The degree to which the effects of a source of stress can be restored.

• Very High: The source produces a stress that is not reversible (e.g., wetlands converted to a shopping centre).

• High: The source produces a stress that is reversible, but not practically affordable (e.g., wetland converted to agriculture).

• Medium: The source produces a stress that is reversible with a reasonable commitment of resources (e.g., ditching and draining of wetland).

• Low: The source produces a stress that is easily reversible at relatively low cost (e.g., off-road vehicles trespassing in wetland).

Key:

Very High

High

Medium

Low/Poor

Note- Definition adapted from TNC (2007).

5.4 Results

5.4.1 Defining projet scope and focal conservation targets

Assessing the viability of tiger population in the CHT is one of the goals in BTAP, 2009-2017 (Ahmad *et al.* 2009). Occupancy and abundance survey of tiger and prey was conducted in 2010-2011 to meet the BTAP strategic action for this goal. In this study 5 areas were assessed as conservation targets under the project scope, the CHT landscape. These have scope to conserve viable populations of medium to large mammals. Among the 5 targets, 3 are reserved forests, 1 is a national park and 1 is a wildlife sanctuary (Table 5.1).

5.4.2 Assessing viability of conservation targets

The viability of conservation targets ranged from poor to good and the overall project health rank was judged as fair. The current rating of each indicator varies from target to target and was assessed from poor to very good. Out of 5 conservation targets only one target (SRF) found very good in terms of landscape context which means the target is well-connected (<1km) with other forest here in with western site of Myanmar a globally important tiger conservation landscape. Among the other targets three landscape context found good and one was found fair. However, none of the targets condition were found good or very good. Among targets 3 conditions are fair and 2 conditions found poor. Size of two targets were found Good, 1 fair and 2 are poor. The overall rank considering landscape context, condition and size of the targets only two targets, KRF and SRF were found Good, two (RRF and KNP) were fair and target PWS were poor (Table 5.1).

5.4.3 Stress and source of stress ranking

Stress: Seven stresses (altered KEAs) were assessed and ranked from low to high chance of alteration. The stress connectivity were ranked as top means there is very high chance of altered the connectivity within 10 years (Table 5.2). A total of 15 threats were identified and overall threats were judged as high in all targets except target Kaptai National Park, in which the threats were ranked as medium. Shifting cultivation, hunting and population growth due to migration or settlement of plain land people to the CHT are priotized as high (Table 5.3).

5.5 Discussion

From the recent occupancy and abundance survey of medium to large mammals (see chapters 3 and 4) no tiger signs were confirmed. However, at least three confirmed tiger killings were recorded in the last 10 years. Based on this result, it is reasonable to assume a very recent extirpation of tigers or a very low unviable extant population. This in turn indicates there is potential to support tiger populations in the CHT in the future provided major threats are reduced (Sanderson *et al.* 2006; Ahmad *et al.* 2009). Alternatively, there would also be scopes to support viable populations of other carnivores including leopard (*Panthera pardus*) and dhole (*Cuon alpines*) by increasing the number of their prey.

The KRF and SRF are two potential areas to support long-term conservation of large mammals in the CHT in terms of KEA indicators used in this assessment. Habitat quality and size are essential for both large prey and predators (Seidensticker 1986, Sunquist 2010). However, none of the targets are solely enough to restore viable populations and ensure the long term conservation of large carnivores and probably elephants due to the small size of the area. The

KRF is potential to restore many large mammals by merging with adjacent Dampa Tiger Reserve (DTR) of India. If merged, the total area will be over 1000 km^2 and could hold many endangered animals including tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), gaur (*Bos gaurus*), sambar deer (*Cervis unicolor*) and elephant (*Elephas maximus*). Corridor between two habitats is not only useful for animals but also plants (Bennett, 1999). The degraded area between KRF and DTR, corridor can be created by restoring habitat in between. The SRF connected with western Myanmar and is designated as level-1 Tiger Conservation Landscape (Sanderson *et al.* 2006). It also connects with RRF although both SRF and RRF habitats are highly degraded. However, considering the very low human population in these two reserve forest areas, it is not impossible to reverse the habitat and increase the abundance of prey species.

5.6 Management implications

The KNP and PWS have potential for another flagship species (i.e. elephant) but the size of the area and current situation of adjacent habitat are not as promising as KRF and SRF. However, these two areas are more protected by existing forest and wildlife Acts. Wildlife sanctuary is the best protected system in Bangladesh from a legal perspective. However, the only wildlife sanctuary in CHT Pablakhali wildlife sanctuary (apart from recently established Sangu wildlife sanctuary) is worse than any other protected areas in the CHT in sense of habitat degradation and encroachment. The overall threats in all targets were judged as high except KNP though, condition and size of both areas are assessed poor. To ensure large mammal survival, areas must be sufficiently large to sustain viable populations and the species habitats must be close enough together for a healthy exchange of individuals among populations. The threat levels supplied in this assessment process is mainly from our field experiences because the information available in scientific publications is either outdated or nor relevant to the targets. Some threats like road construction are interlinked with other threats like overharvesting, logging, migration of plain land people or even hunting because the impact cannot be measure only with the volume of the space used by road. There is no doubt that constructing roads through the forested areas increases the threats level rather than protection facilities particularly in the countries where conservation practice very poor. Many threats like climate change and disease ranked as low probably there is no available information how they are affecting to habitat or species. Finally, the findings could be valuable to researchers and conservation practitioners as well as policy makers in forest department as it provides a source of baseline data for future conservation planning.

Figure

Figure 5.1 Map of the CHT with Conservation Targets

Tables

Table 5.1 Assessing viability of Conservation Targets

Conservation Targets		Current Rating			
		Landscape Context	Condition	Size	Viability Rank
1	Kassalong Reserve Forest (KRF)	Good	Fair	Good	**Good**
2	Sangu Matamuhuri Reserve Forest (SRF)	Very Good	Fair	Good	**Good**
3	Rainkhyong Reserve Forest (RRF)	Good	Fair	Fair	**Fair**
4	Kaptai National Park (KNP)	Good	Poor	Poor	**Fair**
5	Pablakhali Wildlife Sanctuary (PWS)	Fair	Poor	Poor	**Poor**
Project Biodiversity Health Rank					**Fair**

Table 5.2 Stress and source of stress ranking across targets (*Not considered in ranking because of doubtful occurrence in the targets)

	Stresses (Altered Key Ecological Attributes) Across Targets	Kassalong Reserve Forest	Sangu Matamuhuri Reserve Forest	Rainkhyong Reserve Forest	Kaptai National Park	Pablakhali Wildlife Sanctuary
		1	2	3	4	5
1	Connectivity	Medium	High	High	High	High
2	Abundance of sambar deer and other ungulates	High	High	High	*	High
3	Quality of forest	Medium	High	High	Medium	High
4	Carnivore presence	High	High	High	*	*
5	Elephant abundance	Medium	High	Low	Medium	High
6	Legal structured system	Low	Medium	High	Low	Medium
7	Size of the area	Medium	Low	Medium	Low	Medium

Table 5.3 Ranking the source of stress (threats)

Threats Across Targets		Kassalong Reserve Forest	Sangu Matamuhuri Reserve Forest	Rainkhyong Reserve Forest	Kaptai National Park	Pablakhali Wildlife Sanctuary	Overall Threat Rank
1	Shifting cultivation	Medium	High	High	Low	High	High
2	Hunting	High	High	Medium	Low	Medium	High
3	Settlement of plain land people	Medium	High	Low	Low	High	High
4	Legal demarcation of the area	Medium	Medium	Medium	Low	Medium	Medium
5	Road construction and other development	Medium	Medium	Medium	Low	Medium	Medium
6	Traditional laws on land ownership	Medium	Medium	Medium	Low	Medium	Medium
7	Logging	Low	Medium	Medium	Low	Medium	Medium
8	Overharvesting natural resources	Low	Medium	Medium	Low	Medium	Medium
9	Civil unrest & Insurgency	Low	Low	Low	Medium	Low	Low

Threats Across Targets		Kassalong Reserve Forest	Sangu Matamuhuri Reserve Forest	Rainkhyong Reserve Forest	Kaptai National Park	Pablakhali Wildlife Sanctuary	Overall Threat Rank
10	Livestock grazing	Low	Low	Low	Low	Medium	Low
11	Climate change	Low	Low	Low	Low	Low	Low
12	Disease (medium to large mammals)	Low	Low	Low	Low	Low	Low
13	Invasive species	Low	Low	Low	Low	Low	Low
14	Land slide	Low	Low	Low	Low	Low	Low
15	Tourism	Low	Low	Low	Low	Low	Low
	Threat Status for Targets and Project	High	High	High	Medium	High	High

Table 5.4 Assessment of target viability

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
1	Kassalong Reserve Forest (KRF)	Landscape Context	Connectivity	Distance from nearest forest patch	> 5km	3-5 km	**1-3 km**	<1 km	Jun-03	FD GIS map and Google earth image	Good	Rapid Assessment
		Condition	Abundance of sambar deer and other ungulates	Quality abundance	Doubt of occurrence	Has recent record but very rare	**Easy to find their presence by observing track**	Very easy to find the track all over	Jul-11	This study	Good	Rapid Assessment
			Carnivore presence	Number of carnivore species	No carnivore or bear only	**Either leopard or dhole record but rarely seen tracks**	Leopard, dhole and bear but abundance is restricted in few areas	Tiger, leopard, dhole and bear and abundance everywhere	Apr-11	This study	Fair	Rapid Assessment
			Elephant abundance	Resident population	Elephant never visited the area	Elephant partially visited the area	Elephant resident throughout or most of the year but frequently raid to crops	**Elephant reside throughout the year and do not come to human settlement area**	Jul-11	This study	Very Good	Rapid Assessment

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
			Legal structured system	Protected Area	Unclass state forest	**Reserve Forest**	National park	Wildlife Sanctuary	May-13	Existing Forest Acts and Rules	Fair	Expert Knowledge
			Quality of forest	Primary forest	0-30% forest cover	30-50% forest cover	**50-70% primary forest cover**	>70% primary forest cover	May-03	FD gis map and ground base experience	Good	Rapid Assessment
		Size	Size of the area	Conservation potential size of area in km²	<300 km²	300-500 km²	**500-700 km²**	>700 km²	Jun-13	FD official document and vegetation map	Good	Rough Guess
2	Sangu Matamuhuri Reserve Forest (SRF)	Landscape Context	Connectivity	Distance from nearest forest patch	> 5km	3-5 km	1-3 km	**<1 km**	Jun-03	FD GIS map and Google earth image	Very Good	Rapid Assessment
		Condition	Abundance of sambar deer and other ungulates	Quality abundance	Doubt of occurrence	Has recent record but very rare	**Easy to find their presence by observing track**	Very easy to find the track all over	Jun-11	This study	Good	Rapid Assessment
			Carnivore presence	Number of carnivore species	No carnivore or any recent record	**Either leopard or dhole or both record but rarely seen track**	Leopard, dhole and bear but abundance is restricted few pocket	Tiger, leopard, dhole and bear and abundance everywhere	Apr-11	This study	Fair	Rapid Assessment

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
			Elephant abundance	Resident population	Elephant never visited the area	Elephant partially visited the area	**Elephant reside most of the year**	Elephant reside throughout the year	Apr-11	This study	Good	Rapid Assessment
			Legal structured system	Protected Area	Unclass state forest	**Reserve Forest**	National park	Wildlife Sanctuary	May-13	Existing Forest Acts and Rules	Fair	Expert Knowledge
			Quality of forest	Primary forest	0-30% forest cover	**30-50% forest cover**	50-70% primary forest cover	>70% primary forest cover	May-03	FD gis map and ground base experience	Fair	Rough Guess
		Size	Size of the area	Conservation potential size of area in km²	<300 km²	300-500 km²	**500-700 km²**	>700 km²	Jun-13	FD official document and vegetation map	Good	Rough Guess
3	Rainkhyong Reserve Forest (RRF)	Landscape Context	Connectivity	Distance from nearest forest patch	>5 km	3-5 km	**1-3 km**	<1 km	Jul-03	FD GIS map and Google earth image	Good	Rapid Assessment
		Condition	Abundance of sambar deer and other ungulates	Quality abundance	Doubt of occurrence	**Has recent record but very rare**	Easy to find their presence by observing track	Very easy to find the track all over	Jul-11	This study	Fair	Rapid Assessment

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
			Carnivore presence	Number of carnivore species	No carnivore or bear only	**Either leopard or dhole or both record but rarely seen track**	Leopard, dhole and bear but abundance is restricted few pocket	Tiger, leopard, dhole and bear and abundance everywhere	Apr-11	This study	Fair	Rapid Assessment
			Elephant abundance	Resident population	Elephant never visited the area	Elephant partially visited the area	Elephant reside most of the year	**Elephant reside throughout the year**	Feb-11	This study	Very Good	Rough Guess
			Legal structured system	Protected Area	Unclass state forest	**Reserve Forest**	National park	Wildlife Sanctuary	May-13	Existing Forest Acts and Rules	Fair	Expert Knowledge
			Quality of forest	Primary forest	0-30% forest cover	**30-50% forest cover**	50-70% primary forest cover	>70% primary forest cover	May-03	FD gis map and ground base experience	Fair	Rapid Assessment
		Size	Size of the area	Conservation potential size of area in km²	<300 km²	**300-500 km²**	500-700 km²	>700 km²	May-13	FD official document and vegetation map	Fair	Rough Guess
4	Kaptai National Park (KNP)	Landscape Context	Connectivity	Distance from nearest forest patch	>5 km	3-5 km	**1-3 km**	<1 km	Jun-03	FD GIS map and Google earth image	Good	Rapid Assessment

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
		Condition	Abundance of sambar deer and other ungulates	Quality abundance	**Doubt of occurrence**	Has recent record but very rare	Easy to find their presence by observing track	Very easy to find the track all over	Jul-03	This study	Poor	Rapid Assessment
			Carnivore presence	Number of carnivore species	**No carnivore or bear only**	Either leopard or dhole or both record but rarely seen track	Leopard, dhole and bear but abundance is restricted few pocket	Tiger, leopard, dhole and bear and abundance everywhere	May-11	This study	Poor	Rapid Assessment
			Elephant abundance	Resident population	Elephant never visited the area	Elephant partially visited the area	**Elephant reside most of the year**	Elephant reside throughout the year	May-11	This study	Good	Rapid Assessment
			Legal structured system	Protected Area	Unclass state forest	Reserve Forest	**National park**	Wildlife Sanctuary	May-13	Existing Forest Acts and Rules	Good	Expert Knowledge
			Quality of forest	Primary forest	0-30% forest cover	30-50% forest cover	**50-70% primary forest cover**	>70% primary forest cover	May-03	FD gis map and ground base experience	Good	Expert Knowledge
		Size	Size of the area	Conservation potential size of area in km^2	**<300 km^2**	300-500 km^2	500-700 km^2	>700 km^2	May-13	FD official document and vegetation map	Poor	Expert Knowledge

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
5	Pablakhali Wildlife Sanctuary (PWS)	Landscape Context	Connectivity	Distance from nearest forest patch	>5 km	**3-5 km**	1-3 km	<1 km	Jun-03	FD GIS map and Google earth image	Fair	Rough Guess
		Condition	Abundance of sambar deer and other ungulates	Quality abundance	**Doubt of occurrence**	Has recent record but very rare	Easy to find their presence by observing track	Very easy to find the track all over	Jul-03	Expert knowledge	Poor	Rough Guess
			Carnivore presence	Number of carnivore species	**No carnivore or bear only**	Either leopard or dhole or both record but rarely seen track	Leopard, dhole and bear but abundance is restricted few pocket	Tiger, leopard, dhole and bear and abundance everywhere	Apr-11	Expert knowledge	Good	Rough Guess
			Elephant abundance	Resident population	Elephant never visited the area	Elephant partially visited the area	**Elephant reside most of the year**	Elephant reside throughout the year	Mar-11	Expert knowledge	Good	Expert Knowledge
			Legal structured system	Protected Area	Unclass state forest	Reserve Forest	National park	**Wildlife Sanctuary**	May-13	Existing Forest Acts and Rules	Very Good	Expert Knowledge
			Quality of forest	Primary forest	**0-30% forest cover**	30-50% forest cover	50-70% primary forest cover	>70% primary forest cover	May-03	FD gis map and Google earth image	Poor	Expert Knowledge

	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Date	Current Indicator Measurement	Current Rating	Source
		Size	Size of the area	Conservation potential size of area in km²	**<300 km²**	300-500 km²	500-700 km²	>700 km²	May-13	FD official document and vegetation map	Poor	Expert Knowledge

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APPENDICES

APPENDIX A: THE CHT Forest management Timeline:

1860 The CHT separated from Chittagong in the year of 1860 but till 1909 the reserve forests were a part of the Chittagong Forest Division.

1862 Forestry practices started but it was limited in toll collection.

1864 Anderson, superintendent of Calcutta Botanical Garden appointed as the First Conservator of Forest, appointed in Lower Province of Bengal and Assam.

1865 The first Indian Forest act was enacted.

1869 An Assistant Conservator of Forests was appointed.

1870 Systematic inspection of forest tracts suitable for reservation commenced

1871 Declared most of the area of the CHT viz, 5670 square miles out of 6882 square miles to be government forests in accordance with the section 2, Act VII of 1865.

1871 Teak seed was obtained from Burma and artificial regeneration was initiated for the first time in this country.

1872-73 Teak plantation started in Rampahar of Kaptai.

1875 Sir William Schlich, Conservator of Forest of Bengal inspected the forests in the division. First reserve forest established (Sitapahar) followed by Maini head water forests were declared as reserve forests.

1878 Collection of dues at toll stations was transferred from FD to the Deputy Commissioner till 1880.

1879 Headquarters bungalow established at Rangamati with three others toll stations (Chandraghona, Syllock and Ichhamati).

1880 Matamuhari forests were notified as reserved forests.

1881 Kassalong was declared as reserve forests (1940 in a notification Maini headwater forest into a reserve known by the common name of Kassalong Reserve. Later dereserved areas for rehabilitation of displaced persons due to the Karnaphuli Hydro-Electic Project in the year of 1959, 60, 61, and 1966).

1881 Sangu forests were notified as reserve forests.

1882 Rainkhiong was declared as reserve forests but real forestry operation was undertaken in 1920 due to remoteness and inaccessibility.

1890 DFO wrote a letter concerning unrestricted tree felling and practical extinction of such valuable trees once abundant

1905 With the partition of Bengal, the division came under the jurisdiction of eastern Bengal and Assam

1909 The Chittagong Hill Tracts division was formed by the splitting up of the Chittagong division.

1912 Repartition of Bengal and Assam these forests were transferred back to Bengal

1915-16 The dry year; spread fires to the reserve from jhum in 15 different locations

1920 Again the forest division annexed when new division (Cox's Bazar) formed in then Sangu Reserve part gone under Chittagong, and Matamuhuri part under Cox's Bazar

1923 Cowan's Working Plan launched and plantation centre established in Kassalong Reserve Forest. The forest was thereby brought under planned management and managed under this plan till 1943.

1927 Comprehensive Indian Forest Act formulated.

1942 The Chittagong Hill Tracts transit rules passed.

1943 Ten years working plan made by R, Banarjee effect.

1953 Twenty years working plan prepared by A.S.M. Zahiruddin.

1954 CHT Forest Division separated into two Forest Divisions.

1959 East Pakistan Private Forest Ordinance passed.

1959 East Pakistan Forest Development Corporation established.

1960 East Pakistan Forest Industries Development Corporation formed and got right of extraction of timber from the CHT for a period of 30 years. But the large scale extraction started before 1955.

1960 Jhum Control Division/Section created.

1961 M/s. Forestal Forestry Engineering International Limited of Canada was engaged to assist an inventory survey; the inventory continued till 1963 and report received in 1965. This was the first comprehensive and authentic report of the region.

1962 (1983?) Established Pablakhali Wildlife Sanctuary.

1967 WWF expedition report; Chief Secretary wrote a letter to CCF to express government's desire to protect the wildlife. All persons, including government employees, found guilty of illicit shooting should be severely dealt with, and if necessary, declared undesirable for the purpose of posting in or near about any reserve forest.

1972 Working Plan for the CHT (North) from the period of 1969-1988-89 which later revalidated after independence of Bangladesh.

1973 The Chittagong Hill Tracts Transit Rules passed (first transit rule passed in 1942).

1973 Bangladesh Wildlife (Preservation) Order-1973.

1974 Bangladesh Wildlife (preservation) (amendment) Act, 1974.

1978 Kaptai Pulpwood Plantation Division established.

1979 Wildlife Conservation and Management in Bangladesh. Report to FAO, Rome, (Oliver).

1994 National Forest Policy formulated.

1999 Established Kaptai National Park.

2000 Amended the Forest Act of 1927.

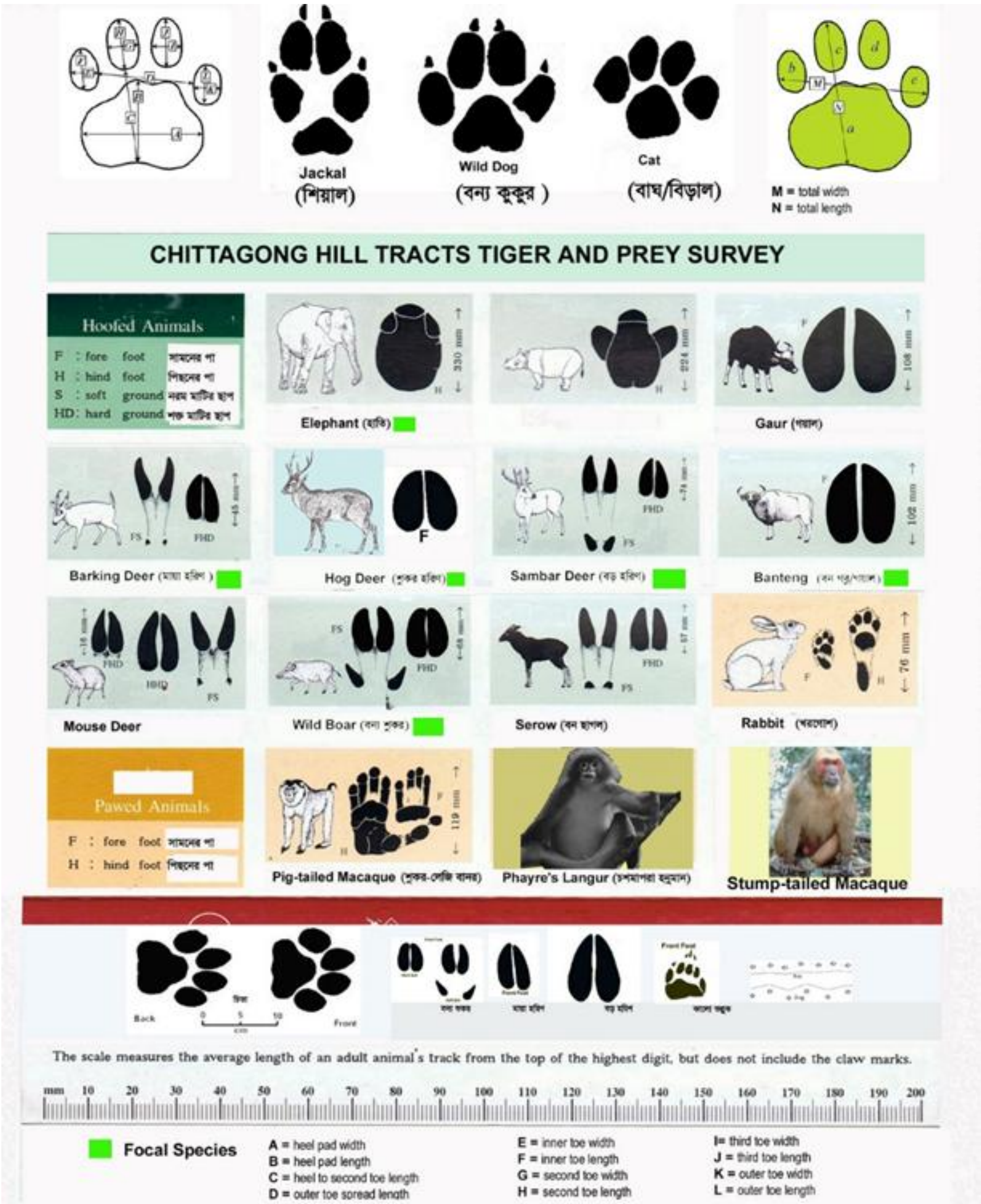
2001 Brick Burning (control) (Amendment) Act, 2001.

2010 Established Sangu Wildlife Sanctuary.

2010 Social Forestry (Amended) Rule.

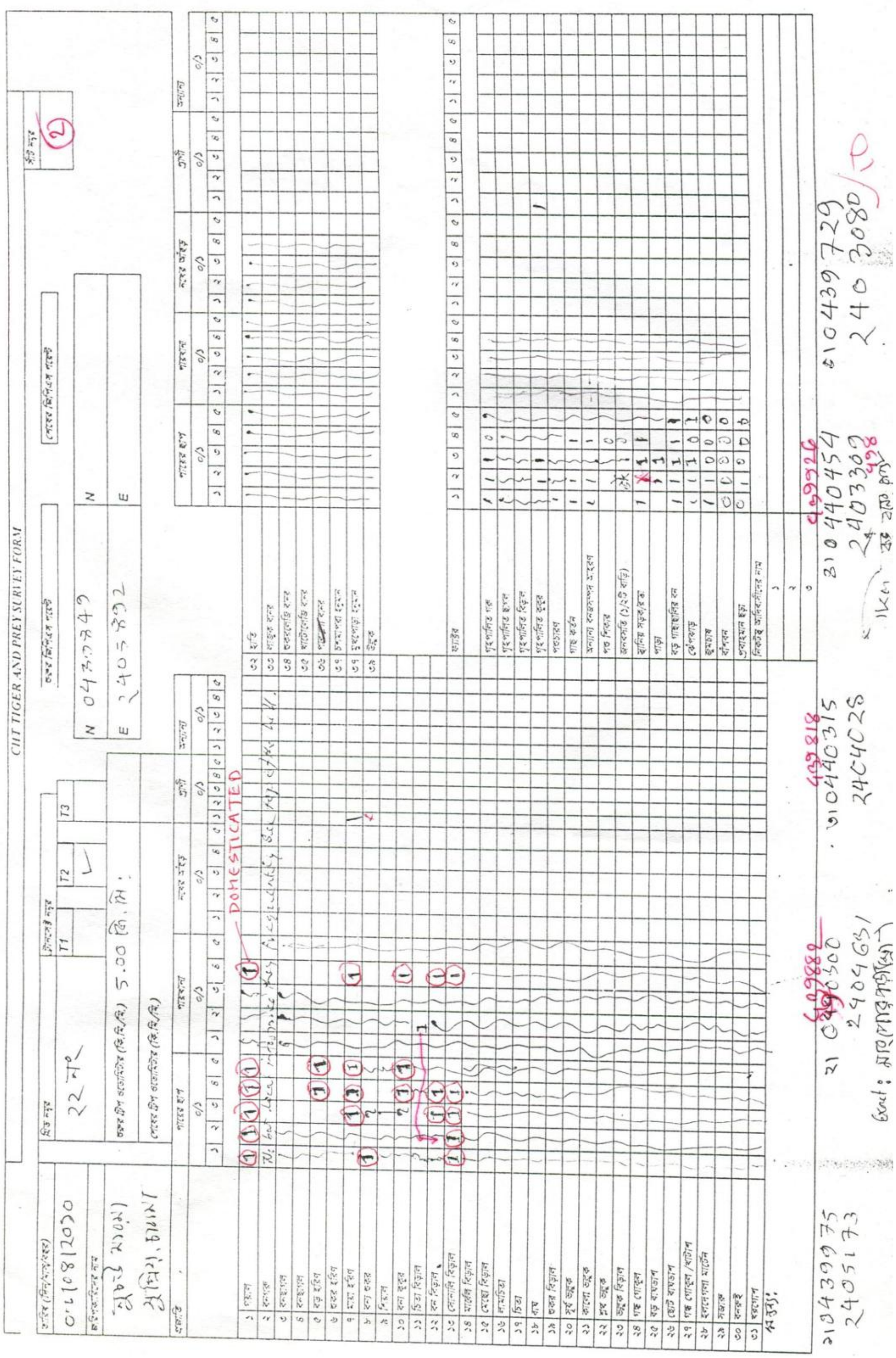
2012 Wildlife (Conservation and Security) Act, 2012 passed.

Appendix B: Track identification tools



F= fore foot
H= hind foot
Tiger
Common Leopard
Clouded Leopard
Golden Cat
Leopard Cat
Fishing Cat
Golden Jackal
Wild Dog
Binturong
Mongoose
Black Bear
Sun Bear
Burmese Ferret Badger
Hog Badger
Pangolin
Yellow-throated Marten
Small-clawed Otter
Eurasian Otter
Smooth-coated Otter
Otter Civet
Large Indian Civet
Small Indian Civet
Common Palm Civet
Masked Palm Civet
Bay Bamboo Rat
Large Bamboo Rat
Bush-tailed Porcupine
Porcupine
Focal Species

Appendix C: Sample Data Sheet



Appendix D: Photograph of different animal signs

Appendix E: Different mammals photo captured by camera traps

Elephant

Sambar

Barking deer

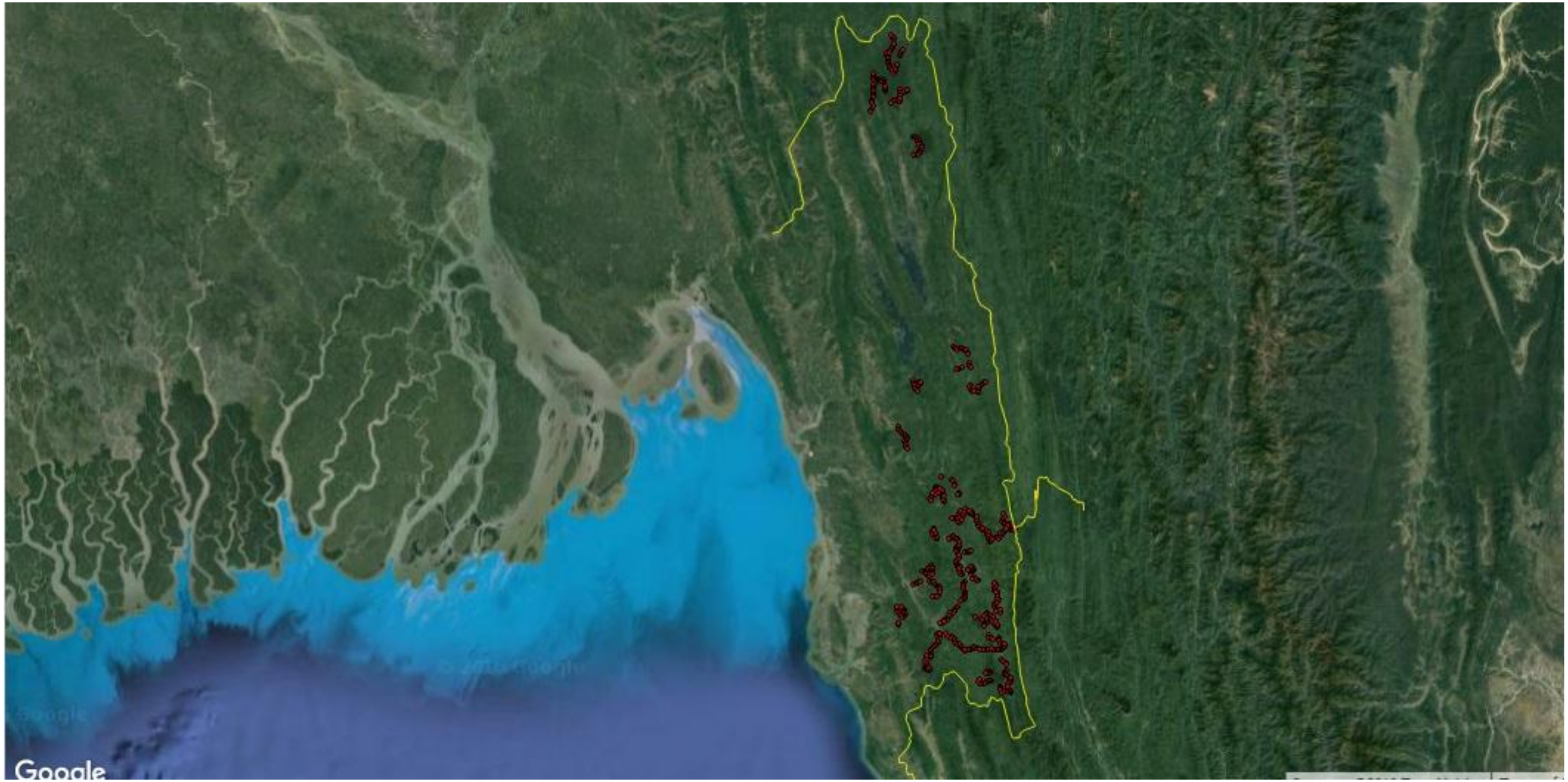
Dhole

Clouded leopard

Red serow

Appendix F: Different kinds of threats to the biodiversity in the CHT

APPENDIX G: Google earth view of study area with Surveyed Trail



Appendix H: New species for Bangladesh (frogs are probably new to science);

A= Deer skin (bottom) likely Fea deer/Fea muntjac (*Muntiacus feae*),. B = Hill long-toungued Fruit Bat (*Macroglossus sobrinus*), C = *Humerana* sp. D = *Rana* cf*. macrodon*