THE HUMAN DIMENSION OF ASIAN ELEPHANT (*ELEPHAS MAXIMUS*) CONSERVATION IN SOUTHEAST BANGLADESH

By

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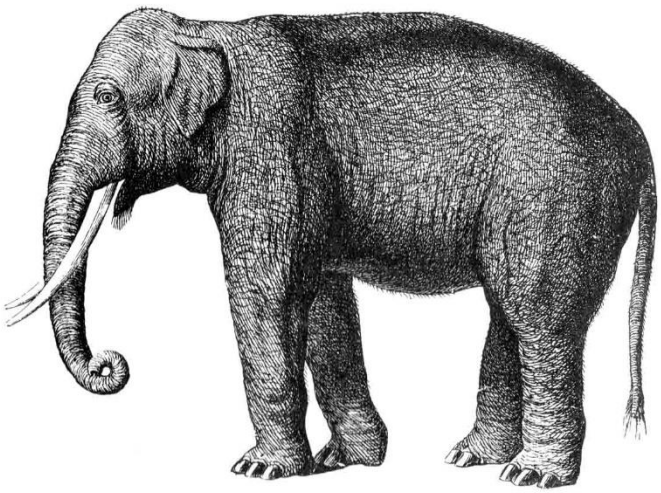

ABSTRACT

The 'human dimension' must be at the forefront when crafting effective management plans for large mammals in heavily-populated countries such as Bangladesh. There, Asian elephants have been declared critically endangered with only 210–330 elephants remaining in highly fragmented pocket of forest, mainly in the southeast part of the country where I based my study. I used a structured questionnaire to explore conflict between the animals and humans; in particular, I investigated how patterns of land use are altering the availability of forage for the animals. The questionnaire was delivered through face-to-face interviews with 171 respondents across 109 villages in and near elephant habitat in southeast Bangladesh. Crop raiding, damage to houses, fruit gardens, and seedlings and other important human values were identified as proximate causes of the human-elephant conflict, occurring throughout the year resulting in at least 18 elephants and 50 humans being killed during 2013-2015. Retaliation methods currently adopted by farmers to deter incursions are traditional and may escalate aggressive interactions. Despite an increasing frequency of incursions, approximately 73% of people surveyed favoured elephant conservation, at least in principle. My second objective in this thesis was to improve our appreciation of how the remaining elephant habitat has been altered as a consequence of human activities. For this work, I collected and analyzed Landsat images from the years 1989-2015, and conducted a ground inventory of the elephant habitat. My study indicates ≈ 36% of elephant habitat has been lost in the past 26 years from this region. The average canopy cover of the patches I sampled was 31%, at the lower threshold of forest cover suggested to support elephants. Within these patches, forage stocking quantity and quality are likely very poor. Moreover, the existing vegetation communities are currently dominated by non- native species, hampering the growth of native forage. However, dung surveys suggest that elephants are using habitats with vegetation that provides more trees and cover. Effective elephant conservation strategies in Bangladesh will need to incorporate human awareness and attitudes as well as the restoration of habitat to be successful. To achieve this, sufficient funding as well as dedication is required.

Key Words: Asian elephant, *Elephas maximus*, human dimension, conservation, questionnaire survey, satellite imagery, habitat, non- native species, forage stocking.

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CHAPTER 1

GENERAL INTRODUCTION AND BACKGROUND INFORMATION

Wildlife and human conflicts normally stem from a complex interaction of ecological, social, and cultural values, on various geographical and temporal scales (Decker et al. 2012). The Canadian wildlife Directors Committee has defined this human dimension as "understanding how people think about and interact with the natural environment to improve stewardship of natural resources" (Canadian wildlife directors Committee 2013). The concept of human dimension deals with the assessment and application of social information to describe, predict, understand and affect human thought and action toward the natural environment (Manfredo et al. 1995; Enck and Decker 1997). From this perspective, wildlife management can in turn be defined as guidance of the decision-making process and implementation of practices to influence interactions among people, and between people, wildlife and wildlife habitat, to achieve impacts valued by stakeholder (adapted from Riley et al. 2002). The assessment of human perception and activity in relation to natural resource management is not new, and natural resource administrators will be influenced in their decisions by interactions with stakeholders (Vaske et al. 1999). The application of the human dimension deals with the tools, techniques and philosophy associated with policy making and managerial use of information (Manfredo et al. 1995). In wildlife conservation, this will focus on the mechanisms through which people's understanding, values, and behaviours are influenced and affected by management decisions. The human dimension is increasingly identified by wildlife managers as an important element to recognize and incorporate into decision-making through public involvement, ideally without compromising scientific underpinnings (Bath 1998).

The human dimension to wildlife management

The history of coexistence between humans and wildlife is lengthy, with interactions constantly occurring since the genesis of civilization. Conflict with humans generally results when resource demands by humans overlap with the habitat requirements of animal species (Distefano 2005). This is not a new phenomenon (Monney et al. 2010), as there is a long

history of competition between man and wildlife occurring across the globe (Mashalla and Ringo 2015). The advent of agriculture and the domestication of animals may have ignited this conflict, perhaps from the beginning of non-nomadic civilizations. A wide range of animals including primates, rodents, antelope, bush pig, elephant, hippo, buffalo, zebra, lions, leopards, and hyenas today come into conflict with humans (Hill 2000; Sillero-Zubiri et al. 2007), often due to losses of crops, property, and livestock, and the injuring or killing of people (Sukumar 1991) . Herbivores find convenient sources of food from agricultural fields, and livestock serve as prey for carnivores. The direct threat to humans posed by some wildlife species is a particularly volatile problem, with increasingly limited resources exacerbating the situation. Surprise, fear, emotion and preconceived notions of wildlife encounters all contribute towards the response of humans to these conflicts. The intensity of human-wildlife conflicts increases as wildlife habitat and connecting corridors become surrounded by a human- dominated landscape (Mayberry 2015 ; Bisi 2005). According to Canover (2001), attacks by alligators, cougars, bears, coyote, bison and moose all have increased during the 20th century. Conflict between human and wildlife causing harm to people creates a negative attitude towards animals (Nyhus et al. 2000).

Human dimensions in elephant conservation

Elephants are distributed in 50 countries across the globe, 13 of which are in Asia and 37 in Africa (Perera 2009). Many literary references since the third millennium BC, as well as archaeological evidence, suggest a unique relationship between humans and elephants (Olivier 1978). Depictions of elephants are found in many ancient rock carvings, often reflecting an interest in the family life of elephants. In pre-colonial times, elephants played a key role in permitting arable farming (Ville 1995). The animals have a long-standing influence on many cultures, religion and history of both Asian and African countries. In the latter, the elephant often reflects wisdom. In Asia, elephant symbolism is common throughout many religions: the Hindu religion respects the animal as “god Ganesh”, a symbol of both strength and wisdom, whereas Buddhism considers the elephant to be a reflection of inner strength. Even in societies where the dominant religion holds no particular reverence for animal (e.g. Muslim and Christian) the elephant is still an iconic symbol of strength.

Interactions between humans and elephants have been occurring since ancient time. Poaching, spread of firearms, farming etc. contributed to a substantial decline of elephant populations and range both in Asia and Africa in the 19th and 20th centuries. Hence, sustaining current populations of elephants poses a significant challenge for wildlife managers. In Africa, the elephant population in 18 countries has declined from some 496,271 in 2007 to approximately 352,271 in 2014 (Chase et al. 2016), while conflict between elephants and humans continues to rise. For example, in 1992 two people were killed in Cameroon and elephants damaged more than US$ 200,000 in crops over 5093 ha of farm land (Thouless et al.1992).

The elephant has been domesticated in Indian sub-continent for military purposes, transport, construction, logging, ceremonial use and ecotourism since ancient times (Banglapedia, 2012). Exponential human population growth, engrained attitudes towards elephants and unchecked development generate conflict, crop and property damage, along with human and elephant casualties for centuries. Farmers in Asia routinely lose entire crops to elephants, causing food shortages and displaced settlements (Ville 1995). Recent estimates indicate farmers in Asia lose up to 10–15% of their total agricultural output due to elephant incursion (Madhusudan and Sankaran 2010). In India alone, elephant damage is estimated to cost approximately $ 3 million per year, including the destruction of 10,000-15,000 houses (Bist 2006). The Indian Ministry of Environment and Forest also reported that each year nearly 400 people and 100 elephants are killed in conflict-related occurrences in that country (Rangarajan et al. 2010). Choudhury (2004) estimated that during 1980-2003, 1500 people lost their lives in north-eastern India as a consequence of human-elephant conflict. Elephants also attempt to raid harvested crop stored in granaries or in homes by knocking down walls of mud or thatched roofs (Sukumar 2003). Currently, throughout India there are approximately 500,000 families affected by human–elephant conflicts (Rangarajan et al. 2010). In this context, conservationists must target a reduction in the impact of elephants on humans while promoting coexistence with the animals and conserving viable populations of elephants (Hoare 1995; Ville 1995).

Status and basic ecology of the Asian elephant

Two species of elephants are currently recognized: the Asian elephant (*Elephas maximus*) and the African elephant (*Loxodonta africana*). The Asian elephant is comparatively smaller than its African counterpart; male Asian elephants usually possess tusks, whereas female Asian elephants are normally tusk-less. The Asian elephant once ranged from west Asia along the Iranian coast into the Indian sub-continent, and eastwards into south-east Asia to include Sri Lanka, Java, Sumatra, Borneo and into China northwards (Sukumar 1992). The recent estimate for the global Asian elephant population was <40,000 animals in the wild, with an additional 16,000 elephants in captivity (Sukumar 2006) . This decline has probably been occurring for centuries with acceleration in the modern era. Not surprisingly, the species has been listed globally as endangered and placed on Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (UNEP-WCMC 2010).

Elephants through their actions (foraging, trampling, etc.) have historically played a significant role as a form of 'natural disturbance', maintaining the ecosystems they inhabited, leading to the animal being referred to as the 'engineer' of the forest (Sukumar 1992). In Asia, the ecological importance of the elephant is now unambiguously established leading to the species often being popularly dubbed as a 'keystone', 'flagship', and/or 'umbrella' species (Sukumar 1992). Asian elephants are herbivores and feed on a variety of plants, including fruit, grasses, tree bark, vegetables and palm leaves. They need to consume about 10% of their body weight every day (up to 150-200kg for an adult), with up to 18 hours/day spent foraging. They also need to drink up to 120 liters of water every day.

Female Asian elephants and their calves may move about together as groups, but upon reaching adolescence, the males disperse. Adult bull elephants live solitarily, however sometime they form groups with other males. The females remain in small family herds consisting of about 8-12 individuals (sizes can vary) led by a matriarch who tends to be the oldest, largest and most experienced female. Calves are cared for by their mothers and aunts. The movements and activities of a group are determined by the matriarch, and on occasion, related family groups may come together to form larger clans. Groups may roam widely depending on the availability of food and water, and often follow traditional, seasonal migration routes, sometimes travelling 3- 30 km per day. Home range size for females was

estimated at 184–326 km² for females and 188–407 km² for males in north India (Williams 2002). In Sri Lanka, smaller home ranges of 30–160 km² for females and 53–345 km² for males have been recorded (Fernando et al. 2005). Males become sexually mature at between 10 and15 years of age; females usually produce their first calf at approximately 10-12 years of age (Clubb and Mason 2002; Stevenson et al. 2006). Female elephants may give birth to a calf every 2.5-4 years under favorable conditions, otherwise every 5-8 years. The life span of Asian elephants is 60 to 70 years.

Asian elephant habitat

Asian elephants are generalist feeders. They inhabit a variety of ecosystems, including grassland, tropical evergreen forest, semi-evergreen forest, moist deciduous forest, dry deciduous forest and dry thorn forest, cultivated and secondary forests and scrublands. The vegetation types of these areas encompass dry thorn forest , deciduous forest and grassland. Because of their ability to consume a wide variety of food, and adaptability to adjust to changed habitat, they can survive a diverse array of habitats although prefer areas where water is available and forage plants are palatable. During the dry months of January to April, they congregate near waterbodies to browse plants with much higher protein content but at the onset of the rainy season, they disperse over a wider area into tall grass forests, to feed on the fresh grasses (Sukumar 2003). During the months of September to December, when the tall grasses became fibrous, they move into lower-elevation short-grass open forest (Sukumar 2003). This normal movement pattern may interrupted depending on geographical location, adverse conditions (e.g. drought, rainfall, prolong winter. human interference etc.) and other factors (e.g. habitat destruction and loss) of the habitat.

Human populations continue to increase near Asian elephant habitat and currently 20% of the world's human population now lives in or near Asian elephant habitat. These areas are being cut down and cleared to make way for agriculture, housing, roads, industry and other amenity for growing populations. Human encroachment in forested area has been shown to be prevalent in the habitats of 80% of Asian elephant habitat (Rood et al. 2010). Additionally, over a period of one year there was a 2.41% loss in total forest coverage as deforestation for agriculture occurred (Rood et al. 2010). Vast areas have been cleared to accommodate millions of people in Indonesia. Unsustainable exploitation of timber and development projects result in loss of considerable amount of forest cover in India, Sri Lanka, Cambodia,

and Laos. The result is that Asian elephants are now confined to isolated "habitat islands" across much of their historical range and nearly half of remaining habitat has become fragmented (Leimgruber et al. 2003).

The human dimension in elephant conservation in Bangladesh

In Bangladesh, the Asian elephant has been declared "critically endangered" and their population is declining at a quickening rate due to an array of threats in the wild as well as interactions with humans. Exacerbating the situation is the fact Bangladesh likely never supported large numbers of Asian elephants: it is estimated that on average, only 500 elephants roamed the country during the 20th century (IUCN 2004). Still, within the country the species was widespread and distributed across the deciduous forests of central Bangladesh (Mymensing, Nertokona, the Sherpur district of, the semi-evergreen forests of Sylhet districts) and the evergreen forests of Chitttagong and Cox's Bazar in the hilly tracts of south-eastern Bangladesh. Current estimates are that only 210-330 elephants now reside in Bangladesh, with another 79-107 non-resident animals that travel in and out of the country (see Table1.1; Motaleb et al. 2016). The reserve at Teknaf once contained the largest number of Bangladesh elephants, with close to 100 individuals, yet it currently has only half that number (Motaleb et al. 2016). Human population increase, deforestation, degradation, land conversion, poaching, and development interventions have all taken their toll on the Bangladesh elephant population. Currently, the animals are confined to highly fragmented "pockets" of forest that are relatively inaccessible to humans, mainly in the Chittagong, Cox's Bazar and the Chittagong Hill Tracts districts in southeast Bangladesh. In addition, some animals periodically cross into the hilly and 'tea garden' area of the north-east (Moulvi Bazar District) and northern (Nertokona, Sherpur district) parts of Bangladesh, coming from the neighboring Indian states of Tripura, Meghalaya, and Assam.

As suggested elephants suffer from severe habitat loss in Bangladesh, with the country being one of the most densely human-populated regions at the planet. Rapidly growing and relatively poor human population surrounds their habitats. People continuously encroach on elephants through the conversion of land for agriculture, dwelling units, shifting cultivation and the collection of a variety of resources. Overall, the forest cover of the country has been declining at a rate of 2,600 ha/year (FAO 2015).

Table 1.1: Estimated elephant populations in Bangladesh according to districts (Motaleb et al. 2016)

District name / Forest Division	Lower limit	Upper limit	Mean elephant population
Chittagong			
Chittagong South forest division	50	78	65
Cox'S Bazar			
Cox's Bazar North Forest Division	46	54	67
Cox's Bazar South Forest Division	46	63	78
Bandarban			
Lama Forest Division	23	30	39
Bandarban Forest Division	9	11	14
Rangamati			
Chittagong Hill Tracts South Forest Division	22	28	33
Chittagong Hill Tracts North Forest Division	13	17	21

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Large numbers of people residing in rural areas require forested areas for subsistence. To grow food, farmers illegally cultivate forest land, often with the blessing of local influential people. Often, over the course of time, huts are constructed near the converted land, eventually growing into full villages. Local governments then create structures like roads, schools, and mosques to meet the need of these villages. Moreover, a significant amount of forest land in Bangladesh has been transferred to other organizations from the Forest Department, which is responsible for managing the forest and wildlife resources. In this manner, areas once covered with productive tropical forest are now fragmented into small patches of forest land.

Elephants require large areas for forage, shelter and roaming. Disruption of habitat connectivity creates unnatural movement patterns, with elephant herds being largely restricted to remaining small patches of forest. In the absence of ecological connectivity, possibilities for exchanging genetic material between herds decline, leading to deleterious inbreeding effects. Poaching of male elephants for ivory is another threat resulting in an imbalance of the male: female ratio. Plantations of non-native species (e.g. acacia, rubber, eucalyptus, etc.) contribute to the shrinking food base for the elephants. The settlement of ‘Rohinga’ (refugees from Myanmar) has also caused significant deforestation of elephant habitat.

The goal of an effective elephant conservation plan is sustainable co-existence and sharing of resources that balances both human and elephant interests. Effective land use planning and appropriate strategies need to be developed to ensure such a harmonious relationship. Recognizing the severity of the problem, the Bangladesh Forest Department sees the conservation of elephants as a mandate. To date, however, efforts have been focused on enhancement through forage crops, with the human dimension of the conflict never receiving high priority. In a densely populated country like Bangladesh, citizen support is likely crucial to conservation. The conflict may in fact be worsened by a lack of education regarding elephant range patterns, behavior and feeding habits. By providing current, timely information, people, crops and homesteads may be better protected from the animals. As a starting point, an assessment of rural peoples’ perception, belief, knowledge, attitudes, and values towards the elephant will contribute to the development of an integrated, multi-dimensional conservation strategy in Bangladesh.

Mitigation methods used to address elephant-human conflicts

Various mitigation measures have been applied to minimize the damage caused by elephants across conflict-prone areas of Africa and Asia. Some of these measures use traditional methods whereas others apply more recently-developed tools.

Traditional methods have been widely used for centuries by local communities to drive elephants away, primarily with noise and fire. Basic approaches to prevent elephant incursions include watchtowers, solar-powered torches, and banger sticks (O'Connell-Rodwell et al. 2000, Zhang and Wang 2003). The removal of problem elephants from conflict areas save animals from being shot, and the re-introduction of these animals into areas previously de-populated by poaching would appear to be a perfect solution for some wildlife conservationists (Nelson et al. 2003). However, Fischer and Lindenmayer (2000) reviewed 180 case studies on animal relocations and concluded that translocations to solve human–animal conflict situations often were unsuccessful. Physical barriers are also considered to be long-term solutions, using trenches, moats, stone walls etc. (Nyhus et al. 2000); these methods become ineffective when elephants use their feet to push soil into the trench (Santiapillai and Suprahman 1986).

Electric and solar fences are the most commonly-used barrier methods in Asia (Desai and Riddle 2015) and generally are considered to be best solution to address human-elephant conflict (Nelson et al. 2003). However, in many cases, these methods also have been proven ineffective as elephants can break fences and topple posts (Santiapillai and Suprahman 1986). The use of olfactory and auditory repellents for elephants is still in an experimental stage (Nelson et al. 2003). Peppers containing capsaicin give a temporary burning sensation to elephant trunk and eyes, which deter elephants from entering into areas of human activity (Patel et al. 2009). Burning "brickettes" made with chili seed and elephant dung, or employing capsicum aerosol spray, has had some success as a short term repellent, but further evaluation is needed (Nelson et al. 2003). Cultivation with non-palatable crops could be a potential solution as elephants often try to avoid non-palatable crops but they might simply cross over them to reach more preferred food types (Hoare 1992). Recent research with African honey bees has demonstrated that beehive fences are more effective at deterring elephants and may have a role in alleviating human–elephant conflict (King et al. 2011).

Desai and Riddle (2015) found raising community awareness towards elephant behaviour could reduce physical attacks.

Conflict between elephants and humans will continue to escalate as human populations climb and elephants continue to be confined to isolated patches and remnant forest (Santiapillai and Read 2010). Restoring habitat with forage plants in elephant habitat and corridors within a human-dominated landscape will always be challenging, given the large home range of the animal. In most cases, remaining habitat patches are small, large numbers of people share the same landscape, and the intrusion of people into habitat is intense. Therefore, the success of habitat improvement relies on the active participation of local people in habitat-reclamation initiatives and the simultaneous reduction in human demand for forest resources.

Using surveys in elephants research

In this study, I used a questionnaire to reveal details of the elephant-human conflict in southeastern Bangladesh (see Objectives below). Many researchers in Asia and Africa have investigated human-elephant interactions and how they involve crop damage, property damage, human and elephant causalities, mitigation measures, poaching etc. Several studies have deployed household surveys using questionnaires (Fonzo 2007; Gandiwa 2012; Karanth et al. 2013; Olsson 2014; Jasmine et al. 2015). These studies provide a better understanding of human-wildlife interactions (knowledge, perception, attitude, behaviour, pattern of conflict etc.) as well as baseline information (damage data, human and wildlife causality etc.). Both structured and semi-structured questionnaires have been used to obtain qualitative and quantitative data. Structured questionnaires are easy to standardize and they provide a relatively cheap, quick and efficient way of obtaining large amounts of information from a large population (Truman 2015) while a semi-structured questionnaire is open, allowing new ideas to be brought up during the interview as a result of what the interviewee says (Denscombe 2010). Several researcher, however have taken the approach of using a combination of social survey methods involving different participatory techniques (focus group discussion, key informant interview), questionnaire surveys, and/or direct observations, (Tchamba 1996; Fernando et al. 2005). In some cases, particular sampling methods (systematic sampling, random sampling) were used to select respondents. Some studies use a five point Likert scale to record views of respondents to different issues. Field verification of

affected sites has been undertaken to assess the extent of damage and cross-validate the information obtained from household interviews. These type of data are more authentic but time consuming.

Some researchers have used participatory rural appraisal (PRA), rapid rural appraisal (RRA), field assessment and household surveys to document information pertinent to elephant conservation (Nyhus et al. 2000; Zhang and Wang 2003). Both PRA and RRA are effective tools to identify genuine priorities for target groups, motivation and mobilization of local development workers and use of local resources. Forming better linkages between communities and development institutions is now widely advocated and documented as a philosophy and model in development and conservation (Chambers 1994).

Research objectives

The overarching goal of my study is to make a significant contribution to the conservation of elephants in Bangladesh. To do this, I had two main objectives. To describe current human dimension of the conflict, as a way to promote elephant conservation within the context of habitat change. To improve our understanding of patterns of land use altering the availability of forage and cover for the animals in the face of increasing human activities. Specifically, my objectives were as follows:

(1) Understanding the human dimension by describing the:
   i) effects of human elephant interaction (causes, intensity and extent of conflicts, crop raiding, property loss, livestock damage, fruit and other tree loss, human and elephant casualty) .
   ii) perception, beliefs and attitudes about elephant and possible elephant conservation options and co-existence with elephants

(2) Record land-use alterations and the status of elephant forage in order to determine:
   i) historic spatial changes occurred to putative elephant habitat
   ii) current status of elephant habitat in terms of providing forage and cover

To address these objectives, I divide my thesis into two principle data chapters.

In the remaining portion of this chapter, I provide a more detailed sketch of the study area where I conducted my work.

In Chapter 2, I use data collected from the interviews with stakeholders carried out in the communities located near elephant habitat, within my study area in southeast Bangladesh. This allowed me to investigate and characterize the nature and magnitude of human-elephant conflict.

In Chapter 3, I investigate the status of elephant habitat. I assess the changes that have occurred in my study region during the period of 1989-2015 through satellite image classification, and report on the current vegetation in remaining patches through on-the-ground surveys of forage plants and cover.

I summarize my overall research findings in chapter 4 and discuss management issues and future research directions.

Description of study area

I carried out my study in the Chittagong and Cox's Bazar districts of southeastern part of Bangladesh (Figure 1.1). This region is located at the apex of the Bay of Bengal and is elsewhere bordered by Myanmar and Chittagong Hill Tracts of Bangladesh. The landscape consists of hillocks, hill, valleys, rivers, and forests that transition into human settlements, roads, and canals. Hilltops range from 30-300 m ASL with brown sandy-loam to clay loam-soil types. The forest type of this area generally is classified as tropical semi-evergreen with moderate floristic and faunal diversity dominated by *Dipterocarp* vegetation. However, almost all natural forests have been altered or reset into secondary forests or plantations mostly with non-native species (see Chapter 3). Annual gross rates of deforestation has been computed as 0.75% during 2006-2014 (Reddy et al. 2016).

The forests of these localities harbor a diverse wild life including Asian elephants (*Elephas maximus),* rhesus macaque (*Macaca mulatta*), barking deer (*Muntiacus muntjak),* wild boar (*Sus scrofa cristatus),* large Indian civet (*Viverra zibetha),* jungle fowl (*Gallus gallus),* greater racket-tailed drongo (*Dicrurus paradiseus*), kalij pheasant (*Lophura leucomelanos*), etc. The climate of southeastern Bangladesh is tropical monsoon, having one of the highest rates of precipitation in the world. Annual quantity of precipitation range from 280 cm -370 cm per year, with most of the rain falling between May to September. Mean monthly relative

humidity varies between 70%-85%. Temperatures in this area fluctuate very little: the average minimum daily temperature is 26º C and the average maximum temperature is 33 ºC (Bangladesh Meteorological Department 2017). The total size of my study area was 1904 $km^{2,}$ which includes a 1370 km^2 forest harboring an estimated human population of 1,528,815 (density 803 per km^2). The literacy rate is approximately 52 % with a male: female ratio of 100: 97 (BBS 2010). Most of the people residing in this area are subsistence farmers that earn their living from agriculture. In addition, a large number of people rely on forest resources for personal use and for their livelihood. Despite legal restrictions on entering the forest people generally have open access to these lands simply due to the limited enforcement capacity of governing organizations. As suggested above, the vegetation in this area has been largely removed due to human activities such as land conversion, exploitation of forest resources, and the construction of settlements.

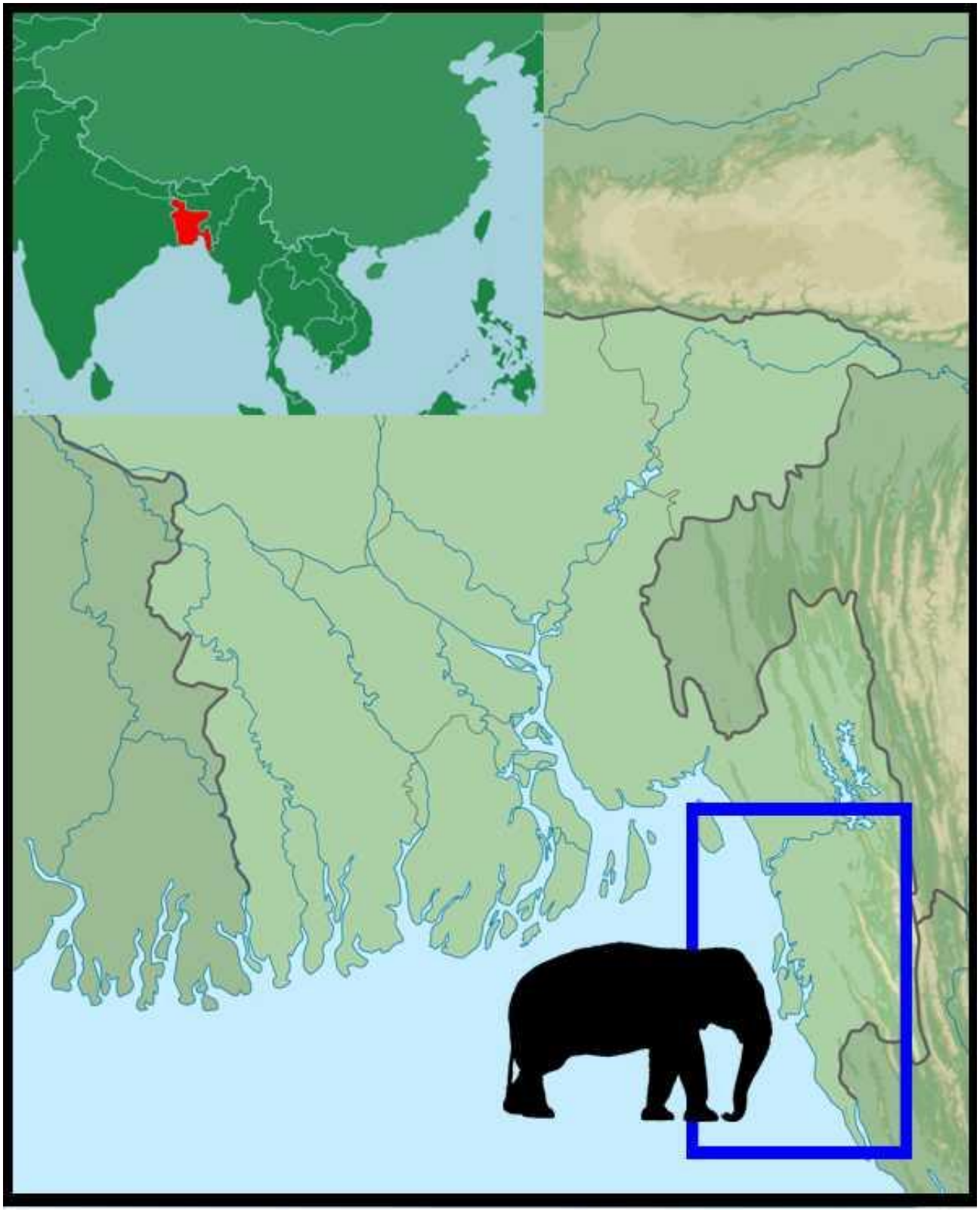

Fig.1.1: Map showing location of study area within southeastern part in Bangladesh. Inset map shows location of Bangladesh in south-eastern Asia.

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CHAPTER 2

ASSESSING THE NATURE AND MAGNITUDE OF HUMAN-ELEPHANT CONFLICT IN SOUTH-EAST BANGLADESH

Introduction

Conflict between humans and elephants has been occurring for centuries (Nelson et al. 2003). Records show colonial farmers in Africa incurred huge losses from elephant depredation (Schweitzer 1922), and elephant crop raiding records existed in Asia as early as 300 BC (Sukumar 1994). As elephant habitat is converted into agriculture and other land uses, increased contact between humans and the animals has led to conflict, resulting in a worldwide decline in elephant populations (Foggin 2003). The success of elephant conservation ultimately will rely on resolving or minimizing conflict (Desai and Riddle 2015), with a primary concern being how elephant and humans can co-exist in fragmented and human-altered landscapes. All told, understanding the reasons, nature, extent and implications of conflict are necessary to devise long-term conservation strategies, including an improvement in on-the-ground relationships between elephants and local communities.

The Asian elephant (*Elephas maximus)* was once found throughout Asia, but is now restricted to a handful of localities in the south Asia, Kalimantan and Sumatra, Peninsular Malaysia and Sabah, South-east Asia (IUCN 2014), primarily due to direct conflict with humans. The major threats to these animals are habitat loss and fragmentation, excessive resource exploitation, conversion of habitat, conflicts with humans, ivory poaching, and the killing of mothers and other herd members during the capture of young elephants to supply the entertainment industries. However, direct conflict between humans and elephants perhaps is the most challenging threat to the animals across all Asian jurisdictions, resulting in the loss of human and elephant life as well as other property damage (Dublin et al. 2006). These impacts affect large numbers of people in Asia each year (Barua et al. 2013), generating anti-conservation sentiment among local communities (Desai and Riddle 2015).

Bangladesh currently supports approximately 210-330 Asian elephants (Motaleb et al. 2016), with conflict between the animals and humans occurring in almost all parts of the country where the animals remain (Sarker and Røskaft 2010). In a small country with nearly 170 million people, depleted resources have forced elephants to look for food outside of their natural habitat (Ramkumar et al. 2014). The result is not only the regular loss of agricultural crops, but also the destruction of property and a loss of life: a minimum of 231 people have been killed since 2003 by elephants, with at least 92 elephants dying since 1992 (unpublished data, Bangladesh Forest Department 2016). Villagers respond to conflict by killing elephants through poisoning, electrocution and shooting, suggesting an antagonistic and relatively intolerant attitude towards the animals (Nyhus et al. 2000). There are virtually no active conservation efforts in Bangladesh other than the proclamation of laws, the declaration of protected areas, and attempts to improve elephant habitat through planting forage plants. However, to date, very few studies have surveyed the opinions of villagers and other residents within elephant-occupied regions of Bangladesh. All the surveys so far conducted address some specific aspect of human-elephants conflicts. In this study, I will provide a more comprehensive picture of the nature and consequences of conflict. Such surveys, particularly those involving face-to-face interviews, have been shown to be extremely useful in identifying attitudes towards animals or other resource issues, as well as providing direction for management initiatives (Smit et al. 2010).

In 2015, I conducted a survey of human perceptions, beliefs and attitudes towards elephants and elephant conservation within the southeastern corner of Bangladesh. Given socio-cultural constraints, demography, the literacy rate in rural Bangladesh and a limited period, I adopted a face-to-face interview method using a semi-structured questionnaire. This type of conversational semi-structure interview promotes comfort and engagement of respondents and interviewer, which can enhance the quality of answers. The goals of my survey were to examine the causes, intensity and extent of the conflicts with crops, property and other losses generated from such conflict. This included understanding the perceptions, beliefs and attitudes of local communities regarding elephant conservation. These types of data aid in understanding the nature of human-elephant interactions in this region. This critical information is needed to ensure coexistence between elephants and local people.

Methods

Study Area

The study was conducted in communities located adjacent to elephant habitat, in Upazilas of the Chittagong and Cox Bazar districts of southeastern Bangladesh, near the international borders with Myanmar and India (See Chapter 1, Figure 1.1). The total size of the study area was ≈1904 km^2 that includes a ≈1370 km^2 hilly area supporting ≈ 1.5 million people (density 803/ km^2) (BBS 2010). The literacy rate here is 52 %, with a male- female ratio of ≈100: 97 (BBS 2010). Most of the people residing in this area are subsistence farmers that earn their living primarily from rice farming, which is the major crop. The climate is tropical with a distinctive monsoon season. The average annual temperatures range from a maximum of 32 °C and a minimum of 11 °C. Although this area was once rich with wildlife, the area has been degraded over time, with all primary forests having been either removed or shifted into secondary forest cover.

Survey approach & design

My survey was inductive in nature (Thomas 2006), asking respondents to focus on specific situations or people. In general, the survey contained questions on the nature of human-elephant interactions, the underlying drivers of change in elephant habitat and the attitude of humans towards elephant conservation. Specific information was collected in six areas, namely (i) background information on the respondent (8 questions), (ii) the respondent's experience with elephants over the past three years (4 questions), (iii) the types of problems created by elephants, (iv) the nature of local elephant intrusions, (v)respondents' feelings and perceptions about elephants, and (vi) questions about the respondent's attitude towards elephant conservation. References to agricultural damage were categorized as either annual (e.g. rice, vegetable), or perennial (e.g. fruit trees, coconut, guava etc.) crops.

Interviews were conducted in Bangla. As most of the respondents were illiterate, I conducted the interviews in person, recording responses on prepared forms. A Bangla version of the questionnaire also was prepared. This approach, along with the use of open-ended and close-ended questions, allowed me to record immediate ideas and thoughts from the

respondents, and avoided the need to distribute large numbers of surveys in order to obtain a sufficient number of responses. The Research Ethics Board at Thompson Rivers University approved my survey design (File number: 100936)(see Appendix E) .

Survey Distribution - The entire survey was conducted from mid-May - September 2015. People residing near elephant habitat were targeted for the interviews. To ensure even geographical distribution, I selected 109 villages located adjacent to seven different elephant habitat patches (see Chapter 3). I stratified my selection of villages across 3 geographical conditions, relating to how the village was situated in relation to forest (elephant) habitat: (i) inside forest, (ii) along forest edge, and (iii) completely removed from forest habitat. This stratification was done to expose potential differences in survey responses based on the level of direct contact with elephants.

To select households within each village I visited, I used the following procedure: I walked a transect line across each village, stopping approximately every 0.5 km to approach the closest residence. If contact could not be made (lack of occupant in residence, or refusal to participate), I approached the next closest residence. Upon contacting a villager, I invited their participation in the survey. Although I attempted to avoid biasing the sex of the respondents, religious and cultural constrains meant there were few female respondents in my survey was minimal. However, I ensured representation of people directly and indirectly impacted by elephants. Verbal consent to the interview was requested before beginning the interview. Appendix A contains the survey in its entirety, including the preamble used to inform the respondents of the purpose of the survey, and to obtain their verbal support to participate. Prior to the start of the interview, respondents were informed that they could abstain from answering any particular question and/or stop the interview at any point in time if they became uncomfortable. Also, realizing that respondents could experience emotional distress as a result of discussing the impacts of elephants (e.g. death of family member), I reinforced that the survey could be terminated or suspended at any time, at their request. During the actual survey, if I detected stress or anxiety developing in the respondent, I would remind them of these options or elect myself to end the interview process. When the respondents indicated they were satisfied with these parameters, I initiated the survey questions. For many questions, participants were allowed to select multiple responses to the same question (e.g., types of crops damaged) which resulted in the total number of responses to some questions exceeding the number of respondents (or, similarly, calculated response

percentages would exceed 100%). There also were reverse situations where respondents refrained from answering a particular question, making the total number of responses resulting in <100%. The time required to conduct each interview was 25-45 minutes. All data were analyzed using IBM SPSS Statistics version 23. An alpha value of 0.05 was used to guide interpretation of statistics.

Results

Background information on the respondent- A total of 171 people participated in survey ranging from 18 - >60 years of age. Eighty percent (137) of the respondents were male. Respondents were mostly (83%) in a low income bracket, earning less than US$2000 per year. People earning less than $394 per year are considered living below the poverty line in Bangladesh (United Nation 2009). Ninety-one percent were either illiterate or possessed only a basic education (i.e. < secondary school). The main occupation of the respondents was subsistence farming, followed by labourer, housewife, and business. Respondents were quite evenly distributed among the three geographical strata—their home relative to the forest (Table 2. 1).

Respondent's experience with elephants over the past three years- Elephant incursion into crops occurs throughout the year, with two noticeable peaks April- June and October—November (Fig 2. 1). In response to the question "How often do elephants come into your village?'', almost all participants indicated these incursions occur every year (Table 2.2). Similarly, all but one respondent reported incursions occurred at night, with a smaller proportion taking place during dusk. Overall, elephants were considered a problem by 86% of the respondents.

Types of problems created by elephants - Crop raiding was identified as a major - problem, followed by house damage and fruit plucking (Table 2.3). Rice was reported to be the crop most frequently impacted by the elephants. Ninety four percent of respondents reported damage to mature crops and 46% reported damage to immature crops. Respondents claimed that the damage caused by elephant raids between 2013 and 2015 affected a total land area of ≈ 67 ha. The damage caused by crop raiding between 2013 and 2015 was equivalent to ≈US$ 53,000, as reported by the respondents.

Table 2:1 Profile of survey respondents (N = 171)

Respondent characteristic		# respondents	%
Homestead	Inside forest	61	36
	Edge of the forest	51	30
	Outside of the forest	59	34
District	Chittagong	93	54
	Cox's Bazar	78	46
Age	18-28 years	29	17
	29-39 years	59	35
	40-50 years	46	27
	50-60 years	28	16
	> 60 years	9	5
Sex	Male	137	80
	Female	34	20
Yearly income	Under US$ 2000	142	83
	US$2000-$2990	25	15
	More than US$2990	4	2
Education	< Secondary school	156	91
	Completed high school	12	7
Livelihood	Farmer	104	61
	Labour	13	8
	Housewife	29	17
	Businessman	10	6
	Others	15	9

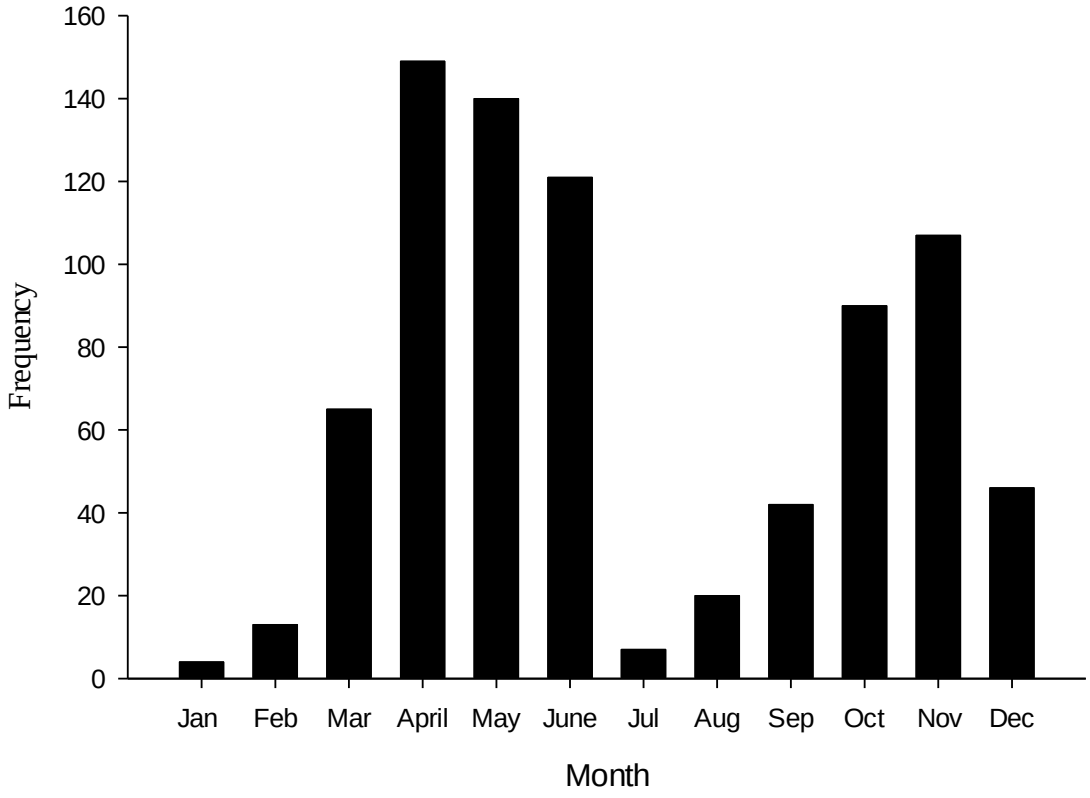

Fig. 2.1 Distribution of reported elephant incursion events by month (N = 171).

Table 2.2: Encounter frequencies with elephant incursions reported by survey respondents (N= 171) in southeastern Bangladesh. Participants were allowed to select multiple responses to the same question resulting in the total number of responses exceeding the number of respondents.

	N	%
Frequency of elephant incursions-------		
Not at all	4	2
Every year	165	97
Others (every 2nd/3rd/ Sometime	2	1
Elephant incursion time		
Dawn	2	1
Early Morning	2	1
Afternoon	4	2
Dusk	32	19
Night	170	100
Considering Elephant as problem------		
Not a problem	24	14
Yes, Problem	147	86

Table 2.3: Nature of elephant incursions into village areas in southeastern Bangladesh as reported by survey respondents. N = 171. Participants were allowed to select multiple responses to the same question resulting in the total number of responses exceeding the number of respondents

	Frequency	≈ %
Elephant Caused damage to ---		
Crop	164	96
House	65	38
Livestock	3	2
Fruit (plucking)	51	30
Damage crop---		
Rice field	141	83
Betel leaf	6	4
Vegetable	43	25
Maize	1	1
Sugar cane	2	1
Fruit plucking	110	64
Chile	1	1
Banana	2	1
Crop status when damage-----		
Newly Planted	2	1
Immature	78	46
Mature	158	94

Impact of elephants incursions- Results indicated that 50 people (45 men and 5 women) had been killed and 51 injured by elephants (Table 2.4) during 2013-2015. Not surprisingly, farmers and firewood collectors represented the majority of people killed (Table 2.5). Proportionally more people were killed within forest habitat and on the edge of the forest than outside of the forest (χ^2 =14.9, df =2, P= 0.001). These findings were compared to government records and found to match exactly the number of officially recorded deaths, with a slight discrepancy in the number of injuries reported. The respondents reported 18 elephant deaths during 2013-2015, with cows being the most likely to be killed. (Table 2.6).

In addition to crop raiding and death and injury to both humans and elephants, the human-elephant conflict in the study area also resulted in house damage, livestock death, fruit plucking, bamboo culm damage, and other damages. The total loss incurred from house damage, livestock death, fruit plucking, and other forms of garden damage reported by participants was equivalent to US$11,854 during 2013-2015.

Respondents' attitudes and perceptions about elephants- Most respondents felt elephant incursions were increasing in their locality. Almost all respondents stated that the primary reason elephants caused damage was the "search of food". Respondents described that approximately 95% of incursions were groups of elephants (i.e. herd), and the composition of these groups was a mix of both males and females (Table 2.7). The most common retaliation to elephant incursions was firecrackers (57%) followed by drumming (40%). Very few respondents indicated they did not retaliate in any way (Table 2.7).

Participants were asked to rate the probable reasons for an increase in elephant incursions. Respondents strongly agreed that a declining food base and a loss of habitat were ultimately responsible for incursions, with less conviction shown towards the other potential factors (Table 2.8). Without prompting, six respondents identified bamboo dying (due to gregarious flowering of bamboo, a unique phenomenon where flowering occurs once in 30-40 years and all the plants in area die) as being responsible for an increase in elephant incursions. Approximately 73% of respondents indicated that they favored elephant conservation, with no difference in this response being seen across the respondents according to their village location (χ^2 = 3.952, df = 2, P = 0.139; Table 2.10). Sixty-five percent of women (N=34) respondents favoured elephant conservation compared to 75% of male (N= 137) respondents

Table 2.4: Human death and injury tallies as a result of elephants incursions in southeastern Bangladesh between 2013-2015, as reported by survey respondents.

Location	Death of Human			Total	Injuries of Human			Total
	Year				Year			
	2013	2014	2015		2013	2014	2015	
Inside Forest	3	9	9	21	7	11	1	19
Edge of Forest	8	10	7	25	11	8	13	32
Outside forest	1	3	0	4	0	0	0	0
Total	12	22	16	50	18	19	14	51

Table 2.5: Professions of humans killed in southeastern Bangladesh during 2013-2015 as a result of elephant incursions , as reported by survey respondents

Profession	Male	Female	Total
Farmer	24	1	25
Firewood collector	12	1	13
Others [1]	9	3	12
Total	45	5	50

[1.]Housewife, Student, Daily Laborer, Service holder ,Village police, Bangladesh Border Guard

Table 2.6: Age/sex class of elephants killed during conflict with villagers in the southeastern region of Bangladesh, as determined through a survey of 171 respondents

Type of elephant killed	2013	2014	2015
Calf	0	1	0
Bull	2	0	0
Cow	3	7	5
Total	5	8	5

Table 2.7: Respondents feeling and perception about elephants with 109 villages in southeastern Bangladesh. Participants were allowed to select multiple responses to the same question resulting in the total number of responses exceeding the number of respondents (or, similarly, calculated response percentages would exceed 100%). In cases where participants refrained from responding to a question, the resulting response count is less than 100%

Views of respondent	Options	Frequency	≈ %
Perceived reason for elephant incursion	In search of food	169	99
	Transit	2	1
Incursion rate	Increasing	153	90
	Not increasing	12	7
	No Change	6	3
No. elephants involved in incursions	Single & group	70	41
	Group	163	95.
Herd type	Female	3	2
	Bull	2	1
	mixed herd	164	96
Peoples' retaliation to elephant incursion	Fire crackers	97	57
	Drumming	68	40
	Nothing	5	3
Condition of elephant habitat in their locality	Moderate	29	17.0
	Bad	139	81
	Not aware	3	2

Table 2.8: Weighing on reasons for elephant incursions in southeastern region of Bangladesh as reported by survey respondents. Participants were allowed to select multiple responses to the same question resulting in the total number of responses exceeding the number of respondents (or, similarly, calculated response percentages would exceed 100%). In cases where participants refrained from responding to a question, the resulting response count is less than 100%.

Reasons for increasing incursions	Strongly disagree (Frequency)	Disagree (Frequency)	Agree (Frequency)	Strongly Agree (Frequency)
Decline food base	1 (≈ 1%)	0	60 (≈35%)	92 (≈ 54%)
Male aggression	2 (≈1%)	99 (≈58%)	47 (≈ 28%)	3 (≈2%)
Shrinking elephant habitat	1 (≈1%)	1 (≈1%)	13 (≈8%)	136(≈ 80%)
Corridor encroachment	0	5 (≈3%)	127 (≈74%)	20(≈ 12%)
Increase housing density	0	0	4 (≈2%)	13(≈8%)

This support for elephant conservation is considerably higher than the reported study conducted in similar human dominated landscape in Terai Arc Landscape, India where 57% respondent favoured elephant conservation (Jasmine et al. 2015).

Respondent's attitudes towards elephant conservation strategy- Table 2.10 shows that respondents considered habitat improvement and community awareness as the two tactics most likely to conserve elephants. In addition to the options provided on the survey, the respondents provided original suggestions, including the relocation of elephants (25% of respondents) and the cessation of exotic crop planting (1% of respondents). A small number of respondents (1 %) in one village indicated that relocating a nearby army-training zone would result in fewer elephants being frightened into settlements by practice artillery (Table 2.11).

Government responsibility toward elephant incidents - Few respondents (13%) were aware of the role played by the Forest Department in the case of elephant incidents. Most of the participants (84%) felt the Forest Department did not respond to elephant incidents. The majority of participants (64%) were unaware of compensation provided by the Forest Department as a means to mitigate elephant damage.

Table 2.9: Respondent attitudes towards elephant conservation based on the location of their villages in southeastern region of Bangladesh

Location of Respondent Homestead	Favor Conservation	Disfavour conservation
Inside forest	52	9
Edge of the forest	35	16
Outside forest	38	21
Total	125	46

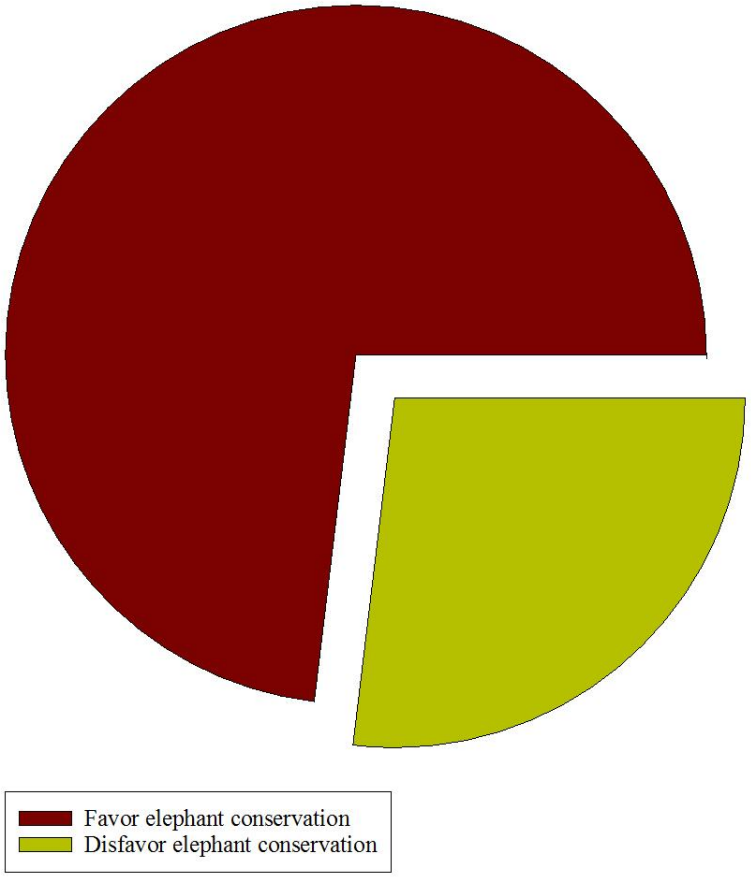

Fig. 2.2: Overall response of respondents towards elephants conservation in southeastern Bangladesh reported by 171 respondents across 109 villages

Table 2.10: Methods to prevent or mitigate impacts from elephant incursions as indicated and evaluated by survey respondents in the southeastern region of Bangladesh. Participants were allowed to select multiple responses to the same question resulting in the total number of responses exceeding the number of respondents (or, similarly, calculated response percentages would exceed 100%). In cases where participants refrained from responding to a question, the resulting response count is less than 100%.

	Not useful	Useful	Very Useful	Don't Know
Measure to conserve elephants—				
Habitat improvement	0	6 (≈ 4%)	120 (≈70%)	0
Community awareness	1 (≈1%)	14 (≈8%)	111(≈65%)	0
Erection of physical barrier	8 (≈ 5)	48 (≈28%)	8 (≈ 5%)	62 (≈36%)
Electric or solar fence	8 (≈5%)	3 (≈2%)	2 (≈1%)	113 (≈ 66%)
Chili cultivation	3(≈2%)	12 (≈7%)	6 (≈ 4%	105(≈61%)
Apiculture	1 (≈ 1%	3(≈2%)	0	122 (≈71%)
Other Strategies-------				
Compensation	0	35 (≈ 21%)	136 (≈80%)	0
Tourism(Elephant viewing)	0	75 (≈44%)	96 (≈56%)	0
Revenue sharing	0	41 (≈24%)	130 (76%)	0

Discussion

Background information on the respondent- The characteristics of respondents, and therefore the sample in this survey, typify the population living in the southeastern region of Bangladesh: income is generally low and farming is the major occupation, with most agricultural lands being situated in or on the periphery of elephant habitat. The bias towards male respondents was expected, given that village culture would generally dissuade women from conversing with unfamiliar men (i.e. a surveyor). Generally speaking, the respondents possessed direct or near-direct experience with the elephant conflict and were able to express their feelings about the situation. Hence, the opinions reflected in the survey results represent a valuable source of information for understanding and enabling coexistence between human and elephants in this locality.

Respondent's experience with elephants over the past three years- The year round pattern of incursion can be best explained by both a 'push factor' (where elephants conduct incursions due to reduced native forage) and a 'pull factor' (when ripening crops cause incursion) (Osborn 2004). As shown in Chapter 3, habitat loss, fragmentation, and degradation of natural food source are likely all associated with the decline of natural habitat. Likely, the inadequate natural forage base causes elephants to be dependent on crop raiding, making incursions a regular phenomenon. Incursions tended to increase during the transition between dry and wet seasons in the study region (Nyhus et al. 2000), with April-June and October-November representing the maximum availability of crops and fruit. Two distinct cultivation seasons occur in Bangladesh: Aman (July-December) and Boro (November - June). Vegetables are mostly cultivated during September –January, with jackfruit ripening during April-June. Further, wild forage contains less nutrients compared to cultivated crops, and hence elephants likely maximize quality as well as quantity in their nutrient intake by raiding crops (Sukumar 1994). The relative scarcity of mid-day incursions may represent avoiding those times when people are most likely working in the field, similar to that reported by Desai and Riddle (2015).

Types of problems created by elephants- The impacts from elephant incursions were manifested in a variety of ways (crop raiding, house damage, livestock damage, and fruit

plucking) all generating substantial economic impacts on the local scale. This suggests a multidimensional approach to management will be needed.

The cost associated with elephant incursions as reported by the respondents to this survey may appear insignificant at the regional or national level, but it represents a significant cost to impoverished people residing in and around elephant habitats of southeastern Bangladesh. Further, the actual costs likely extend beyond a monetary value: for example, a loss of fruit may result in nutrition deficiency for a family. All told, the losses generated from these damages will have long-term impacts on this poorest class of rural people (Karanth and Madhusudan 2002).

Nature of local elephant intrusions

Human and elephant death and injury- Each year a significant number of human death and injury result from direct confrontation with elephants in the study area; such confrontations likely lead to an increase aggressive behavior on the part of the animals as reported in India by Das and Chattopadhyay (2011). Farmers and firewood collectors (predominantly men) appear more prone to injury from elephants, likely because farmers are most likely to contact the animals on agricultural land. Firewood collectors often work alone and when entering elephant habitat may not remain vigilant. Because men predominantly assume these roles, their death and/or injury impart a major economic cost on the affected family groups (Sarker and Røskaft 2010). Injured workers also may suffer from depression, post- traumatic stress disorder or other psychological impacts and in certain cultures, the local community may consider the death or injury caused by elephant as a foreordained punishment (Jadhav and Barua 2012).

Every year significant number of elephants are being killed in Bangladesh, as indicated by this survey as well as unpublished data (Bangladesh Forest Department 2016). Killings of elephants indicate local communities have become aggressive and intolerant towards elephant incursions (Study et al. 2003) . Although villagers openly shared the number of elephants killed in their locality, they were reluctant to reveal details about retaliation as such action is punishable under Bangladeshi law. The growing intolerance of incursions by farmers can lead to retaliation, the killing of animals through poisoning, electrocution and shooting (Nyhus et al. 2000). From my conversations with respondents, I reason that this type of

backlash occurred in my study area, but I intentionally did not probe this matter for fear of causing apprehension and discomfort.

Respondents' feelings and perceptions about elephants- Respondents reported that all types of elephants (sex, age, solitary/herding) were involved in incursions. This differs from previous suggestions that elephant incursions tend to be dominated by bull animals (Chiyo and Cochrane 2005; Ekanayaka et al. 2011; Jackson et al. 2008) but are consistent with other studies stating that bulls, cows, and entire herds take part in crop raiding (Musaasiza et al. 2005; Ramkumar et al. 2014) . Cows in particular would be expected to benefit from nutritional gains during raids with improved nutrition leading to shorter inter-birth intervals and healthier babies (Chiyo and Cochrane 2005). My findings here and in Chapter 3 support Sukumar's (2003) assertion that elephant incursions occur more frequently in fragmented landscapes where remaining habitat is in poor condition.

Deterrent methods currently adopted by farmers to deter elephant incursions may have initial effect, but some farmers believed that any kind of disturbance created by noise, yelling or other means made the elephants aggressive and resulted in more damage to properties. Traditional methods such as those cited in this survey have been used by farmers to protect crops for centuries in both in Asia and Africa; such methods may provide temporary relief from the elephants, but in the long term the animals become habituated and such methods have limited effect (Nelson et al. 2003). Consequently, no single solution is likely to have long lasting effects, and a combination of different measures may increase the likelihood of successful human-elephant mitigation efforts. Nelson et al. (2003) suggest that different deterrents be used in irregular rotation as no optimal combination of deterrents are yet identified to lessen the risk of habituation, and with new knowledge and technology, approaches should be regularly revised and updated .

Response of participants about elephant conservation- Despite the increasing trend of incursions indicated by my survey, a large portion of respondents appeared to still support elephant conservation in their area, at least in principle. This tolerance may come about for different reasons: for example, respondents may be aware that they are illegally encroaching on elephant habitat and thus are harboring feelings of guilt. Farmers also expressed support toward conservation initiatives because of their aesthetic value (Sarker and Røskaft 2010), contribution to the environment, and protection of natural habitat. Unfortunately, verbal

support such as presented in this survey can only be transformed into action when the damage done by elephants is halted or reduced. Continued crop raiding, destruction of homes, injury and death to livestock or people eventually will exceed the limits of tolerance directed towards the remaining elephant population. In accordance with Maslow's hierarchy of needs (McLeod 2007), villagers will not care about elephant conservation from a moral or ecological–evolutionary argument when their subsistence and wellbeing are not secured (Balmford and Whitten 2003).

Participants highly supported those mitigation options that they were familiar with and/or also generated direct benefit for the community. Habitat improvement, community awareness, compensation, tourism and revenue sharing are mechanisms of conflict mitigation used in other countries facing similar problems. To date, compensation has been the most visible human-elephant conflict mitigation tactic adopted by the Bangladesh government, and it appeared to be attractive among participants. The recently promulgated policy "Human-wildlife conflicts: Wildlife Compensation Policy, 2010" empowers the government to compensate victims of wildlife. Under this rule, any death/ injury/ damage caused by wildlife occurring on private lands are compensable. Families experiencing a death due to elephant attack are compensated with BD TK 100,000 (US$ 1250) and injuries with BD TK 50,000 (≈US$ 625). To date, families of the people killed by elephants on private lands have received this form of compensation, while deaths on government land (public land) are not addressed (unpublished data, Bangladesh Forest Department). However, people may not apply for compensation because they often have to sacrifice work time and travel considerable distances to government offices to register a complaint, and crop and property damage alone are currently not compensated. In general, compensation has proven to be an ineffective elephant conservation strategy (Hoare 1995) as it addresses the outcome rather that the root cause of conflict. Moreover, compensation will not deter future elephant incursions. Alternatively, local communities may come to view elephants as a revenue-generating asset (e.g.: through tourism) rather than a burden, thereby increasing peoples tolerance to elephants (Nelson et al. 2003).

Community based natural resources management (CBNRM) was not examined in this study; however, it might be worth considering as an approach to engage the people of Bangladesh more actively in elephant conservation. CBNRM is a bottom up practice designed for stakeholder participation in planning, research, and decision-making, and creating

management activities to alleviate poverty in the local community (Lepper et.al. 2010). In other words, it is a process designed to empower local people to rebuild their communities based on natural resources. Under this approach, the local community plays a central and integral role in the sustainable management of habitat and wildlife (like elephants) in their respective area in this process. In the present case, local people would take ownership for developing and sustaining the depleted habitat in their area, bearing the cost of conservation to manage the resources, and benefiting from the outcomes. To take this approach in my study area, an alliance based on trust between the government forest department and local community would be essential. While CBNRM has been applied successfully in many cases (Blaikie, 2006), it often has unique challenges in developing countries (DeGeorges et al. 2009; Lepper et al. 2010). The likelihood of a CBNRM approach being used successfully to address the elephant situation in south-east Bangladesh is not clear. The author of the current study questions the viability of CBRMN in Bangladesh given his knowledge of the population and minimal ability to engage in elephant conservation concurrent with subsistence agriculture. The extreme poverty in the villages within my study site would require a substantial improvement as a direct result of elephant conservation. Quite possibly buy-in from local farmers would require at least a short-term subsidy to alleviate a total dependency on subsistence agriculture, at least in the short term while elephant conservation schemes and ventures are delivered. However, the potential and approach needed to implement a CBNRM approach in this situation warrants further consideration, as it is beyond the scope of this study.

Participants generally were skeptical or ignorant of other elephant-conflict mitigating measures attempted in other countries, such as erections of physical barriers, electric fences, chili cultivation, and apiculture. These measures were reported to be effective at least for short durations or in some specific contexts (Nelson et al. 2003; Patel et al. 2009; King et al. 2011; Desai and Riddle 2015) but argued to be ineffective over extended periods of time (Santiapillai and Suprahman 1986). Few respondents recommended non-traditional measures of mitigation, such as the relocation of elephants, stop planting of exotic species acacia, etc. These approaches may contribute to a larger human-elephant conflict mitigation plan, but are unlikely to succeed on their own within the current economic and cultural environment of Bangladesh.

Government responsibility toward elephant incidents- Participants generally reported dissatisfaction with Bangladesh Forest Department (BFD), the government agency responsible for elephant conservation. In fact, the BFD currently plays no role other than processing compensation claims, conducting post-mortems of elephants and planting some fodder species in elephant habitat. No formal elephant conservation plan currently exists, much less an institutional capacity to keep records of human-elephant conflict. Increased resources will be needed to enable BFD to play a pivotal role in managing human-elephant conflicts.

Conclusion

This study establishes a baseline on how to address the issue of human-elephant conflict in southeastern Bangladesh. Along with the information presented in Chapter 3, my survey strongly suggests that these conflicts are likely to continue until elephant habitat is restored, or the species is extirpated. Local communities appear tolerant towards the animals; however, continued incursions eventually will erode this attitude. In the short term, the coexistence of people and elephants on this landscape can be facilitated by reducing crop damage, improving deterrent technology and minimizing death or injury to people. Current strategies to mitigate human-elephant conflicts, like compensation or aggressive responses to incursions, fail to address the root cause of the conflict. If we want villagers, particularly farmers, to act as allies in conservation planning, programs that provide partial compensation for losses as well as reduce villager dependency on elephant habitat for resources should be adopted. Cultivation of non-palatable crops (e.g. chili, bitter grout, etc.-Warner 2008) at the ecotone between agricultural land and elephant habitat may also contribute to reducing the conflict. Awareness programs might educate people about wild elephant behavior for protecting local community as well as reduce human-elephant conflicts (FAO 2008). Additional programs such as development of protocol for dealing wild animal and formation of wildlife response unit consisting of local people may aid in deterring elephants from conducting incursions (Parker et al. 2007). The implementation of mitigation measures (such as cultivating beehives) should be done such that their effectiveness can be quantified. If the conservation of elephants is to succeed in southeast Bangladesh, conflict must be replaced by coexistence.

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CHAPTER 3

ASSESSING ASIAN ELEPHANT (*ELEPHAS MAXIMUS*) HABITAT IN SOUTH-EAST BANGLADESH

Introduction

Wildlife habitat continues to disappear at an alarming rate across the globe (FAO 2016). This is particularly evident in the case of large mammals that require extensive home ranges to meet life history requirements (Leimgruber et al. 2003). The fundamental driver of habitat alteration has been human population growth, resulting in a large proportion of the earth's natural habitat being converted into agricultural land, human settlements, roads, industrial area and other anthropocentric uses. Further, as continuous habitat becomes fragmented, degraded and reduced in quality, wildlife may come to persist only in less suitable remnants or 'habitat islands' – leading to other factors taking a toll, such as edge effects and deleterious inbreeding. In south-east Asia alone, 79 mammalian, 49 avian and 184 amphibian species are now threatened due to rapid loss of habitat, primarily deforestation (Li et al. 2016). The retention and restoration of natural habitat is thus a critical tool in stemming the loss of species. A critical first step is quantifying and assessing the status of remaining habitat, thus providing a foundation to devise realistic habitat restoration plans.

The natural habitat of the Asian elephant *(Elephas maximus)* is undergoing increasing reduction and fragmentation across all 13 Asian countries where it occur. Nearly 15 years ago, Leimgruber *et al.* (2003) *estimated* that nearly half of the land inhabited by Asian elephants had become fragmented and unable to support large populations, and Sukumar (2003) calculated that the animal was restricted to only 15% of its historical range. These figures are likely now too conservative, given approximately 20% of the earth's human population is also living in or near the current range of the Asian elephant (Stevenson et al. 2006), leading to continuous habitat encroachment and conversion (Rood, et al. 2010). Indeed, during 2000-2016, approximately 480,000 ha of natural forest was removed each year (Li et al. 2016). An unavoidable consequence of these trends likely is an increase in the frequency of encounters and conflicts between humans and Asian elephants as they vie for dwindling resources (Chapter 2).

Nowhere is the loss of Asian elephant habitat more pronounced than in Bangladesh, where a rapidly growing (density 964/ km^2 (BBS 2010)) and predominantly poor human population has severely impacted the endemic population of the animals (210-330 individuals remaining (Motaleb et al.2016). Further, the forest cover of the country declined nearly 20% to 9% during 1963-2003 (Brown and Durst 2003). The influx of refugees from Myanmar (‘Rohinga`) and their encroachment on elephant habitat likely has exacerbated this situation. Consequently, any remaining elephant habitat has likely decreased significantly in value for the animals, in terms of providing forage, cover, and other resources required to support healthy elephant populations. Traditional migration routes also likely have become disrupted as the animals become dependent on small patches of forests

Despite the obvious plight of the Bangladeshi elephant population, qualitative information on the status of remaining elephant habitat (e.g. vegetation cover and land-use) is scant. Within this narrative, a formal assessment of remaining elephant habitat is essential to begin stabilizing (much less reducing) detrimental impacts on elephants, minimizing human-elephant conflicts, and devising a comprehensive habitat restoration plan. In Chapter 2, I presented the results of a survey on human attitudes and elephant conflicts in the southeastern region of Bangladesh, where the majority of the country’s elephants remain. Those results revealed the proximate factors causing elephants to raid or threaten human settlements, leading in some cases to a loss of both human and elephant life. In this chapter, I present the first formal assessment of elephant habitat in this region. In doing so, I pursue two main objectives: (i) to ascertain the historical changes that have occurred to putative elephant habitat and (ii) to understand the current status of elephant habitat as it provides for forage and cover.

Methods

Site Description - The study was conducted in the Chittagong and Cox’s Bazar districts (administrative units) of southeastern Bangladesh. This region consist of hillocks, hills, valleys and forests ranging from 30-300 m elevation. The average minimum and maximum temperatures here are 26º and 33º C, respectively, and annual precipitation ranges from 280 cm -370 cm per year (Bangladesh Meteorological Department 2017). Overall, the forest type of this area has been classified as a tropical semi-evergreen forest with moderate floristic

and faunal diversity (Biswas and Choudhury 2007). The current annual deforestation rate in the country is estimated by Food and Agricultural Organization (FAO) at less than 1%, with per capita forest land at approximately 0.022 hectares. Extensive agriculture and human settlements exist inside and surrounding remaining forest and, as mentioned above, human density is high. Regional data are not available but the population growth rate for the country 1.43%. Despite legal restrictions on entering the forest, compliance is weak due to a lack of enforcement capacity. Almost all natural forests have been altered or converted into secondary forest or plantation with mostly non-native species, either intentionally or due to human disturbance. See Chapter 1 of this thesis for more details on this region.

Satellite image classification for detecting habitat change trend- Landsat imagery with 30 m resolution acquired and used to identify forest loss (land cover change) that occurred within the study area during the period 1989-2015. Efforts made to collect imagery with minimum atmospheric haze. Four set of satellite imagery selected: February 22, 1989 (acquired by Landsat 5 TM); November 7, 2001 (acquired by Landsat 7 ETM); January 23, 2010 (acquired by Landsat 5 TM) and November 21, 2015 (acquired by Landsat 8 OLI) (Source: USGS Explorer). The different spectral bands (i.e. red, green, blue, near infrared and short-wave infrared 1 and 2) of the imageries were stacked. The images first projected to UTM zone 47N to match the geographical projection of the reference data. The study area delineated using the existing forest divisional maps prepared by the divisional offices of the Bangladesh Forest Department. On-screen digitalization of the study area boundary produced using the both hard-copy maps and Google Earth™ to ensure further refine. The boundary polygon converted to shapefile format using ArcGIS Desktop 10.3.1 software to subset the extent of study area from the satellite imagery. ERDAS Imagine software (HEXAGON Geospatial , Version: 15.1) was used to carry out supervised classification based on six land cover classes, namely forest, degraded forest, agriculture, settlement, hill shade and water bodies. At least ten training sample were defined for each land cover class using ERDAS Imagine. The land cover classifications assigned by the classifier were post processed using the clump-and-eliminate procedure to remove mixed classes and take care of salt-and-pepper error (Forest et al. 2015; Reddy et al. 2016). The thematic maps then converted to shapefiles and imported into ArcGIS Desktop software to process layout and area calculation. Throughout the operation, historical satellite photos from Google Earth™ used to corroborate logical class boundaries and areal distribution of classes.

Ground inventory of elephant habitat- With the aid of an assistant, I surveyed and sampled habitat patches of the study area where elephants reside. Personal security issues placed constraints on the portions of this area that I could work in safely. For sampling, I selected two districts of the area where most of the resident elephants in Bangladesh remain (see Chapter 1). Fifteen candidate habitat patches were identified, and from these seven were selected randomly for ground sampling. Table 3.1 provides a list of these patches with their recognized names and their respective area. Within each of these patches, I established a systematic placement of plots within each habitat patches using a grid interval of 2.76 km X 1.86 km (1 º 30′ x 1 º 00′). Each plot coordinate was calculated prior to the start of fieldwork. A GPS instrument (Garmin 78) was used to locate each plot center. The numbers of plots sampled in each habitat patches are also summarized in Table 3.1.

Using each plot center, I sampled habitat using three nested circular plots. Within the largest plot (17.84 m radius, or 1000 m^2), I identified and measured height and DBH of all trees > 10 cm DBH. All bamboo (an important forage for elephants - Sitompul et al. 2013) in this plot were also identified to species, enumerated, and measured for diameter breast-height (DBH). Canopy cover was measured at the center of the plot using a densiometer.

Within a mid-sized 10 m radius plot, DBH and height of trees ≤10 cm were measured and recorded. Inside the smallest plot (2 m radius), I counted all live seedlings and saplings, and visually estimated tall grass coverage (%). The form I used to record these data is provided in Appendix B of this thesis.

Forest regeneration Index - A forest regeneration index (FRI) value was calculated for each 2 m plot, based on seedling and sapling abundance. Following Shirer and Zimmerman (2010), I obtained the FRI index for each plot using the formula

$$FRI = (20 \times \textit{SEEDLING COUNT}) + (50 \times \textit{SAPLING COUNT})$$

The resultant FRI values were assigned into four categories based on their magnitude [adapted from Shirer and Zimmerman (2010) and shown in Table 3.2], and the overall mean of all plots and the percentage of plots within each category was calculated.

Table 3.1: Number of sample plots surveyed in habitat patches arranged in increased habitat patch size.

Habitat patches	Area		No of Sample plots
	Ha	Km^2	
Medakachhapia	396	3.96	4
Fasiakhali	1302	13.02	6
Himchari	1729	17.29	5
Inani	2933	29.33	7
Dudpukuria-Dhopachari	4716	47.16	11
Chunati	7764	77.64	14
Teknaf	11615	116.15	10

Table 3.2: Forest Regeneration categories taken from Shirer and Zimmerman 2010

Categories	Index Range	Stem density per ha
Poor	0-200	< 1899 seedlings or < 758saplings
Fair	201-400	1900-3799 seedlings or 759-1519 Saplings
Good	401-600	3800-5700 seedlings or 1520- 2280 saplings
Very good	>600	More than 5700 seedlings or 2280 saplings

Forage Species categorization - I compiled a list of forage plants eaten by the elephants as reported in by Joshi and Singh (2008) and Feeroz (2014). For each forage species, I then used the percentage at large plots (17.84 m radius) where the plant was detected as an indication of abundance within the study area (1 = very common, >60% of plots ; 2= common, 40%-60% of plots; 3 = Fairly common 20-40% of plots; 4= Infrequent, <20% of plots).

Dung Counts - Similar to other studies on herbivores (Kumar et al. 2010; Rood et al. 2010) , I used dung pile counts as an indirect assessment of habitat use by elephants. I could not differentiate the age of dung pile with any precision. However, dung piles that were visibly severely eroded, weather or deformed, were excluded. Individual dung piles were counted within each large plot (17.84 m radius) of habitat patch.

Phytosociological attributes- I calculated phytosociological attributes [relative density, relative frequency , relative dominance, and Importance Value Index (IVI)] for all plant species of my study area recorded during inventory following Fieschi and Nukada (1979)). Species diversity was expressed using the Shannon-Weaver (1963) index of diversity (Pielou 1975) for each patches .

Data Analysis - All habitat data were entered into Microsoft Excel and analyzed using statistical software Minitab 17 (Version: 17, Minitab Inc). Simple linear regression analysis was performed to assess the relationship between elephant usage (dung piles) with canopy cover, forage species abundance, the number of plant species present.

Results

Land use/Land cover (LULC) change- Fig. 3.1 shows the spatial change of LULC during 1989-2015. The LULC class area statistics derived from these spatial data are summarized in Table 3.3. My analysis indicated that ≈ 36 % of forest area was converted to other land use during the period of 1989-2015. In particular, following 2010, approximately 21,183 ha of elephant habitat was removed over the last five years of the survey period (See Table 3.3).

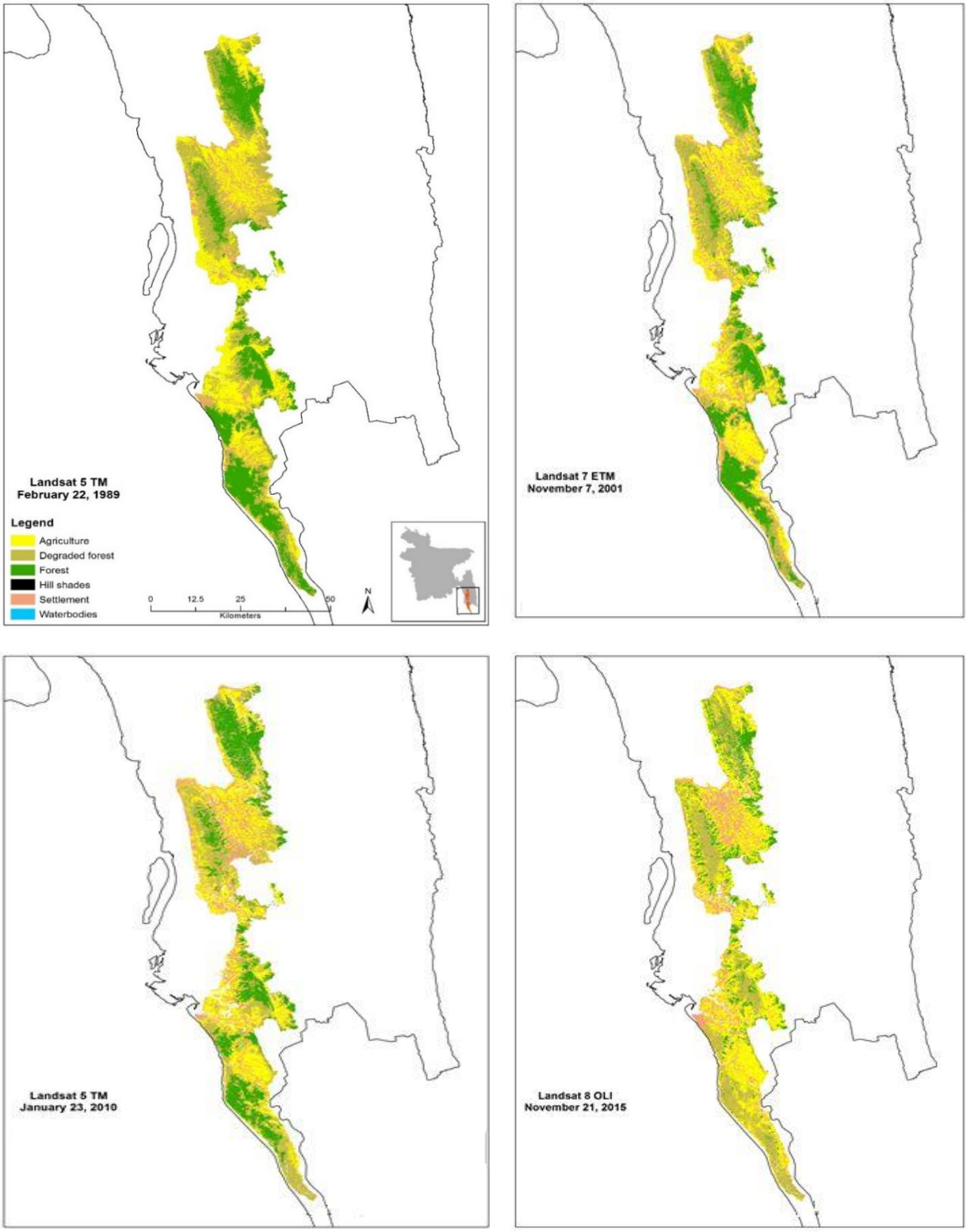

Fig. 3.1. Satellite image (Landsat 5 TM of February 22, 1989, Landsat ETM of November 7, 2001, Landsat 5 TM of January 23, 2010 and Landsat 8 OLI from November 21, 2015) showing land use change during 1989, 2001, 2010, 2015.

Table 3.3. Land use/Landover (LULC) class change for 1989, 2001, 2010, 2015 image of the study area of southeastern Bangladesh

LULC	Area(ha)				+ and – (ha)			
class	1989	2001	2010	2015	1989-2001	2001-2010	2010-2015	1989-2015
Forest	60,542	52,604	50,234	29,050	- 13%	- 4.5%	- 42%	- 52%
Degraded	76,363	74,954	67,361	58,634	- 1.8%	- 10%	- 13%	- 23 %
Agriculture	59,492	69,999	69,019	96,249	+ 19%	- 1.4%	+ 40%	+ 62%
Settlement	17,565	32,075	36,335	42,011	+ 83%	+ 13%	+ 16%	+139%
Water bodies	18,705	4,343	10,103	7,284	- 76%	- 31%	+ 57%	- 61%
Hill shades	2,056	749	1,670	1,495	- 64%	+ 114%	- 10%	- 27%

Vegetation Structure:

The distribution of FRI categories varied by habitat patches (Fig. 3.2). Only two habitat patches (Dhopachari and Medakachapia) had the majority of plots falling into the Very Good or Good categories (73 % and 100%, respectively). Average canopy cover for the 7 patches was ≈ 31% (SD = 17.81) (see Fig. 3.3). The highest percentage of tree species occurred in the lower DBH size classes, showing a decline up to the larger class sizes (Fig. 3.4). The average high tall grass cover measurements occurred in the Teknaf patch, followed by Himchari, Innani, Dhopachari-dudpukuria, Chunati, Medakachhapia, Faiakhali. However, lower tall grass coverage was observed in all habitat patches, ranging only from 2-17% (Fig. 3.5). Table 3.5 lists the densities of bamboo measured in the seven patches. Dopachari-Dudpukuria and Chunati had higher clump and culm density compare to other habitat patches. All told, I detected 40 different species of forage plants (fodder) associated with elephants across the seven habitat patches (see Appendix C for complete list). The relative abundance of these species ranged from rare to quite common.

Phytosociological attributes- Non-native species (specifically *Acacia auriculiformis* and *Eucalyptus camaldulensis)* dominated five of the seven habitat patches as indicated by their relative frequency, relative dominance, relative density and important Value index (IVI). Only one patch (Dhopoachari- Dudpukuria) showed domination by native species. The phytosociological value of the top five species recorded in all habitat patches presented in Appendix C. Although native species like *Dipterocarpus* spp and *Ficus hispida* showed the highest phytosociological value in habitat patches Medakachhapia and Fasiakhali, non-native species *Acacia auriculiformis, Eucalyptus camaldulensis* and domesticated species likes *Mangifera indica and Artocarpus heterophyllus* possessed higher phytosociological values in other habitat patches. Two signature taxa (*Dipterocarpus* spp and *Syzygium spp*) of the study area have lost their dominance in terms of phytosociological attributes.

Species diversity Index - The Shannon-Wiener Indices of all patches ranged from 2.10 -3.33 except for Himchari and Faiakhali (See Table 3.4). Himchari also displayed the greatest evenness value followed by Fasiakhali (See Table 3.5).

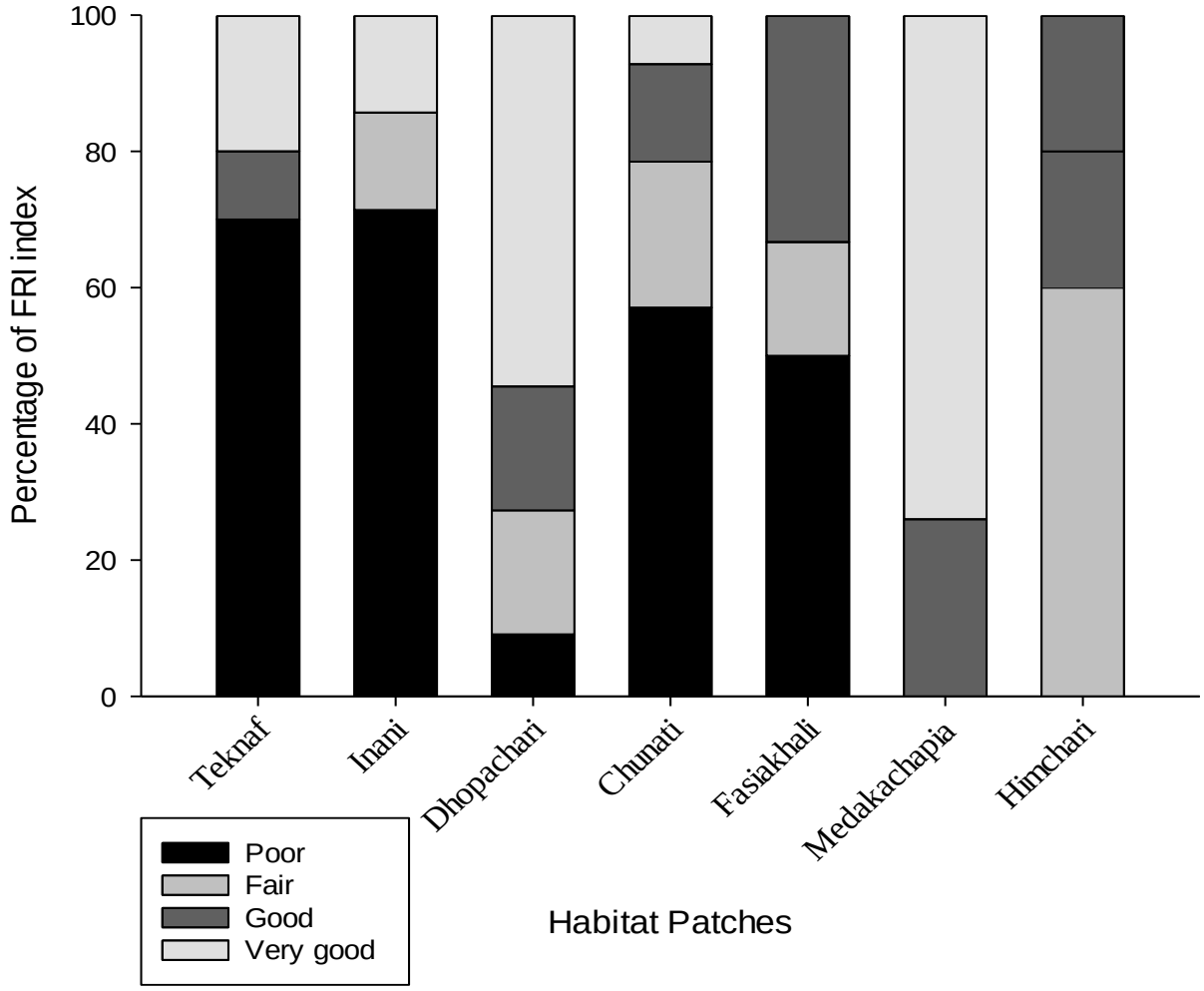

Fig. 3.2. Forest regeneration index (Poor, Fair, Good, Very good) of different habitat.

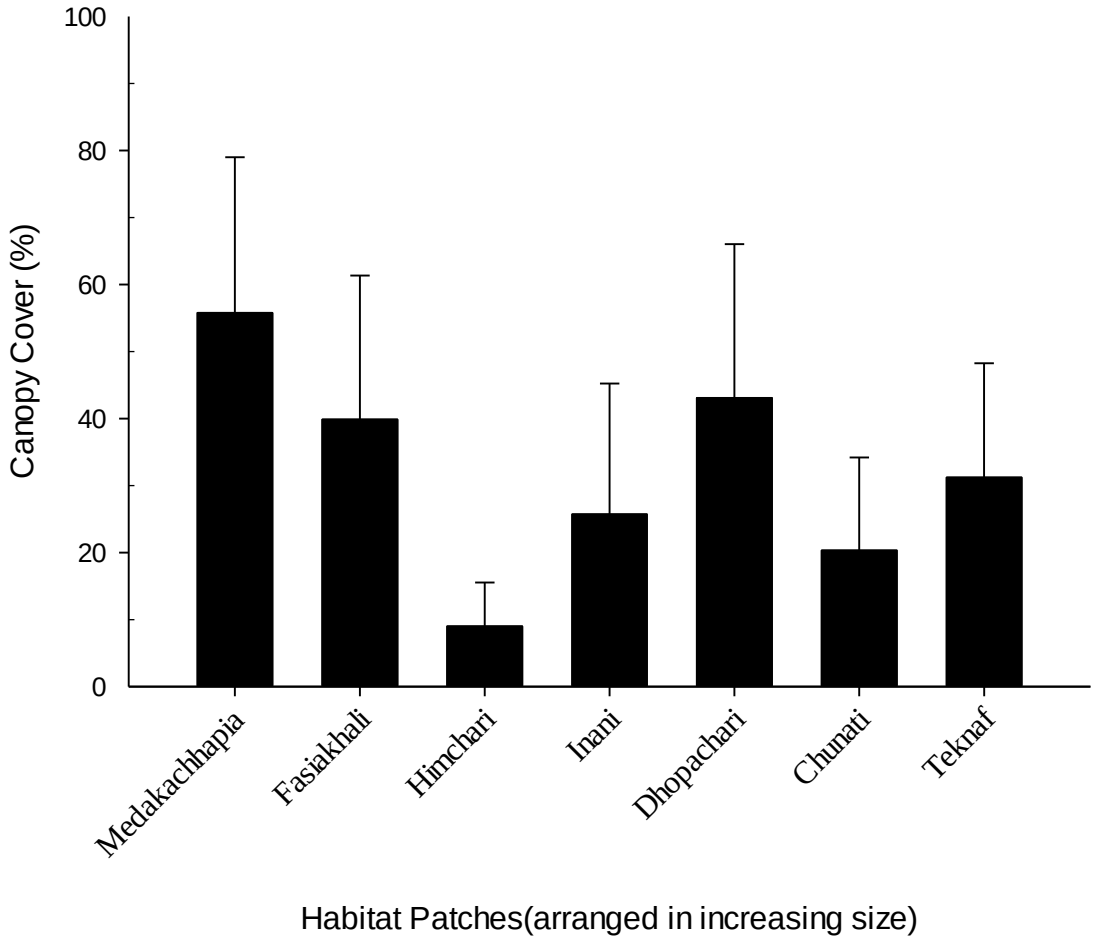

Fig. 3.3. Percentage of canopy cover in different elephant habitat patches in different habitat patches of southeastern Bangladesh(all 7 habitat patches pooled). Error bar indicate ± 1 standard deviation.

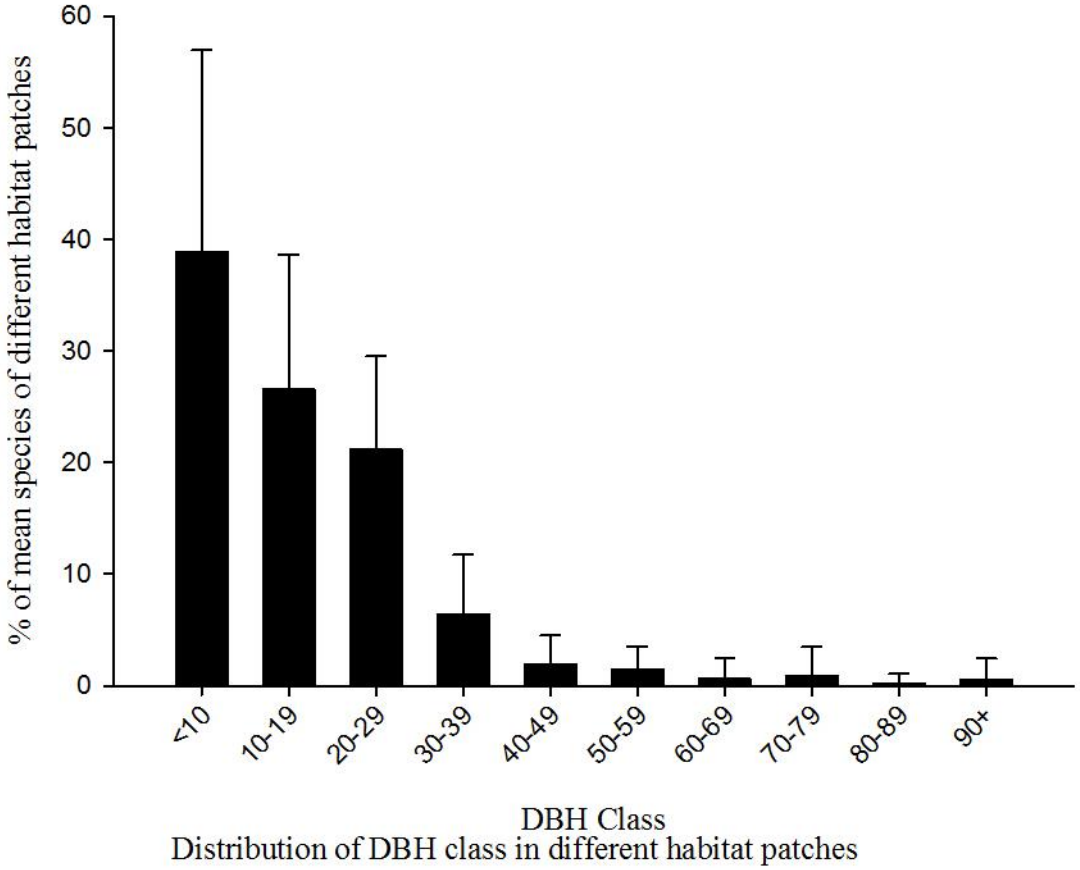

Fig. 3.4. DBH class distribution of tree species in different habitat patches (all 7 habitat patches pooled). Error bar indicate ± 1 standard deviation.

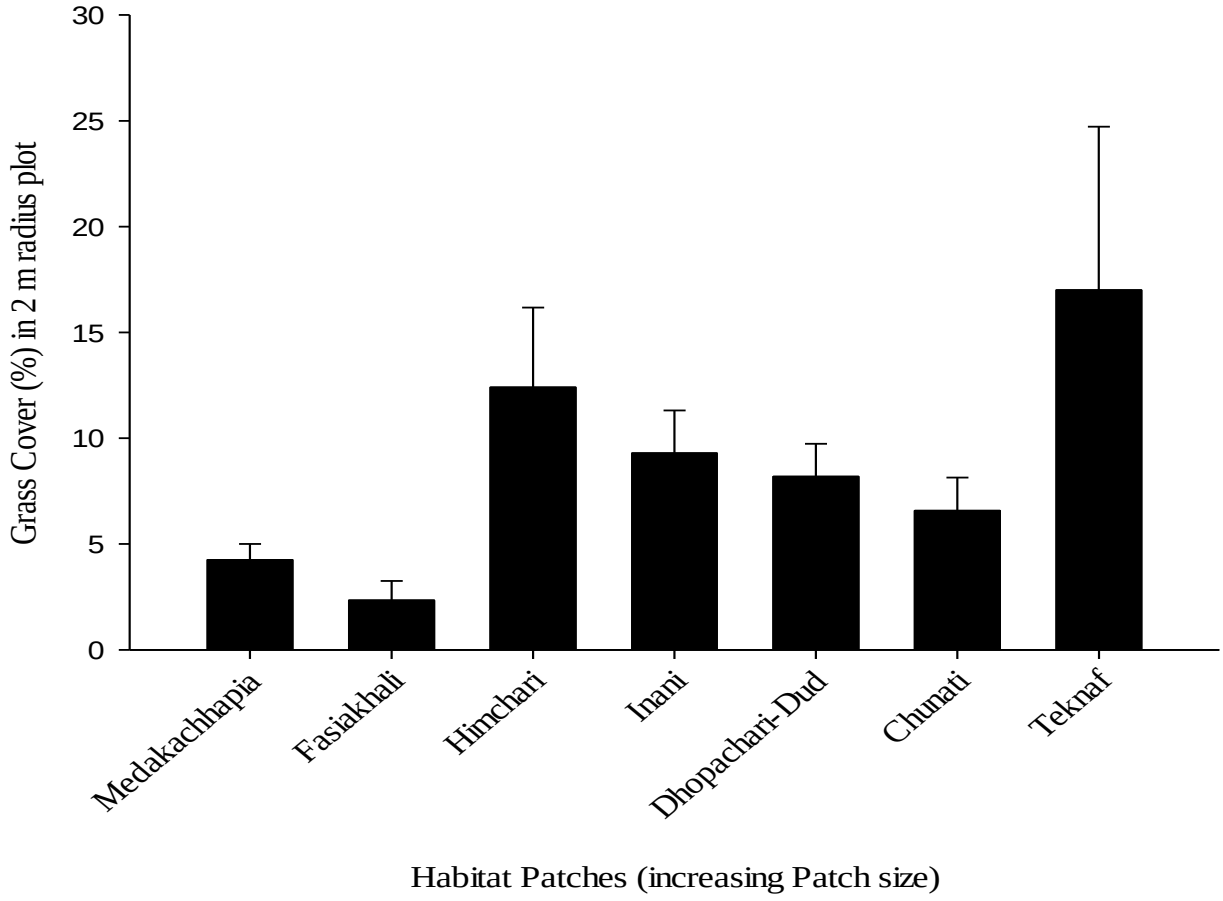

Fig. 3.5. Percentage of tall grass cover (in 2 m radius sub-plot) in different habitat patches of southeastern Bangladesh (all 7 habitat patches pooled). Error bar indicate ± 1 standard deviation. See Table 3.1 for plot sample size of each habitat plot.

Table 3.4 Bamboo density (clumps and culms per hectare) in 7 different elephant habitat patches of southeastern Bangladesh

Habitat Patches	Clump	Culm
Teknaf	11	138
Inani	14	97
Himchari	4	44
Medakachhapia	12	240
Fasiakhali	6.7	22
Chunati	31	175
Dopachari-Dudpukuria	162	1449

Table: 3.5: Shanon-Wiener diversity index and evenness for 7 different elephant habitat patches in southeast Bangladesh

Habitat Patches	SW diversity index	Evenness
Teknaf	3.11	0.80
Inani	3.10	0.84
Himchari	1.04	0.95
Medakachhapia	2.10	0.74
Fasiakhali	1.89	0.71
Chunati	2.51	0.87
Dudpukuria	3.33	0.88

Elephant Habitat Use - I detected elephant dung piles in all seven habitat patches, and 61% (35/57) of all plots (most of them in degraded forest) contained dung. A strong positive relationship was shown between these counts and the average number of trees and bamboo stems detected in each patch ($F = 34.95$, df =1, 5, $P< 0.001$, $R^2 = 0.88$, see Fig 3.6). Similarly, I found a significant relationship between the dung pile counts and average number of trees and bamboo species ($F = 39.56$, df = 1, 5, $P < 0.001$, $R^2 = 0.86$, see Fig 3.7). It followed that the relationship between dung pile abundance and canopy cover also was significant ($F = 8.06$ df = 1, 5, $P < 0.001$, $R^2 = 0.62$, $P < 0.001$; Fig 3.8). Interestingly, overall patch size (i.e. hectares) was not related to the dung pile counts ($F = 0.01$, df = 1, 5 $P = 0.189$, $R^2 = 0.03$).

Discussion

Land use/Land cover change- The overall deforestation rate (~ 1.71%) estimated in this study for the time period 1989-2015 is significantly higher than the national annual deforestation rate of 0.77% reported for 2006-2014 in Bangladesh (Reddy et al. 2016). Further, 31% (36,275 ha) of the elephant habitat lost to human land use conversion (unpublished data, Bangladesh Forest Department). My results suggests that these government estimate may be conservative but all point to a serious habitat loss perhaps more than expected. The LULC changes recorded by satellite imagery also suggests that forest and degraded forest are being fractionated into smaller patches, making the habitat more discontinuous.

The consequences of LULC changes are multifold. The decline in habitat will increasingly require elephants to seek out those patches that still contain forage, cover and other resources, increasing disturbance to existing vegetation cover. And, as the animals extend their search for additional food sources, conflict with humans will rise (Chapter 2). Blake et al. (2008) found that the average movement rates speed of African elephants *(Loxodonta africana)* in the Congo Basin increased 14 fold when the animals were crossing human-dominated landscapes, presumably as a means to minimize risk exposure. My data strongly suggest that in southeastern Bangladesh, elephants are likely even now being forced to forage larger distances and to expend more energy. Such landscapes are unlikely to sustain elephant populations (Leimgruber et al. 2003).

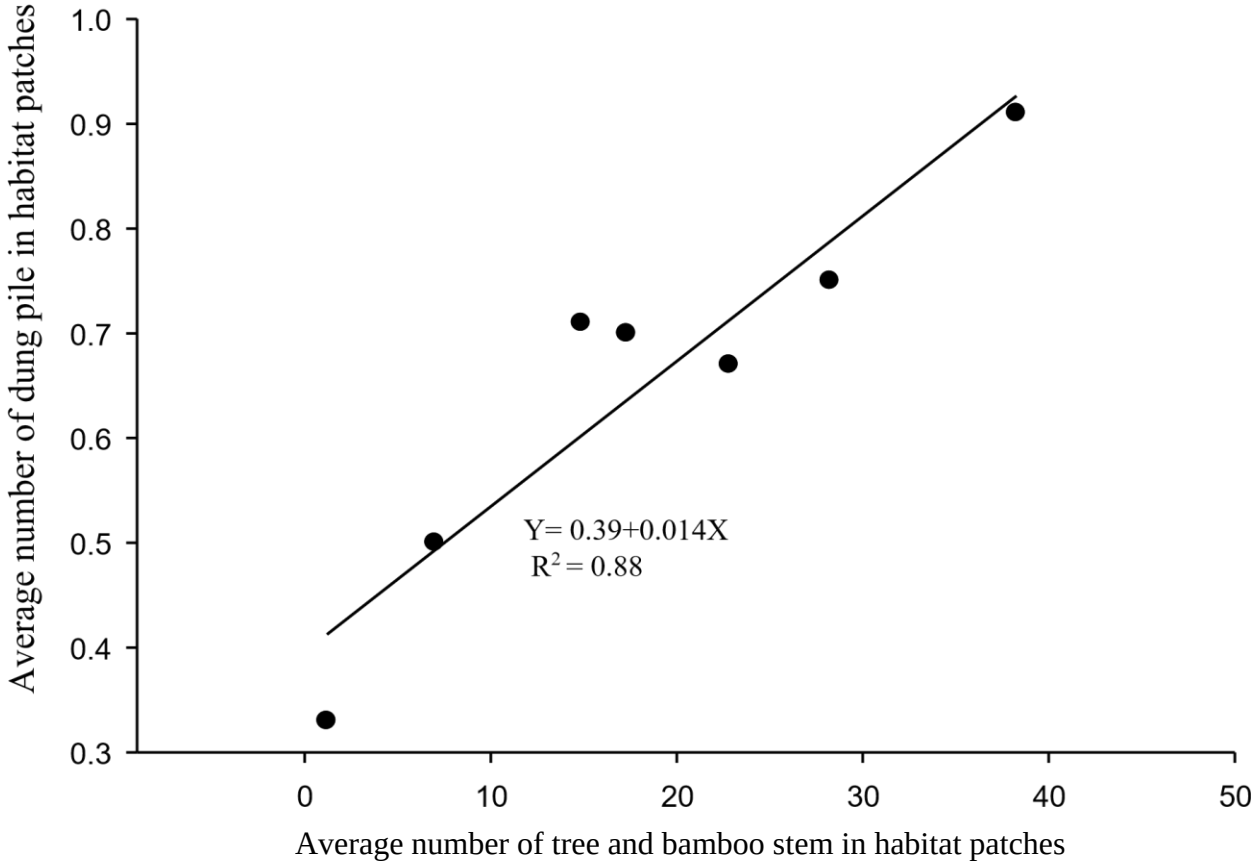

Fig. 3.6: Relationship between average numbers of dung piles recorded through plot sampling in 7 different patches of elephant habitat, in relation to the average number of trees and bamboo stem recorded in the same patch.

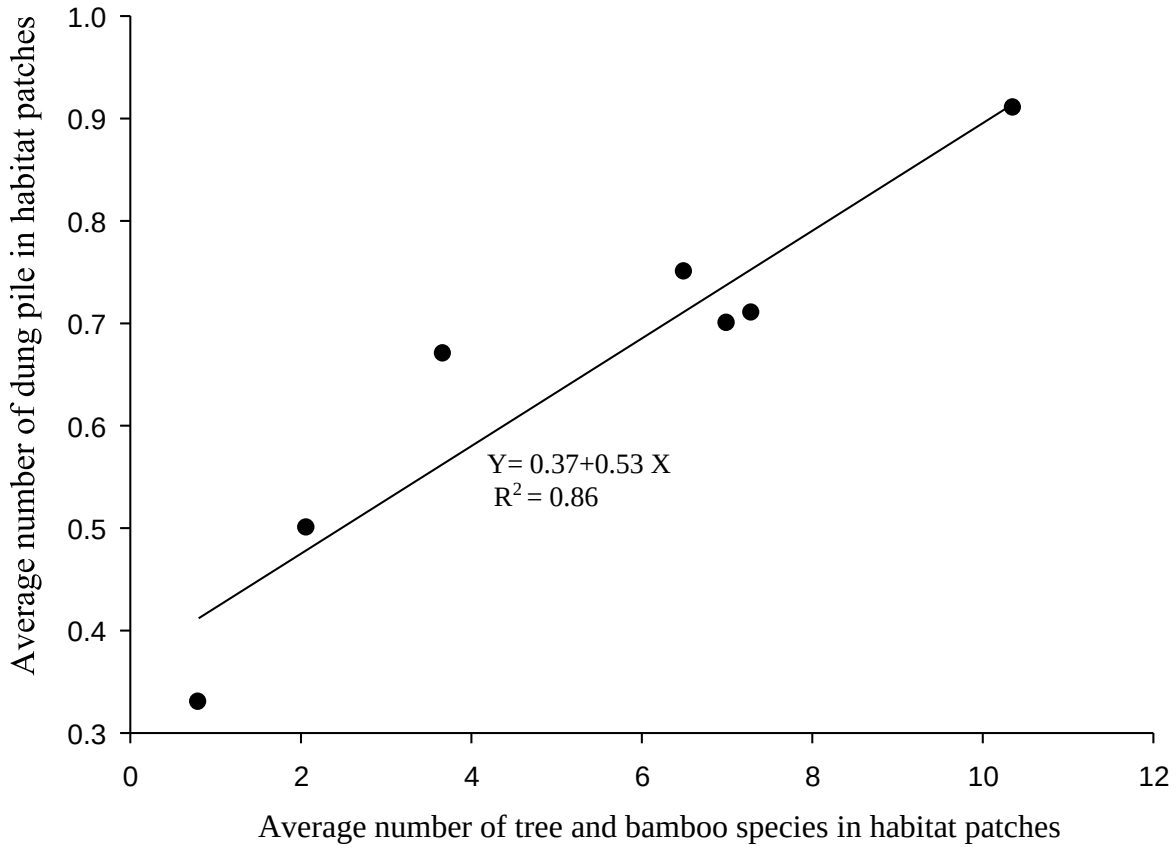

Fig. 3.7: Relationship between average numbers of dung piles recorded plot sampling in patches of elephant habitat and the average number of tree and bamboo species recorded in the same patch.

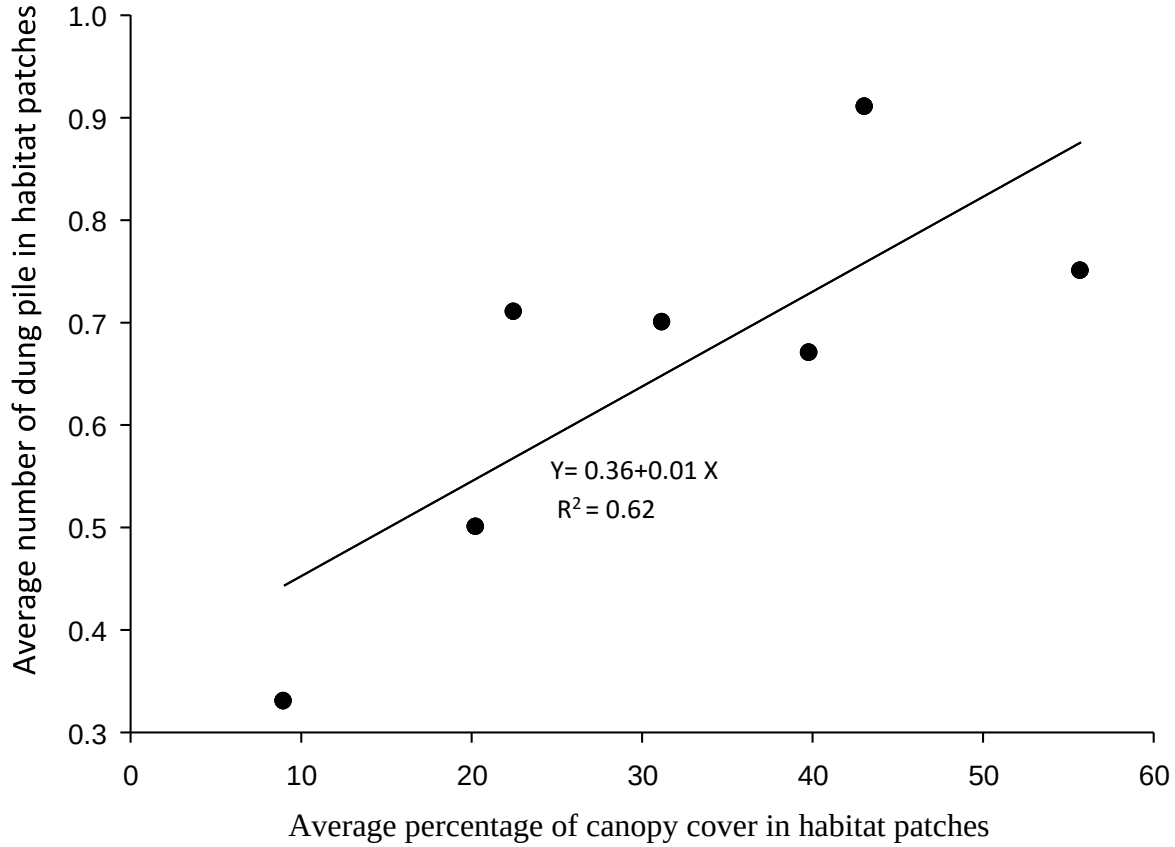

Fig. 3.8: Relationship between average numbers of dung pile recorded through plot sampling in patches of elephant habitat and the average percentage of canopy cover recorded in the same patches.

Vegetation Structure:

The FRI values calculated in this study clearly indicate the status of forest regeneration in most of the habitat patches is a major concern. Likely a number of factors are at work to suppress plant regeneration in this region: The scarcity of large mature trees suggests less potential to recruit seedlings or saplings. Villagers intentionally set fire to seedlings and sapling, enabling them to convince forestry officials that they are collecting dead and dry firewood rather than harvesting live vegetation (pers. observ.). Saplings also are valued as construction materials (i.e. garden platforms for climbing vegetables - pers. observ.). Afforestation and reforestation with exotic species is a core forest management practice in Bangladesh at present (Hossain 2003). Native plants species (including potential elephant forage) are removed during maintenance operations on these plantation forest. The long standing practice of clear-cutting also prevents shade tolerant species from recruiting (Godefroid et al. 2005).

Asian elephants seek habitat with high canopy cover (Harris et al. 2008). Chartier et al. (2011) proposed that habitat with <30-40% forest cover would precipitate human-elephant conflict. In my study, the average canopy coverage within the remaining habitat patches was very close (≈ 31%) to the this lower limit, Shade is an important resource for thermoregulation by megaherbivores (Sitompul et al. 2013). To deal with excessive heating, elephants adjust their behavior by increased resting and decreased feeding (Mole 2015) with associated costs.

In addition to canopy cover, the preponderance of small diameter trees in the habitat plots indicates unsustainable recruitment and a long-term change in species composition of the plant community, in turn impacting the already-lowered habitat value for the elephants. However, lower basal area or fewer trees/ha also may produce more forage at ground level (Moore and Deiter 1992). Less vertical complexity associated with fewer large trees also indicates degraded habitat, including lower abundance of forage. The loss of habitat may be more visible but alteration of habitat effectiveness through stand structure change will contribute to a decline of suitable elephant habitat.

The stocking of tall grasses and bamboo density in my study plots (and patches) are poor in terms of elephant habitat quality. Elephant diets can contain 3-14% of grasses (Sukumar 1992; Joshi and Singh 2008). Tall grasses like Sungrass (*Cypetus difformis)*, and Ful jharu (*Thysanolaena maxima)* are relentlessly collected for roofing and makeshift brooms (unpublished data, Bangladesh Forest Department). Bamboos when present constitute important forage supply for elephants, but unregulated and unremitting extractions of bamboos from this region by the local community has resulted in this resource being scarce on the landscape. Admittedly, gregarious bamboo flowering (where synchronous flowering occurs once in 30-40 years, with all mature plants dying after fruiting) may have partially explained the low levels of bamboo on the landscape. Even so, my data show the severity of the situation, which would only be exacerbated by a gregarious flowering event. All told, the excessive harvesting of bamboo and tall grasses likely puts added pressure on the elephants to look for alternative food sources.

Overall, the level of forage I documented would appear inadequate to support 210 elephants in my study area (See Chapter 1), assuming those patches of habitat I did not sample are equally degraded. The lack of forage likely drives elephants to look for cultivated crop as the animal is generalist feeder and able to browse and graze a wide variety of vegetation (Lukacs et al. 2016). This increase dependence on cultivated crops exacerbates conflict with human. Also, elephants in the wild have been known to use different types of herbs, climbers, leaves etc. to treat themselves in case of sickness (Baruah 1997). For example, digestive dilemmas can be treated by fasting or consuming bitter herbs or bark. Shortage of certain forage also have a negative impact on birthrates affecting population decline(Eleaid 2016) and forcing the animals to migrate to areas outside their traditional territory for alternative forage (Sukumar 1992). As a bulk feeder the animals have to consume large amount of forage containing leaves, twigs, barks, fruits etc. Even barks of exotic species *Acacia auriculiformis* have been observed to peel and eaten during field visit although it does not constitute normal diet in this particular habitat. This is an indication of wider food choice permitting habitation of a diverse range of setting (Sukumar 1992).

Phytosociological attributes

Plant community domination by non-native species (*Acacia auriculiformis, Eucalyptus camaldulensis*) has profound impact on regeneration, growth and abundance of elephant

forage species. The invasion of non-native species likely alters elephant habitat use (Prasad and Williams 2011). The historical multistoried-forests of Bangladesh are now converted to single-storied forests with minimal or zero ground cover (Hossain 2003). Non-native species like *Eucalyptus* and *Acacia* inhibit natural regeneration of some native forest species and influence the distribution, quantity and seasonality of natural forage making habitat less favorable (Islam 2002; Carnus et al. 2006). This in turn may lead to increased levels of human-elephants conflicts (Prasad and Williams 2011).

The domination of non-native species is not unexpected in a situation where exotic plants were deliberately introduced since 1871, one notable example being teak (*Tectona grandis*). Other species (e.g. *Acacia auriculiformis, Eucalyptus camaldulensis*) were introduced in the 1980s for large scale afforestation, with the objective of replacing low yield heterogeneous forest with commercially-valuable species (Hossain 2003). The fact that most of the native species showed lower IVI values indicate their scarcity and need of higher conservation priority.

Species diversity Index- Despite the apparent degradation of the remaining habitat plots, the diversity of the habitat patches appears relatively similar to that reported for other tropical forest indicating high potential for restoration if appropriate conservation initiatives are taken. However, the domination of non-native species will result in the extinction of more palatable species (Hossain 2003). Elephants looking for a specific forage species or for a particular phenological phase like leafing, flowering and/or fruiting may not find such resources, which will put them at risk of negative demographic effect.

Current elephant use of remaining habitat patches:

The use of animal sign such as dung piles is a strong indicator of animal presence, but becomes less reliable for assessing abundance or frequency of use (William et al. 2002). Admittedly, I could not use my dung pile counts to distinguish between recent versus past use, or to provide a strong measurement of animal numbers in the patches. However, several studies have found this approach to be a crude but useful way to represent animal activity (Williams et al. 2002). In this study, strong and multiple relationships between my dung counts and patch attributes suggest it provides a valuable if somewhat cursory assessment

tool. These data suggest the animals are still recognizing and responding to habitat patches that provide at least a minimal level of resources and thermal cover. However, elephants might not use dense canopy cover, as medium and open canopy cover appeared to be the most important habitat providing forage (Sitompul et al. 2013). Other studied have cited a strong association between elephants and natural vegetation, even when the latter is occurring in a patchy distribution (Kumar et al. 2010). Natural vegetation has the potential to provide more forage and thermal refuge. Plantations (especially monoculture plantations) usually have lower forage levels and become of limited use for elephants (Sukumar 2003). My results also support the assumption that elephants respond strongly to habitat patches with more numerous and variety of trees and bamboos and canopy cover.

Conclusion:

This study signals that elephant habitat in Southeast Bangladesh is diminishing and degrading at an alarming rate. A comprehensive habitat restoration program is urgently required to save this iconic and important species of the Bangladesh ecosystem from extirpation. However, habitat restoration is not straight forward in a human-dominated landscape like Bangladesh. The continued persistence of elephants on this landscape will depend on how adeptly a restoration program addresses both human (Chapter 2) and elephants needs simultaneously. Partitioning of habitats into different usage zones, such as those where human activity is and is not permitted, may be good starting point for such a restoration effort. To ensure elephants are able to conduct uninterrupted movements, all remaining habitat patches must be networked with well-designed connectivity corridors that will allow animals to move between foraging patches and ultimately allow genetic exchange between herds. The extensive restoration program needed to retain Bangladesh's elephants must not only safeguard elephant habitat but also address the roots of human-elephant conflict across the country.

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CHAPTER 4

SUMMARY AND MANAGEMENT IMPLICATIONS

Summary

This study explored aspects of elephant conservation within a human-dominated landscape. More specifically, I investigated human-elephant conflict and the state of elephant habitat in southeast Bangladesh. The objectives of the thesis were to describe the knowledge, attitudes and opinions of local people about elephant conservation and describe changes to elephant habitat 1989-2015 as a consequence of human activities.

The following points represent the major findings of my thesis:

- Elephant incursions occur throughout the year, likely driven by a reduction of native forage Combined with accessible crop. The intensity of incursions appear to increase after crops are cultivated. Elephants show opportunistic raiding behavior, with raids occurring primarily during April- June, October - November.
- A significant number of human and elephant lives are lost due to human-elephant conflict. During 2013-2015, a minimum of 50 people and 18 elephants were killed within my study area. In addition, the conflicts included house damage, livestock death, crop loss, and other damage.
- Despite the incursions, a large number of respondents indicated support for elephant conservation programs. Respondents in particular supported conservation efforts that they are familiar with and/or also generated direct benefit for the community like compensation, revenue sharing through eco-tourism etc.
- Within my study area, approximately 36% of elephant habitat has been lost during the period of 1989-2015. The overall deforestation rate on this landscape during that time was 1.7% which is significantly higher than the country's annual deforestation rate.
- Within remaining patches of 'elephant habitat', forage stocking quantity and quality appears poor. The average canopy cover in the patches I sampled was 31% , very close to the suggested lower threshold of forest cover required to sustain elephants. Moreover, the existing vegetation in these patches currently is dominated by non- native species that likely impede the growth of native forage.

- Based on dung counts, elephants appear to be more heavily-using habitat patches with higher tree abundance and cover.

The results of this study generally confirm that degradation and deforestation of elephant habitat is likely responsible for increased human-elephant conflicts across the landscape. Ignorance of wild elephant behaviour also appears to contribute to human fatalities. A comprehensive strategy addressing the need of both the local community and the elephants appears necessary to reduce these conflicts. The results of my study contribute to our understanding of elephant behavior and habitat and the view of local communities towards elephant conservation. The nagging question that remains, however, is - can the Asian elephant in Bangladesh avoid extirpation?

Management and Conservation

Elephant conservation is a 'business of luxury' for developing countries such as Bangladesh. Poor people residing at the proximity of elephant habitat cannot afford such consideration unless their reliance on the habitat is compensated. My study indicated the conflict between human-elephants fundamentally arises from destruction and degradation of elephant habitat; this can be only minimized by simultaneously addressing both human and elephant needs. The dichotomy of human and elephant interests makes an elephant conservation program in this region challenging. A comprehensive conservation plan must address the following points:

- Agriculture is ubiquitous throughout the landscape of my study area, and hence farming practice must accommodate or deter incursion by the elephants. Cultivation of non-palatable crops at the interface area of the habitat may be one way to deter elephant incursions.
- Awareness programs could improve villagers' understanding of wild elephants, and bring about an attitudinal and behavioral change among people living in or near habitats, thus helping to avoid confrontation and conflict (Desai and Riddle 2015).
- The dependency of people residing adjacent to elephant habitat need to be reduced by introducing alternative sources of income, such as tourism. However, based on research on tourism, it is a challenging option (Alam et. al. 2010).
- Community based elephant conservation might be another potential approach to ensure participation of local community for the management of human-elephant conflicts and

restoration of habitat simultaneously.

- The formation of wildlife response teams that consist of local people, forest department officials and other local government organizations may provide better deterrence against elephant incursions. Trained teams could be equipped with non-lethal deterrence tools, [e.g. halogen light, pepper spray, chilly briquettes, tear gas, lithium chloride, quinine sulphate, chloro-quine hydrochloride, and tannic acid home- made fireworks and grenade-like bomblets, , vehicle horns, throwing devices (e.g. plastic balls or smell-bombs that discharge on impact] with ammonia or other noxious substance inside. This is best achieved by involving the most affected local communities, encouraging them to take ownership of the management strategies (Nelson et al. 2003) .
- Recently Desai and Riddle 2015 argue that the minimum area of habitat patches needed to support viable elephant populations is 250 km^2 . All of the habitat patches I studied were smaller than this minimum requirement. However, Desai and Riddle did not take into account the role of connectivity; if corridors can be secured to permit the uninterrupted movement of elephants between patches such as those I sampled, the value of these habitat patches can be maintained.

My study implies the overall tolerance to human-elephant conflict is gradually eroding as indicated by indiscriminate killing of elephants and endless damage of resources every year. However, the strong support showed by local people towards wild elephants could be an asset, but failure to mitigate the conflict in the immediate future could reverse the situation. The findings of my study have implications for the mitigation of this complicated problem. At the outset, we must recognize that this conflict cannot be eliminated but can be minimized. No single measure likely will be effective in isolation; rather, a combination of several mitigation measures is required. The overall goal of the conflict management should be increasing tolerance of the local communities. Strategies need to be developed and continuously upgraded based on new knowledge, technology and situation to address elephant incursion (Nelson et al. 2003).

The retention and restoration of natural vegetation in this particular landscape is a pressing need. In a highly fragmented landscape, like southeastern Bangladesh, forests fragment and vegetation play an important role in elephant ecology. Further deterioration of available habitat and the absence of habitat replenishment may ultimately lead to increasing human-elephant conflict and a declining elephant population. Land use planning, elephants

behaviour and the responses of local people are important consideration in devising a long-term elephant conservation plan (Rood et al. 2010). My study provided an initial step in this direction by identifying and prioritizing the area need to be focus for elephant conservation. Currently, habitat management focuses largely on raising plantations of non-native plant species, where the participation of local people is ensured by addressing their needs without attention to the forage needs of elephants. The conversion of natural vegetation to non-native plantations renders habitat patches unsuitable for elephants, as the understory becomes dominated by regeneration of non-native species (Sukumar 2003; Islam 2002; Carnus et al. 2006). The planting of natural species (particularly forage spp.) should be a major consideration in the reclamation or enhancement of degraded habitat patches. This includes delineating the minimum area of strictly protected enclaves for elephants required to ensure the natural regeneration of herbaceous forage for elephants. Degraded forests with minimal human activity needs to be considered as a starting point. Current plantations of non-native plant species should be continued only at the periphery of elephant habitat near human localities.

Limitation and future research priorities

Within my study, there were several limitations that must be recognized.

- Due to logistics and available resources, questionnaire data were collected during only one year, and the physical measurement of damage claimed by participants could not be verified at field level .
- Opportunities to become fully immersed in conversations and dialogue with the communities were limited. Also, given the culture of villages, the majority of the participants in my interviews were male. The survey also was limited to villages in proximity of elephant habitat. Hence, the opinion expressed in this survey may not be used for wide generalization to the entire region, much less all of Bangladesh.
- The satellite imageries were taken using different sensors that may have contributed some error during image classification. The classification was based on the spectral response of different land cover type. However, some land cover may show similar reflectance; for example, agricultural lands during pre-monsoon winter season show high reflectance because most crops have already been harvested. Semi- automatic classification also shows low-moisture content among these areas and may lead to

confusion with bare soils and degraded lands. This is why visual interpretation becomes important when comparing Google Earth images.

- Seasonal variations also have an influence on vegetation. The mixed vegetative species shows different spectral response in different areas. However, the acquisitions dates of all the images generally occurred within dry seasons when deciduous trees have limited response on Landsat imageries. Further, an accuracy assessment was not carried out due to time and resource limitations. Future study could use images of high resolution (e.g.: 0.5 m) with detailed field verification, and assessment the accuracy of the classification.
- Elephant dung pile counts were collected for one season to reveal elephant habitat usage. Given that there is seasonal variation in the movement patterns of elephants (Marasinghe et al. 2015), this cursory method may not reflect important shifts in habitat use by the animals (Williams et al. 2002). However, my approach provides a preliminary if crude assessment of habitat use.
- Elephant habitat quality also will be influenced by the proximity of water; season variations in water availability may be considerable, but this was not a habitat attribute I was able to quantify. Further assessment of habitat use patterns over longer time periods would likely help reveal important aspects of behavior of elephants (Marasinghe et al. 2015).
- The location, design and vegetation of connectivity corridors (both existing and reclaimed) and their effectiveness must be explored in future research.
- GPS tracking of elephants would provide a much clearer picture about elephant habitat use, home range, average movement/day, vegetation selection etc. Such data would in turn allow a better understanding of how the effect of water and forage quality/quantity influences habitat use within a human-modified habitat.
- Population viability assessment of the remaining elephant population must done following the established IUCN protocol (IUCN Species Survival Commission 2003) to evaluate and predict the likelihood of elephant persistence of this landscape and Bangladesh as a whole.

Conclusion

My results contribute to our understanding of how elephants in Bangladesh may be conserved within a landscape of deforested and degraded habitat. The findings of this study demonstrate diminishing elephant habitat and growing human-elephant conflict. It stresses the need for policy enforcement to enable human-elephant co-existence in order to save the majestic animal. I believe conserving the elephant population in my study region will require the restoration of habitat along with community participation and further research on the animal - these admittedly are substantial undertakings. Still, I believe the future of elephants in Bangladesh is not forsaken: the animals are adaptable, and with the support of local communities and government, persistence is possible. I hope that future generations will be able to appreciate the role these iconic and majestic animals play in the social and ecological fabric of Bangladesh.

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Appendix A: Understanding and Managing Asian Elephants in Southeast Bangladesh Survey Questionnaire

Hello, my name is Shorf uddin Ahmed Chowdrury, and I work with the Bangladesh Forest Department. I am very interested to know about your interactions with elephants (e.g. in the past 2 years - often we declare a specific time frame), how they impact your life and livelihood, how you feel about elephants in general, and if you believe there are ways to live peacefully with elephants in the years ahead. This information will be used to develop better management plans for the animals, and also to help people deal with the problems that elephants cause. Therefore, I invite you to participate in my study by responding to this questionnaire. Your views are important to me and I will keep all the information confidential (e.g. I will not record your name or use your name in any reports I write). I will interview up to 200 men and women across Southeast Bangladesh. The results will help me and Forest Department managers to manage and conserve elephants while respecting people and their livelihoods in the region. The survey takes up to 45 minutes to complete, your participation is voluntary, and you may stop anytime if you are not comfortable with answering any of the questions. When we conclude the survey I will assume that you are satisfied with me using your responses to the questions. Do you have time to participate today?

1 = Yes 2 = No 3 = Time convenient for you _____ (note day and time to return)

Interview #_____ Village_____Date_____ Time_____

A. Please tell me about yourself

1. Name

   (<u>do not</u> record name, simply note name for friendly interaction during the interview)

2. Age

   1= 18-28 years **3**= 40- 50 years **5**= More than 60 years

   2= 29-39 years **4**= 50-60 years

3. Sex 1 = Male 2 = Female

Education

4. **How many years of school have you completed?***(Circle your response)*

   1 = Less than high school 5 = Completed bachelor's degree

   2 = Completed high school 6 = Some post graduate work

3 = Some college or technical school
7 = Completed graduate work

4 = Technical or college diploma
8 = Other (please specify)
_____

5. Livelihoods activities involved in :

6. Monthly/yearly income : **What was your total household income before taxes for 2014**

1 = Under $2,000
2 = $2,000 - $2,999
3 = $3,000 - $4,999
4 = $5,000-$7,999
5 = $8,000-$9,999
6 = $10,000 or more

7. Location of your homestead (*specify location*):

_____

8. How long you have been living here? _____ # of years

B. Now I wish to know about your experience with elephants in the past 2 years.

9. How often do elephants come into your village area?

1 = Not at all
2 = Every year
3 = Every ____ thyear
4 = Don't know
5 = Other (please specify) _____

10. Which months of the year do elephants come? *(circle the months stated)*

Month 1 = Jan 2 = Feb 3 = Mar 4 = Apr 5 = May 6 = Jun
7 = Jul 8 = Aug 9 = Sep 10 = Oct 11 = Nov 12 = Dec

11. On average, what hour of the day do elephants arrive?

1 = dawn
2 = early morning
3 = late morning
4 = afternoon
5 = dusk
6 = night

12. Are elephants a problem for you and your family? If so how long have they caused problems?

1 = Not a problem 2 = Yes, a problem for____ years

C. Let's talk about the problems created by elephants in the past 2 years

13. What are the problems caused by elephants?*(Select all that apply)*

1 = Crop raiding 2 =House damage 3 =Livestock damage

4 = Other (Please specify) _____

14. What kind of crop fields do elephants usually raid? *(Select all that apply)*

1= Rice field
2= Wheat field
3= Vegetable field
4= Maize
5=Sugar cane
6= Others (Please specify)

15. On average, what was the condition of crop(s) at the time of raiding?

1= Just planted 2= Immature 3= Mature

16. How much area did the elephants impact in your village?

1= Year 2014 acre/ha
2= Year 2013 acre/ha

D. Now let us talk about the results of elephant intrusions in this locality over the past 2 years:

17. How many people have died from as a result of elephant attacks?

1= Year 2014 _____ nos **2**= Year 2013 _____ nos

18. What was the profession of the people that were killed?

_____

19. What was sex of the people that were killed?

(record multiple numbers if more than one case): 1= Male 2= Female

20. How many people have been injured from elephant attacks in your village?

1= Year 2014 nos
2= Year 2013 nos

21. Where did injuries or deaths to people occur? Here are the choices:
(record multiple numbers if more than one case)

1= Inside the forest
2= On the edge of the forest
3= Outside of the forest

22. How many elephants have died in your locality?

1= Year 2014 _____ nos 2= Year 2013 _____ nos

23. What are the types of elephants that have died due to human-elephant conflict?

1= Calf 2= Bull 3= Cow

24. What other damage was caused by elephants in your locality during the year 2014?

1= House damage 2= Livestock death 3= Nursery damage
4= Fruit tree damage 5= bamboo 6= others(Please specify)

25. In 2013, what damage other than death or injuries to people was caused by elephants in your locality?

1= House damage 2= Livestock death 3= Nursery damage
4= Fruit tree damage 5= bamboo 6= others(Please specify)

26. Where do these additional impacts normally occur (crop raiding/ property damage etc.)?

1= Within elephant habitat
2= Edge of elephant habitat
3= Outside forest
4= Do not know

E. Now I wish to understand your feeling and perception about elephants

27. On average, are elephants coming to your locality in a group?

1 = Yes 2 = No

28. If the elephants appear most often in a group, please describe the most common type of group?

1= Female(s) 2= Calf(s) 3= Bull(s) 4=mixed herd

29. Why do you think elephants come to your locality?

1= In search of Food
2= In search of water
3= Property damage
4= Others (Please specify) _____

30. Do you think elephant attacks (crop raiding/ property damage/livestock damage etc) have been increasing in recent years?

1= Yes 2= No 3= no change

31. If you think attacks are increasing, how strongly do you agree or disagree with each as the reasons for increasing elephant attacks?

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
Declining food base of elephants	1	2	3	4
Growing male aggression	1	2	3	4
Shrinking elephant habitat	1	2	3	4
Corridor encroachment	1	2	3	4
Other (Please specify) _____	1	2	3	4

32. What do you do when elephants come to your locality? (*indicate all that apply*)

1= Make noise with fire crackers
2= Make noise with dram
3= others (Specify)

33. What would you say is the overall condition of elephant habitat in this region?

1= Very good 2= moderate 3= bad 4=I don't know

F. **I wish to know about your thoughts about elephant conservation?**

34. Do you think elephants in your locality should be conserved?

1= Yes 2= No

35. If you think elephants should be conserved, what measures should we take to do this in your locality?

	Not Useful	Useful	Very Useful	Don't Know
Habitat improvement	1	2	3	4
Community awareness	1	2	3	4
Erection of Physical barrier	1	2	3	4
Electric or solar fence	1	2	3	4
Chilli cultivation or chilli smoke briquettes	1	2	3	4
Apiculture	1	2	3	4
Other (Please specify) _____	1	2	3	4

36. What do you think about other strategies to help conserve elephants?

	Not Useful	Useful	Very Useful	Don't Know
Compensation for damage ($)	1	2	3	4
Tourism (e.g. elephant viewing)	1	2	3	4
Revenue sharing from tourism	1	2	3	4

37. What % revenue sharing do you except from community based tourism?
_____ %

G. Finally, I wish to know about the professional response you have received following elephant incidents?

38. What role did the Bangladesh Forest Department (FD) play following the last elephant incident that involved death and/or injury? *(check all that apply*)

1= Compensation was provided
2= A medical facility was provided
3= FD did nothing

39. Did any family of injured/ dead person in your locality receive any compensation?

1= Yes 2= No 3= Do not know

That is the end of my survey. Thank you so much for your time. Do you have questions you want to ask me?

Appendix B: **Form 1: Measurement of Seedlings, Saplings, Trees**

Name of Habitat Patches	Plot ID:	Range
GPS location(latitude & longitude)		

# of Seedling in 2 m radius sub-plot :
# of sapling in 2 m radius sub-plot :
# of dung pile in 17.84 m radius plot:
% of Tall grass coverage in 2 m radius sub plot :

Live Tree Measurements: Nested Plots

Plot radius: small, 10.0m Tree diameter: ≤ 10.0cm			
Tree #	Species	DBH (cm)	HT/ RHT

Plot radius: medium, 17. 84m Tree diameter: ≥10.0cm			
Tree #	Species	DBH (cm)	HT/ RHT

Form 2: Non-Tree Woody Vegetation: Bamboos

Name of Habitat Patches:_____ Plot ID:_____

Plot radius 17.84 m

Clump #	Species	Average DBH (cm) of the culm	Height (m)	Number of Culms/Stems in the clump (n)

Appendix C: Occurrence of forage species in different habitat patches of southeastern Bangladesh

Scientific Name	Local Name	Family	Occurrence Status
Acacia auriculiformis	Akashmoni	Fabaceae	Fairly Common
Aegle marnelos	Bel	Rutaceae	Infrequent
Albizia lebbek	Kala koroi	Mimosaceae	Infrequent
Albizia procera	Sil koroi	Mimosaceae	Infrequent
Artocarpus chaplasha	Chapalish	Moraceae	Infrequent
Artocarpus heterophyllus	Kantal	Moraceae	Infrequent
Artocarpus lacucha	Borta	Moraceae	Infrequent
Bambusa tulda	Mirtinga Bans	Graminae	Infrequent
Bombax ceiba	Simul	Mulvaceae	Infrequent
Cajanus cajan	Arhor	Fabaceae	Infrequent
Casia fistula	Sonalu	Fabaceae	Infrequent
Citrus grandis	Jambura	Citraceae	Infrequent
Cypetus difformis	Chan	Cyperaceae	Fairly Common
Cynodon dactylon	Durba	Graminae	Fairly common
Demnostacya bipinnata	Kusa	Poeceae	Infrequent
Dentrocalamus stictus	Lathi bans	Graminae	Infrequent
Dillenia indica	Calta	Dilleniaceae	Infrequent
Dillenia pentagyna	Hargoza	Dilleniaceae	Infrequent
Emblica officinalis	Amloki	Euphorbiaceae	Infrequent
Ficus bengalensis	Bot	Moraceae	Infrequent
Ficus hispida	Dumur	Moraceae	Fairly common
Gmelina arborea	Gamer	Verbenaceae	Infrequent
Lannea coromandelica	Bhadi	Anacardiaceae	Fairly common
Mangifera indica	Am	Anacardiaceae	Infrequent
Mangifera sylvatica	Uriam	Anacardiaceae	Infrequent
Melocanna baccifera	Muli bans	Graminae	Fairly common
Mimosa pudica L	Lazzaboti	Fabaceae	Fairly Common
Mitragyna parviflora	Dakrum	Rubiaceae	Fairly common
Musa sp	Bonna kala	Musaceae	Fairly common
Neauhozia zeylanica	Dolu bans	Graminae	Infrequent
Oxytenanthera nigrocilita	Kali bans	Graminae	Infrequent
Psidium guava	Guava	Myrtaceae	Infrequent
Smilax zeylanica L	Kumarialata	Smilacaceae	Fairly Common
Swintonia floribunda	Civit	Citraceae	Infrequent
Syzgium cumin	Kalo jam	Myrtaceae	Fairly Common
Tectona grandis	Segun	Verbenaceae	Infrequent
Terminalia bellirica((Gaetn) Roxb	Bohera	Combretaceae	Infrequent
Terminalia chebula	Horitoki	Combretaceae	Infrequent
Thysanolaena maxima	Ful jharu	Graminae	Fairly Common
Zizyphus mauritiana	Boroi	Rhamanaceae	Infrequent

Appendix D: Top five Phytosociological attributes(Relative frequency, Relative dominance , Relative density , Important Value Index (IVI) of species occur in different habitat patches of southeastern Bangladesh.

	Species	Relative frequency	Relative dominance	Relative density	Important Value Index (IVI)
Teknaf	*Acacia auriculiformis*	6.15	42.20	24.69	73.05
	Erythrina fusca	3.08	20.24	6.17	29.49
	Gmelina arborea	9.23	5.89	4.32	19.45
	Protium serratum	6.15	5.01	5.55	16.71
	Artocarpus heterophyllus	1.54	7.51	6.17	15.22
Inani	*Acacia auriculiformis*	4.17	14.13	26.59	44.89
	Ficus bebghalensis	6.25	28.49	6.38	41.12
	Dipterocarpus spp	2.08	9.94	2.13	14.16
	Gmelina arborea	2.08	3.64	6.38	12.12
	Garuga pinnata	4.17	1.55	5.32	11.03
Himchari	*Syzygium spp*	33.33	56.68	50.00	140.01
	Albizia sp	33.33	40.05	25.00	98.38
	Spondias mombin	33.33	3.27	25.00	61.60
Medakachh-apia	*Dipterocarpus* spp	16.67	80.07	35.19	131.92
	Mangifera indica	8.33	7.25	18.52	34.10
	Artocarpus heterophyllus	8.33	2.63	8.33	19.29
	Eucalyptus camaldulensis	4.17	6.01	7.41	17.58
	Aquilaria agallocha	4.17	0.33	11.11	15.61
Fasiakhali	*Dipterocarpus* spp	15.00	43.84	30.83	89.67
	Syzygium frimum	15.00	19.31	26.32	60.63
	Mangifera indica	5.00	25.32	9.77	40.09
	Acacia auriculiformis	5.00	1.59	16.54	23.13
	Hopea odorata	10.0	3.70	2.26	15.96
Chunati	*Acacia auriculiformis*	4.35	5.83	25.45	35.63
	Ficus hispida	8.70	20.23	5.45	34.38
	Callicarpa arborea	13.04	6.20	9.09	28.34
	Alstonia scholaris	4.35	13.32	5.45	23.13
	Psidium guajaba	4.34	3.48	12.73	20.55
Dhopoachari-Dudpukuria	*Ficus hispida*	6.93	23.05	6.10	36.08
	Stereospermum coais	8.91	12.78	9.35	31.04
	(asar)	4.95	5.22	9.35	19.53
	Garuga pinnata	4.95	7.45	3.25	15.66
	Dipterocarpus spp	4.95	3.63	6.91	15.49

Appendix E: Research Ethics Board (REB) Approval

THOMPSON RIVERS UNIVERSITY

May 21, 2015

Mr. Shorf uddin Ahmed Chowdhury
Faculty of Science\Natural Resource Science
Thompson Rivers University

File Number: 100936
Approval Date: May 15, 2015
Expiry Date: May 20, 2016

Dear Mr. Shorf uddin Ahmed Chowdhury,

The Research Ethics Board has reviewed your application titled 'The human dimension to elephant conservation in Bangladesh'. Your application has been approved. You may begin the proposed research. This REB approval, dated May 15, 2015, is valid for one year less a day: May 20, 2016.

One item to be added: Please add information on the consent form exactly what will happen to the participant's information should they withdraw from the project.

Throughout the duration of this REB approval, all requests for modifications, renewals and serious adverse event reports are submitted via the Research Portal. To continue your proposed research beyond May 20, 2016, you must submit a Renewal Form before May 20, 2016. If your research ends before May 20, 2016, please submit a Final Report Form to close out REB approval monitoring efforts.

If you have any questions about the REB review & approval process, please contact the Research Ethics Office via 250.852.7122. If you encounter any issues when working in the Research Portal, please contact the Research Office at 250.371.5586.

Sincerely,

Andrew Fergus
Chair, Research Ethics Board