HUMAN-TIGER CONFLICT, RANGING PATTERN AND HABITAT USE BY TIGER IN SUNDARBAN TIGER RESERVE, INDIA

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Certificate

This is to certify that the thesis entitled **"Human-tiger conflict, ranging pattern and habitat use by tiger in Sundarban Tiger Reserve, India"** submitted for the award of the **Doctor of Philosophy** in Wildlife Science to Saurashtra University, Rajkot is a record of original and independent research work carried out by **Mr. Dipanjan Naha** under our guidance. No part of this thesis has been submitted to any other university or institution for the award of any degree and it fulfills all the requirements laid down by the Saurashtra University.

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EXECUTIVE SUMMARY

Sundarbans of India and Bangladesh is the only mangrove in the world where tigers still live and is classified as a Tiger Conservation Landscape of Global Priority. The Sundarban tiger inhabits a unique mangrove habitat type, isolated from neighboring tiger populations by hundreds of kilometers of agricultural and urban land. This is the world's largest contiguous mangrove forest created at the confluence of the deltas of rivers Brahmaputra, Ganga and Meghna. The tiger is an integral part of Sundarban and partly responsible for the great publicity obtained by this area for two reasons, first, the highest concentration of tigers in the world was believed to exist here and second, for the highest concentration of man-eating tigers in the world. Local legends mention that about 100 years ago 4,218 people were eaten by tigers in just six years while historical records indicate that 800 human lives were lost in a span of 20 years in the undivided Sundarbans. More recent estimates proclaim that on an average 36 lives are lost to tigers on the Indian side of Sundarbans each year with only 28.5% of bodies recovered. Finding solutions to these issues were essential for securing the support of villagers, who have a large impact on forest management.

Studies from other countries such as Nepal, Russia has told us a lot about some general life history characteristics and behavior that can probably be applied to all tigers, but there was a lack of baseline information about the current Sundarban tiger population on the Indian side and how current management strategies are affecting it.

Though a few studies have been initiated on the Bangladesh side, yet detailed information on ecology of tigers is crucial for formulating long term conservation plans for the entire landscape. There was a pressing need to address the severe tiger-human conflict to minimize the resulting human misery and loss of tigers. The main objectives of the present study were to (a) understand ranging pattern and habitat use of tiger (b) to quantify livestock losses by tiger predation and identify spatio-temporal patterns in conflict in and around the Tiger Reserve (c) to document and quantify the geographic distribution of tiger-human incidents and (d) to evaluate the perception and level of tolerance of people living in the vicinity of Tiger Reserve.

Four tigers (1 adult female and 3 adult males) were radio-collared in 2010. The tigers were trapped in cages using bait and tranquilized using 2.5 mg/kg Ketamine and 1 mg/kg Xylazene administered intra-muscularly using a blow pipe. The collars were equipped with programmable GPS schedule, IRIDIUM Satellite data uploading facility and a VHF beacon for ground tracking. The satellite collars were programmed to transmit GPS fixes every three hours which was downloaded remotely via internet access. The estimated average tiger home range (95% FK) size was 137.12 km² (SE 39.19) (range 60.7 - 191.31 km²). The lone tigress which was a dispersing individual had a larger home range as compared to the male tigers. The average core area of tigers was estimated to be 65.33 (SE 19.31) km². Range size of India Sundarban tigers are somewhere between the two extremes, the Russian Far East and tropical deciduous forests and suggests higher resource availability compared to the Siberian region but lower than that of deciduous forests and alluvial grasslands.

This study showed that tiger home range range sizes are much larger than reported from Bangladesh Sundarban.

Program Oriana version 4.0, a circular statistics software for Windows, was used to evaluate daily activity pattern of tigers based on hourly distance moved. The average distance moved by tigers per day was 5.43 (SE 0.93) and the estimated minimum and maximum distance moved was 0.1 km to 23 km. There was no difference between daily distances moved by individual tigers (Kruskal Wallis, KW Analysis of Variance, χ^2 = 2.40, df = 3, P = 0.49). There was significant difference between distance moved by tigers per day during day and night (Paired t test, Z = 2.09, P =0.03), with movement peaks in the early hours of dawn and dusk. There was no difference in tiger movement per day between neap tide phase i.e. 5.1 km (SE 0.47) and spring tide phase i.e. 4.43 km (SE 0.40) (Mann-Whitney U, Z = 0.99, P = 0.16). Tigers are crepuscular and nocturnal elsewhere, an adaptation to evade confrontation with humans in majority of landscapes where they co-exist and in synchrony with the activity of their principal prey i.e. sambar. Sundarban Tigers are probably the least persecuted tigers in the world and therefore do not fear people as much. This seems to be the reason for their diurnal activity which coincides with the activity of their prey, the spotted deer. Diurnal movement pattern of tigers in Sundarban seems to be a major factor resulting in fatal attacks on humans. Out of 2500 km² of the Tiger Reserve, 1600 km² comprises of land and the rest water.

Tigers are reported to cross water channels regularly, moving across islands in search of prey and mates. Individual daily tiger paths were overlaid on digitized Google Earth Pro imagery to determine the number and width of channels crossed per day by radio-collared tigers. Considering all radio locations from all tigers, a common Minimum Convex Polygon was created using Arc GIS 9.3. Five random paths for each tiger path were generated within the common polygon using Hawth's Tool in Arc GIS 9.3. Water channels were classified into 50 meter increasing categories till 1000 meters and then into 500 meter beyond 1000 meter respectively. Availability of different width channels for tigers to cross in the landscape were determined by the number of channels in each width class crossed by random paths. Tigers were not observed to cross different width of channels as per their availability, with relatively higher frequency of crossing channels within 50 to 350 meters ($\chi^2 = 676.94$, df = 27, $P < 0.05$). Tigers rarely crossed channels more than 400 meters in width. The mean number of channels crossed by tigers per day was 5.19 (SE 0.99). There was no difference in mean number of channels crossed by individual tigers (Kruskal Wallis, KW Analysis of Variance, $\chi^2 = 6.19$, df = 3, $P = 0.1$).

Remotely sensed False Color Composite (FCC) maps on 1:50,000 scale of the study area from Landsat-5-ETM + imagery (30M resolution) was obtained for the month of February 2010. The imagery was ground validated by sampling 145 circular plots of 15 m radius along water channels across the Tiger Reserve by a small single engine boat between February and June 2010. Unsupervised maximum likelihood classifier followed by supervised classification was used for preparing the vegetation map.

Five habitat classes were identified based on vegetation classification, these were i) Water/Channels ii) *Phoenix* dominated iii) *Ceriops* dominated iv) Barren dry areas like salt pans along with fallow agricultural fields and v) *Avicennia-Sonneratia* dominated patches. Habitat selection was examined by comparing use and availability of habitat types within the study area using the Neu Method. Bonferroni Confidence Interval was used to understand individual habitat use and preference by tigers. Results of Bonferroni Confidence Interval showed that tigers preferred *Avicennia-Sonneratia* patches whereas *Phoenix* and *Ceriops* habitat were used according to their availability. Though *Avicennia-Sonneratia* was preferred, yet 50% of the locations were in *Phoenix* dominated habitat followed by 20% within *Ceriops* dominated habitats signifying their importance as most used habitats by tigers in mangroves. There was an avoidance observed for water by the tiger as expected in the overall habitat preference.

From existing published literature and forest department records, past and present scenario of human-tiger interactions in Sundarban were collected. Twenty nine sites were visited where tigers have attacked humans, within Sajnekhali Wildlife Sanctuary and West Range of the Tiger Reserve between 2010 and 2013. The mean number of human casualties to tiger attacks between 1963 and 1978 and 1985 to 2000, in Sundarban Tiger Reserve were 35 (SE 3.15) and 18 (SE 3.4) respectively. Between 2001 and 2013 the average human mortality was observed to be 6.7 (SE 1.04).

A total of 80 tiger attack events on humans have been recorded between January 2001 and December 2013 (Forest Department records and survey of villages) out of which 95% were fatal claiming the victim's life, only in 5% of the cases people were admitted to hospital with mild to medium mauling. Out of 80 attacks, information on 62 cases could be gathered from interviewing local people and checking Forest Department records. There was significant difference observed in the nature of fatal attacks (χ^2 = 136.9, df = 4, $p < 0.05$) with 65% cases where human body was not recovered, 20% when body was recovered by either family members, companions or forest officials, 3% when victim died on way to hospital, 2% died after being admitted to hospital and rest 9% survived after nursing injuries sustained. Only 5% of the tiger attacks were reported inside the villages, rest 95% were reported from within the Protected Area.

Tiger attacks varied across seasons with the majority of attack events recorded in April 27% followed by winter months November, December, January and February i.e. 31% (χ^2 = 52.97, df = 11, $p < 0.05$). Monsoon months (July, August and September) recorded 24% of the incidents. 32% of the attacks were recorded between 2 and 5 PM, 24% in the morning between 5 and 8 AM and 19% between 8 and 11 AM (χ^2 = 87.31, df = 7, $p < 0.05$). Most of the tiger victims were middle aged, with the average age being 39.9 years (SE 9.3). Majority of the humans killed by tigers were dependent on forests, of which 77% fishermen, 13% honey collectors, 6% crab collectors and rest 2% forest personnel and 2% villagers (χ^2 = 0.6, df = 4, $p < 0.05$). The average group composition of fishermen killed were 5 (SD 1.7) with range 2 to 8, for honey collectors it was 12 (SD 1.9) with range 10 to 14.

Channels of width 30 to 50 meters were present in 78% of the conflict sites, whereas rest 22% occurred near channels more than 200 meters in width. Seventy seven percent of the incidents occurred during last three hours of low tide and 23% in last 3 hours of high tide (χ^2= 29.16, df = 1, $p < 0.05$).

On an average tigers strayed 12.4 times per year (SE 0.3) during the period between 1998 and 2010 in peripheral villages with no significant seasonal variation. During 1998 and 2010 tigers killed on an average 3 goats (SE 0.4) and 2 cows (SE 0.2) per year. Fifty percent livestock kills were recorded in summer (April to June) and 38% during monsoon (July-September) (χ^2 = 94.4, df = 11, $p < 0.05$). There seems to be a clustering of human kills by tigers along the central (eastern and western) part of the Tiger Reserve. Conflict intensity was low on the northern and southern tip of the Tiger Reserve. The southern tip is flanked by the Bay of Bengal and Northern tip by hard boundaries i.e. peripheral villages.

A closed and open ended structured questionnaire was administered to 411 respondents across 19 peripheral villages of Sundarban Tiger Reserve to get an overview of the socio-economic conditions of the people, occupational patterns in the area and attitude towards tigers. All respondents were above 18 years and were questioned only when they were willing to answer the questions and participate in the survey. Opinion and attitudes towards tigers and wildlife conservation in general was assumed to vary based on economic losses due to livestock depredation and death of a person in the neighborhood.

The villages were categorized into three classes, according to the intensity of conflict i.e. loss of human lives and livestock depredation by tigers (i) Low, (ii) Medium, (iii) High respectively. Majority of the respondents were middle aged (47 years SD 15.3), with 38% illiterate followed by 31% having completed education till class X, 2% secondary school, 2% graduates and rest 26% studied till class V. Sixty-five percent of the respondents were males followed by 35% females. Majority of the respondents (60%) lived in kutcha houses with mud baked walls and thatch, hay, used as roofing material, whereas 32% lived in semi-pucca houses with cemented or concrete sheets as roof covers, rest 7% in pucca household made of bricks and cement The average age of fishermen interviewed was 50 years (SD 14.23).

Majority (69%) of honey collectors interviewed comprised of groups of 6 to 9 persons, 23% with 2 to 5 persons and 8% having more than 10 persons ($\chi^2 = 60.62$, $df = 2$, $p < 0.05$) while harvesting honey. Fishing groups consisted of 3 persons (57%), 4-6 persons (41%) and more than 6 persons (8%) while going for harvesting fish inside the forest ($\chi^2 = 30.38$, $df = 2$, $p < 0.05$). Sixty five percent of tiger attacks were recorded on groups comprising 2-5 persons, 25% on 6-10 and 10% on groups with more than 10 men. As means of self defense 86% used machete, 5% wooden sticks and poles and 9% without any defense item ($\chi^2 = 127.82$, $df = 2$, $p < 0.05$).

There was no significant difference observed regarding the attitude of respondents with 54% being negative and 46% positive towards tigers in the study area ($\chi^2 = 0.64$, $df = 1$, $p > 0.05$).

Occupation and status wise dislike towards tigers in peripheral villages of Sundarban Tiger Reserve was in the following order: housewives (83%) > fishermen (60%) > service holders (51%) > agriculturists (50%) > boat owners (25%) ($\chi^2 = 32.39$, df = 4, $p < 0.05$). There was no significant difference observed in opinion concerning negative attitude towards tigers among different age class respondents in the 18-30 years age category 43% in the 30-60 years category 55% and in the 60 plus category 58%, ($\chi^2 = 2.42$, df = 2, $p > 0.05$).

Thirty four percent of the respondents stated that the main function of tigers is to play an ecological role in the wild regulating ecosystems, 33% viewed them to be destroyers of all life forms subduing others, 25% opined that they kept prey populations at control, whereas rest 7% were unaware of any role played by the tigers as such ($\chi^2 = 18.94$, df = 3, $p < 0.05$). Sixty percent of the respondents opined that the declaration of Tiger Reserve was not useful for their livelihood followed by 28%, who felt that it was partially beneficial and the rest 12% stated it to be useful ($\chi^2 = 35.84$, df = 2, $p < 0.05$).

Majority of the respondents 90% stated that tigers considered humans as natural prey in Sundarban with a mere 8% who felt that they were killed in self defense ($\chi^2 = 145.04$, df = 2, $p < 0.05$). Forty three percent of the respondents stated that loss and scarcity of natural prey in the wild forced tigers to stray into human habitations, whereas 33% said that easy prey in the form of livestock and difficulty in catching native prey were responsible for straying incidents ($\chi^2 = 119.1$, df = 6, $p < 0.05$).

Fifty two percent agriculturists, 36% fishermen, 8% service holders and 4% housewives opined that the main role of tigers in the wild is to destroy or subdue other animals (χ^2 = 63.2, df = 3, $p < 0.05$). Gender wise 60% males and 40% female respondents viewed tigers to be destroyers of all life forms ($\chi^2 = 4$, df = 1, $p < 0.05$).

Since tiger attacks were frequent on fishermen and honey collectors, the respondents were asked as to whether they were willing to switch profession. Majority (84%) declined to comment and only 16% responded positive for a changeover ($\chi^2 = 46.24$, df = 1, $p < 0.05$). When inquired about their choice of profession with high risks involved, 39% said that it gave instant cash rewards, 39% cited no other means of secure alternative, 5% spoke about limitations of agriculture and rest 17% stated that they were best and apt at this compared to other sources of livelihood ($\chi^2 = 34.24$, df = 3, $p < 0.05$).

The Sundarban Tiger Population is of global importance for the conservation of the species due to the size of the contiguous nature of the habitat and the unique adaptations of the tigers that inhabit these mangrove forests. In spite of only four tigers that could be radio-collared and monitored this study enhances our understanding aspects of tiger ecology in this unique landscape. Sundarban tigers are primarily diurnal, prefer certain habitat types and are reluctant to cross wide expanse of water. This information can be used to minimize human-tiger conflict which is a major impediment to tiger conservation in this region.

People dependent on fishing earns comparatively more as compared to other occupation, yet it is a hazardous occupation and alternate employment opportunities such as eco-tourism, home stays, pisciculture and apiculture should be promoted in villages. To treat tiger victims instantaneously and reduce risk of deaths due to lack of timely aid, Mobile Medical Emergency Units should be set up along conflict prone sites especially during April and May. Village Tiger response units can be mobilized from the local youth in collaboration with the Forest Department to garner public support and efficiently resolve human-tiger conflicts. Radio-collaring should also be taken up to monitor movement and behavior of problem tigers and ward off possible fatal attacks on humans. Awareness programs and campaigns for local inhabitants should be organized by the forest department and local NGO's to prioritize threats and plausible reasons of tiger attacks to reduce intensity of human tiger conflict.

The tiger population of India and Bangladesh Sundarbans is a single continuous population and hence trans-boundary conservation between the two countries is vital for long-term population persistence. With increasing commercial boat traffic across wide water channels especially along the International border and in some water channels of Bangladesh, these wide channels could become barriers to tiger gene flow, effectively fragmenting the population of Sundarban tigers into smaller isolated populations. Careful planning and management of "tiger corridors" across Sundarbans is required to maintain the Sundarban tiger population as a contiguous population with gene flow between larger islands and also between the two countries.

CHAPTER 1

INTRODUCTION

1. Introduction

Large carnivores are often regarded as indicator or umbrella species, with their presence also benefiting the conservation of other life forms in their ranges, and hence there is a great emphasis on their conservation (Linnell 2000). Large home ranges, spanning varied habitats, make large carnivore conservation a challenging task for wildlife managers (Mech 1995). Outside of the Protected Areas (PAs), land use practice such as cultivation of certain crops or plantations can change the characteristics of the landscapes and these changed landscapes can act as habitats for the carnivores (Treves and Karanth 2003). Even if PAs are designated for conservation of large carnivores, the wide ranging habits of carnivores and the dispersal needs of young adults can result in a spill over to these human dominated landscapes (Primm 1996). Conflict with humans is a major issue in large carnivore conservation (Nowell and Jackson 1996). Conflict can have multiple implications ranging from fear evoked by the presence of the carnivore (Quammen 2003), to fatal attacks on humans (Loe 2004). Such conflict is seen with tigers in Indonesia and India (Nyhus 2004) and lions in Africa and India (Patterson *et al*. 2004 and Saberwal *et al*. 1994). Even in the absence of attacks on humans, livestock depredation by carnivores can hamper the livelihoods of people and affect their economic condition (Ogada *et al*. 2003). Human-carnivore conflict in terms of livestock depredation is perhaps more

common and is seen in several reported cases across the world. Studies on puma and jaguar (Conforti 2003, Zimmermann 2005) in Brazil, lynx (Odden *et al.* 2002) in Norway, and lion (Patterson *et al.* 2004), wild dogs and leopard (Romanach *et al.* 2007) in Africa, leopard and tiger in Bhutan (Wang 2006) exemplify this.

1.1. Felid Biology

Felids belong to the cat-branch of the order Carnivora and have been distinguished from the Canoidea (dog-like carnivores) by the structure of the auditory bulla. Among the 36 extant species of wild felid, surviving today, they range in size over two orders of magnitude from the massive Siberian tiger *(Panthera tigris altaica)* (200–325 kg) to the dainty black-footed cat *(Felis nigripes)* (1–2 kg) of southern Africa and diminutive rusty-spotted cat *(Prionailurus rubiginosus)* (1 kg) of India and Sri Lanka. In palaeogeological terms, the Felinae radiated relatively recently and rapidly in the late Miocene 13 to 14 million years ago, with extinct and extant genera of the family Felidae derived from a common ancestor 27 million years ago (Werdelin *et al.* 2005). Felids are obligate carnivores with adherence to eating flesh, generally of vertebrate prey. Because of their recent evolution and mode of catching and consuming prey either by ambush, subduing the basic morphology of most felids are remarkably related (Kitchner *et al.* 1999). Being expert stalkers they deliver a lethal killing bite along with specialized protractile claws for holding and pulling down struggling prey. Limbs are relatively long, with five digits on the fore and

four digits on the hind feet. The cheetah's *(Acinonyx jubatus)* claws, though partially protractile, are exposed at rest and the points blunted through contact with the ground acting as 'running spikes' providing traction for rapid acceleration in pursuit of prey. Perfectly adapted for dispatching prey and cutting flesh, felids are equipped with razor sharp teeth (28 to 30), shortened faces, roundish heads and wide zygomatic arches to accommodate large jaw muscles (Smithers 1983).

Apart from Australasia and Antartica, felidae inhabits all continents with diverse habitats such as boreal and tropical forests, savannahs, deserts, mangrove swamps including numerous islands. Thirty two species occur in closed forest and woodland habitats with the smaller tropical species being forest specialists (Nowell and Jackson 1996). Twenty-one species, almost 60% of all living felids, occur on the Asian continent, 14 of which are endemic there. Tropical and temperate Asian regions have the greatest number of cat species (12, with 10 found only in this biome), and Europe and the cold continental regions of Asia have seven species (with four found only here). Hot–dry south-west Asia also has seven species, all shared with Africa, although in south-west Asia, the lion *(Panthera leo)* and cheetah *(Acinonyx jubatus)* have only small relict populations, and the tiger *(Panthera tigris)* became extinct there decades ago. In Africa, the jungle cat *(Felis chaus)* occurs only in the vicinity of Egypt's Nile River. Africa has just three endemic species out of a total of ten. A few species have very large ranges spanning several continents. Leopard *(Panthera pardus)* are found from the Russian Far East and parts of Eurasia through tropical Asia, the Middle East, and throughout sub-Saharan Africa. The wildcat *(Felis silvestris)* is widely

distributed in Africa, Asia, and Europe (Macdonald *et al.* 2004). The puma *(Puma concolor)* ranges across both North and South America, although it was extirpated a century ago from most of eastern North America. In contrast, some felid species are highly specialized and confined to limited areas of habitat in just a few countries. The Andean cat (*Leopardus jacobita*) occurs only in association with rocky outcrops in the arid zones of the high Andes, typically above 4200 m, a specialist predator of chinchillids (*Lagidium* spp.). The Iberian lynx *(Lynx pardinus)* is similarly a specialized rabbit hunter and its distribution is limited by the distribution of its prey on the Iberian Peninsula, where disease has greatly reduced rabbit populations and there has been extensive habitat loss (Ferreras *et al.* 2001). Less than 10% of the felids range consists of designated Protected Areas making their conservation challenging, exposing them to anthropogenic threats and vulnerable to environmental or climate change (Nowell and Jackson 1996).

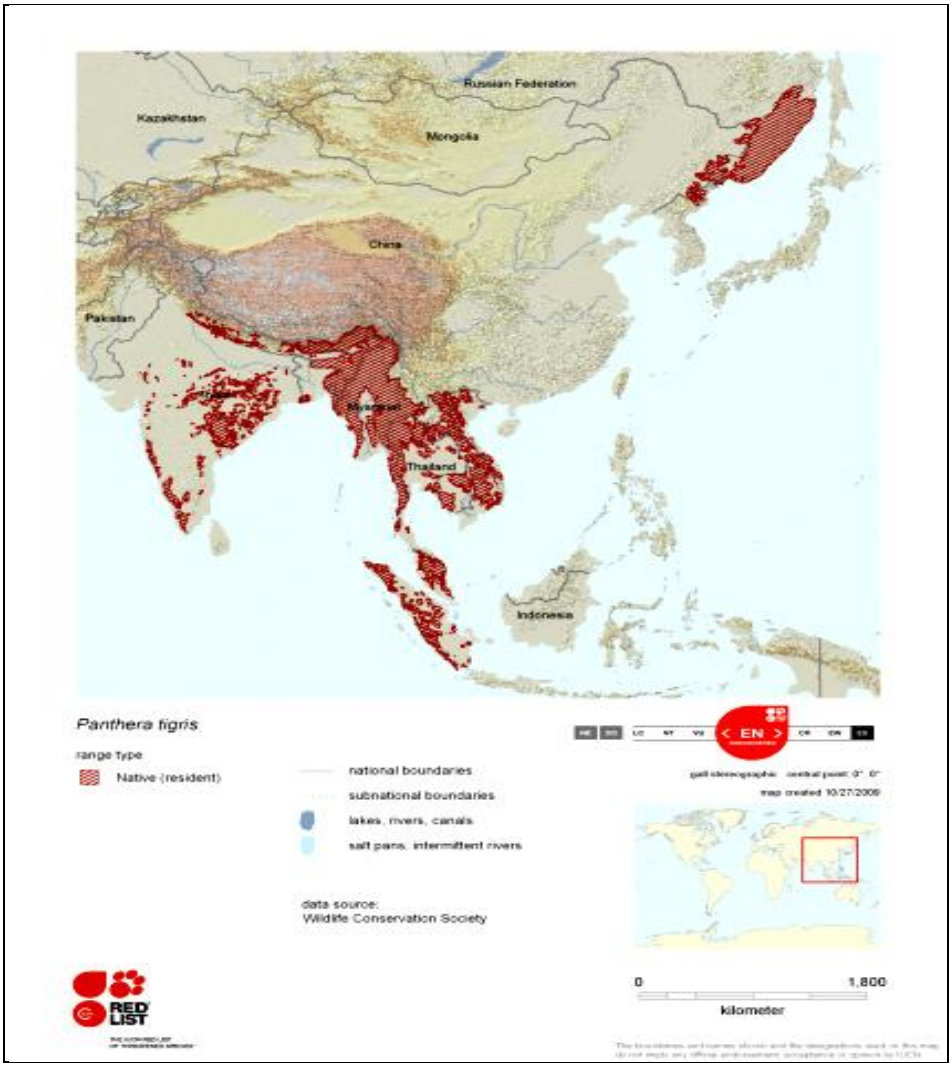
1.2. Tiger *(Panthera tigris)* (Linnaeus 1758)

1.2.1. Status and distribution

Six subspecies of tiger such as *Panthera tigris altaica* in the Russian Far East; *Panthera tigirs amoyensis* in South China (now possibly extinct in the wild; IUCN 2008); *Panthera tigris corbetti* in south-east Asia; *Panthera tigris sumatrae* on the Indonesian island of Sumatra; *Panthera tigris tigris* on the Indian subcontinent and *Panthera tigris jacksonii*, restricted to Peninsular Malaysia (Luo *et al.* 2004) are recognized today by genetic studies. Tigers have lost 93% of their historic

range, with local extinction from south-west and central Asia, two Indonesian islands (Bali and Java), large areas of south-east and eastern Asia over the past 100 years (Nowell and Jackson 1996, Sanderson *et al.* 2006) (Figure 1). There has been a 41% shrinkage in the current range of tigers compared to a decade ago the (1.1 million km²; Sanderson *et al.* 2006, Wikramanayake *et al.* 1998) which is primarily attributed to poaching and habitat loss (Dinerstein *et al.* 2007). Though recent improved and precise population estimation methods used to enumerate tiger populations are not comparable with past approaches to count tiger populations (Miquelle *et al.* 2007, Jhala *et al.* 2008), yet compared to previous estimates of 5000-7000 (Seidensticker *et al.* 1999) there are around 3500-5000 wild tiger surviving today (IUCN 2008). Sanderson *et al.* (2006) still considers 77% of current range to consist of 'known and secured breeding populations of tiger in areas large enough for a substantive population'. Tiger occurs along a diversity of habitat types from tropical, subtropical moist broadleaf forests (60%), temperate and broadleaf mixed forests (21%), tropical and subtropical dry broadleaf forests (10%) to (9%) coniferous, mangrove and tropical grass, shrub lands (Sanderson *et al.* 2006). They have even been recorded at 4500 m elevation in the eastern Himalayas of Bhutan (Wang 2008).

Figure 1. GLOBAL Distribution of Tiger (Wildlife Conservation Society, IUCN Map RED LIST).



1.2.2. Biology of tiger

A large ungulate prey base is essential to sustain tigers though they are reported to kill prey as large as adult Asian rhinos, water buffaloes and elephants (Sunquist *et al.* 1999, 2000). On an average tigers eat 18-27 kg of food in a single feeding session as reported by studies from Kanha and Royal Chitwan

National Park (Schaller 1967, McDougal 1977). Females spent 3 days with large kills in Chitwan National Park (Sunquist 1981). Tigers need to kill at least 50 medium sized prey with a mean body weight of 50 kg per year to sustain themselves (Karanth *et al.* 2004). Being solitary predators, they are highly territorial exclusively defending their core areas of activity with male home ranges encompassing one to three females. Female home ranges seldom overlap showing intensive intraspecific competition for resources (Sunquist and Sunquist 2002). Home ranges are proportional to the abundance of prey with the smallest reported from alluvial grasslands of India and Nepal (15-20 km²) (Smith *et al.* 1987, Karanth 1993) to 500-1400 km² in the Russia Far East (Goodrich *et al.* 2008). Tigers reach their highest densities in the alluvial grasslands of Corbett and Kaziranga Tiger Reserve in India (Jhala *et al.* 2010) to as low as 0.13–0.45/100 km^2 as in Russia's Sikhote Alin Mountains where prey is more thinly distributed (Nowell and Jackson 1996).

1.2.3. Threats

Prey base holds the key to tiger conservation today being threatened with hunting pressure from humans and competition from livestock. Existing in pockets of wilderness surrounded by seas of humanity, tigers compete with humans for resources. This often leads to livestock depredation and occasional fatal attacks claiming human lives. Thus retaliatory killings take place resulting in negative perception towards tigers. Apart from human-tiger conflict, another eminent threat to tigers is organized commercial poaching for skin and bones

used in traditional Chinese medicine. In 1993 China banned trade in tiger parts, but recent proposal to farm tigers in captivity for making wine out of tiger bones have surfaced as a matter of grave concern. Five thousand tigers are supposedly alive in captivity, and tiger farming threatens to re-ignite consumer demand (Nowell and Xu 2007; Nowell 2009). In 2007, CITES enacted a decision stating that 'tigers should not be bred for trade in their parts and derivatives' (Nowell *et al.* 2007). Tiger is classified as endangered according to the present status of IUCN Red List category (IUCN 2011) and listed in Schedule – I of Indian Wildlife Protection Act 1972.

1.2.4. Present status of tigers in India and Sundarban

Tiger Occupied forests in India have been classified into six landscape complexes, namely a) Shivali -Gangetic Plains b) Central India Landscape Complex c) Eastern Ghats d) Western Ghats e) North-Eastern Hills and Bhramaputra Plains and f) Sundarban (Jhala *et al*. 2010). Tiger populations within these landscape complexes were contiguous during the recent past sharing a common gene pool. Each landscape complex consists of landscape units having contiguous tiger habitat with source population of tigers. Thus each of these units has a potential to manage some of the tiger populations as meta-populations, enhancing the conservation potential of single populations and their long-term persistence. The Sundarban Landscape Complex is the smallest isolated landscape with a single tiger population across India and Bangladesh with tiger occupancy of 1,645 km² on the Indian side assessed in 2010. Tiger

population was estimated to be around 64-90 using a combination of mark-recapture based camera trapping and satellite telemetry on the Indian side (Jhala *et al.* 2010).

1.3. Human-animal conflict

Increasing human population and the associated increase in rates of resource use and habitat loss worldwide are, in many areas, forcing wildlife to live in increasing proximity to humans. In such circumstances competition arises between wildlife and people for space and food resources, often leading to human-wildlife conflict (Conover 2002, IUCN 2003, Madden 2004). We define human-wildlife conflict as the situation that arises when behavior of a non-pest, wild animal species poses a direct and recurring threat to the livelihood or safety of a person or a community and, in response, persecution of the species ensues. Human-wildlife conflicts most commonly involve damage to crops or killing of livestock or game, and occasionally involve attacks on people. They are of particular concern when the animal persecuted in retaliation for these events is a threatened species. Carnivores are particularly predisposed to conflict with humans because of their large home ranges and dietary requirements (Linnell *et al.* 2001, Macdonald and Sillero-Zubiri 2002). Human-carnivore conflict appears to be increasing in frequency in many areas (Treves and Karanth 2003), presenting a significant threat to many carnivore species, including many threatened species of wild felids. Human attitudes towards carnivores tend to be shaped by understanding and knowledge of a particular species, as well as by

past and present interactions with that species (Kellert *et al.* 1996). Where large carnivores prey upon livestock, local people often hold negative attitudes, as reported for snow leopards (*Panthera uncia*) by Oli *et al.*(1994) and wolves (*Canis lupus*) by Lenihan (1996). To assess the perceptions towards large cats, surveys of local people have been used as tools to gather information about human-cat interactions (Oli *et al.* 1994). Such studies also have been used as a basis for long-term strategies for conserving large cats and their habitats (Nyhus *et al.* 1999).

1.3.1. Human-felid conflict

Human-felid conflict typically occurs when wild cats prey on livestock or game, or even attack people, and the people affected respond by killing or harming felids, either in retaliation or as a preventative measure. Carnivores are particularly susceptible to damaging effects of incidental mortality caused by humans outside of Protected Areas because of specific behavioral and ecological characteristics, such as their trophic position, low population densities, and ranging over large distances (Sillero-Zubiri and Laurenson 2001). The type of land bordering a protected area largely influences the level of conflict with humans. When a park is adjacent to farmland or communally owned tribal land, where livestock husbandry is often the main source of income, predators are rarely accepted but perceived as a threat and associated with large financial costs (Mishra 1997, Butler 2000, Patterson *et al.* 2004, Frank *et al.* 2005).

Predator-livestock conflicts exist on most continents and involve nearly every large carnivore species, making it an issue of global conservation concern (Berger 1998, Bekoff 2001, Sillero-Zubiri and Laurenson 2001). Meier *et al.* (2010) analyzed Problem Animal Control Registers from the Kweneng District of Botswana to assess the impact of native predators on livestock over three years. Leopards and lions caused 64% of the livestock losses. Leopard-livestock predation mainly affected calves and was consistent over the district and over time. In contrast, lion predation on adult cattle was characterized by local hot spots close to reserve borders and decreased with increasing distance to a reserve.

Patterson *et al*. (2004) studied lion depredations on livestock over a four-year period on two neighboring arid-land ranches adjoining Tsavo East National Park, Kenya. A total of 312 attacks claiming 433 head of stock were examined. Lions were responsible for 85.9% of the attacks, hyenas and cheetahs were the other predators responsible. Lions and hyenas attacked mainly cattle at night, whereas cheetahs almost exclusively took smaller sheep and goats. Both, number of attacks and number of stock killed showed significant seasonal differences and their monthly totals correlated positively with precipitation. Intensified predation in the wet season differed from patterns of lion predation elsewhere, but reinforced the pattern that large carnivores take more livestock when native prey are most difficult to find and kill. On an average, wildlife attacks claimed 2.4% of range stock annually, and livestock represented ca. 5.8% of the diet of ranch lions. This predation represented 2.6% of the herds' estimated economic value, and cost the

ranch $8749 per annum. Each lion cost ranchers approximately $290 per year in depredations.

1.3.2. Human-tiger conflict

Balancing the goals of human development and wildlife conservation are a challenge especially when dealing with large carnivores like tigers. In reality conflict is a rarity even among people staying near tiger occupied landscapes across vast tracts of Asia. But even those rare events are scary and tragic for people in a way that habitat degradation and poaching are not. Often this leads to pessimistic views on tiger conservation and political pressure accumulates to eliminate them for instant benefits to the people. Being solitary hunters they rely on ambush or stalk and surprise prey, livestock and people and adapt themselves to survive in close proximity of human habitations (Sunquist 2002). Certain life stages, ecological, behavioral or geographic circumstances aggravate the risk of tigers attacking humans and livestock, but they tend to be chance events and not a repetitive phenomenon (McDougal 1987).

1.3.3. Characteristics of tigers that Influence conflict

Depletion of prey or inability to hunt prey effectively, hunger, old age, illness or injury, learned behavior from individual experience or from parents, older former residents that are no longer able defend a home range, and lack of aversion due to limited or ineffective retaliation are some of the frequent well documented reasons cited for human-tiger conflicts (Nowell and Jackson 1996). Dispersal phenomenon in sub-adult males, transients moving into sub-optimal habitats are

prone to conflict with humans and livestock compared to resident tigers in core areas (Sunquist 2002). Detailed studies from Russia with intriguing facts of 120 incidents over the past 20 years identified four behavioral patterns in tiger interacting with humans. Majority (80%) of cases involved tiger holding their ground when confronting humans and finally backing off and 12% cases with tiger escaping instantaneously when fired upon or scared away with loud sounds. The rest 4% cases occurred when tiger behaved aggressively particularly females with cubs or confronted by hunting dogs and actually attacked people being provoked. Fatal attacks claiming human lives are generally unprovoked with victims being attacked on the head and shoulders from the rear or side (Miquelle *et al.* 2005). Miquelle *et al.* (2005) also concluded that 80% of tiger deaths prior to 1990's were result of human-caused mortality due to revenge killing or self defense in the Russian Far East. Tiger are known to scavenge on human carcasses as reported from Bangladesh, Burma, India, Indonesia, Vietnam and other locations (Gurung *et al.* 2008, Jackson 1985, Khramstov 1995).

1.3.4. Characteristics of landscapes that Influence conflict

Over the past century, rapid encroachment and habitat loss has lead to loss of areas where tiger-human conflict could have taken place. Tiger-human conflict zone in India might be less than even 1% of the geographical area of the country (Woodroffe *et al.* 2005). Historically places with abundant prey was negatively correlated with intensity of conflict, whereas present day conflict intensifies along

peripheral edges of protected areas or areas where people are dependent on forest based resources (McDougal 1977). In multiple-use forests in India, where prey populations are low, Madhusudan *et al.* (2003) estimated that tigers and other large carnivores annually kill 12% of livestock herds. In the Russian Far East, where livestock are less common, depredation rates of livestock probably do not exceed 100 animals per year (Woodroffe *et al.* 2005). In Sumatra, tiger attacks on humans were most likely to occur while people were engaged in activities near forest edges, particularly with agriculture and estate crops and in areas with high or intermediate levels of disturbance (Nyhus *et al.* 2004). Studies from Way Kambas NP in Sumatra reveals high prey density and avoidance of people kept tiger inside the park; fear of the forest and guards kept the majority of villagers out of the core of the park in spite of 60% of the park boundary area overlapping with human settlements resulting in low levels of conflict (Nyhus *et al*. 2004).

1.3.5. Eliminating problem tigers and tigers as a problem worldwide

Across many areas of Asia fear and admiration for tiger historically resulted in a‘balance of power’ (Bakels 1993) where people and tigers lived and killed in relationships ordered by spirits, myths, and rituals (Bakels 1993, McNeely 1988, Provencher 1986). A wide variety of local traditional beliefs evolved to explain conflict, tigers killed people because someone was wicked, or people killed tigers because the animal itself had sinned. Specialists like the *pawang harimau* (tiger

shaman) of Sumatra could speak to tiger and forest spirits (McNeely 1988). Tiger were regarded as grand, valiant, and noble, but also savage and fierce and the ultimate symbol of strength. The Javanese believed that a person being born just before sunup or sundown is destined to be killed by a tiger, while among the Batak of north Sumatra a person's soul could choose to be devoured by a tiger before birth (Provencher 1986). Being surrounded by tiger occupied forests the diverse cultural and livelihood strategies were means of coping with frequent attacks and injuries. However, over time this 'balance' shifted. With rising human populations, conflict between communities and tiger escalated, people eradicated tiger and their food and habitat, confining them to isolated or remnant forests across much of Asia.

The deliberate elimination of tiger and habitat became viable when human population densities, economic activities, and technology made habitat alteration and effective hunting possible. Records of human-tiger conflict peaked in China during the mid-1500s to 1800s when vast tracts of forests were cleared and settled by waves of migrants (Coggins 2003). At the same time, far to the west, the Roman Emperor Augustus organized shows between tigers and people to entertain the public (Hughes 2003). Written accounts of tiger attacks were common across Asia by the seventeenth century and the Governor-General of the Dutch East India Company reported in 1625 that tigers killed more of his people than the enemy (Boomgaard 2001). Conflict peaked in the eighteenth and nineteenth centuries in many areas of Asia, and records of tiger attacks were

kept in many countries and regions, including parts of India, China, and Indonesia. Many old British tombstones in India bear the testimony of these as in words ‘Died of injuries received from a tiger’ (Jackson 1985). J.H. Moor, an editor from Singapore, reported from a trip from Bali in 1837 that ‘the hills abound with tigers, particularly in the western part of the island, which makes traveling alone dangerous’ (Moor 1837).

Conflict between tiger and people was significantly high in areas where they co-existed. Man-eating was a serious and persistent problem in some areas like South China, Singapore and Manchuria (Tilson *et al.* 1987). Though attacks on humans were publicized, livestock depredation continued and received no public attention. In 1822 in Khandesh District of the Bombay Residency, 550 people were killed but 20,000 head of cattle were estimated killed by carnivores, mainly tiger (Gouldsbury 1915). These stories and reports continued well into the twentieth century when detailed accounts of man-eating tigers were provided by the legendary hunter Colonel Jim Corbett from Northern India (Corbett 1944). Tiger were also eliminated by the hundreds and thousands for sport. Large hunting expeditions comprising of thousands of people were organized by Mughal emperors (Burton 1931). With the advent of firearms it escalated, with British accounts suggesting tiger-shooting as ‘the most exciting and glorious sport this world affords’ (McDougal 1977). An estimated 80,000 tiger were killed in India between 1875 and 1925 (Woodroffe 2005), in Indonesia between 1910 and 1940 the ‘fanatical tiger hunter’ A.J.M. Ledeboer tried to kill as many Javan

tiger as possible, reportedly in part to beat the record set by a tiger hunter on Sumatra, who killed over 100 (Hoogerwerf 1970).

Tiger have been responsible for claiming more lives than any other large carnivores over the span of the twentieth century (Loe 2004). Tiger extinction accelerated with huge chunks of forests being cleared for agriculture and availability of modernized weapons and poisons to eradicate their population. Small islands like Bali and Java were packed with too many people and too few forests, prey to support tiger. The Bali tiger disappeared by the mid-1900s and the last Javan tiger was shot in the 1980s (Seidensticker *et al.* 1987). The Caspian tiger suffered similar fate being effectively eliminated sometime in the mid-twentieth century after eradication campaigns, cultivation of habitat and fires, and retaliation for conflict in parts of the former Soviet Union, Iran, Turkey, Afghanistan, and China (Nowell and Jackson 1996). Tiger tracks were reported in the Tigrovaya Balka Nature Reserve in Tajikistan in the 1950s (Sokolov *et al.* 1990) and the last known Caspian tiger in Iran was shot in 1959 (Tilson *et al.* 1987). However, unconfirmed reports of possible tracks and sightings continued for years, including reported tiger sightings in south Uzbekistan during the Afghan War in 1989–1990 (Sievers 1995, 1997). Official eradication campaigns promoted by Mao Zedong in 1990s led to extinction of the South China tiger from the wild (Tilson 2004).

1.3.6. Human-tiger conflict in Sundarban

Tigers are believed to have killed 1,000,000 Asians, or about 2,500 people annually, or 25 people/1,000 tigers in the past four centuries (Matthiessen 2000). Unlike other tiger populations, tigers of Sundarban are held responsible for a considerable number of human deaths annually (Montgomery 1995, Karanth 2000). Man-eating has emerged as one of the most imperative issues facing the conservation of tigers in the Sundarban (Sunquist and Sunquist 2002). Man-eating as reported from other parts of the tiger's distribution range is primarily an outcome of old age or injury, making tigers incapable of catching wild prey, though the scenario here reveals animals in their prime to predate on humans (Mountfort 1969, Nowell and Jackson 1996). The Sundarban of Bangladesh and India is home to some of the highest level of tiger-human conflict in the world (Blanford 1891, Siddiqui and Choudhury 1987, Chakrabarti 1992), probably because many people are dependent on the natural resources of the Sundarban. This high level of human activity does not create a suitable habitat situation for tigers (Griffith and van Schaik 1993). Man-eating tigers have been well-known in the Sundarban since at least the 17th century (Bernier 1670, Rahman 1992). Blanford (1891) notes the death of 4,218 people due to tiger attacks over a six-year period from 1860 to 1866 in the forests of the Sundarban (Bangladesh and Indian Sundarban). Meumann-Denzau (2006) hypothesized that large number of human deaths by snake bites eventually landing up in the Sundarban, might have habituated tiger to consume human carcasses.

1.4. Previous ecological research on tiger in the Sundarban

Though several studies have been conducted in this region to study structure and composition of mangroves (Prain 1903, Champion 1936), dependence of local communities on such systems (Naskar, Guha and Bakshi 1987), pollutant levels (Sarkar 2002, Guzzella *et al.* 2005) effects of climate change and sea level on Sundarban (Naskar, Guha and Bakshi 1987, Mukherjee 2002, Hazra 2002) and geology of the area (Bhattacharya 1999), (in Sen and Naskar 2003), yet few studies have been conducted on ecology of tiger and their prey in the Indian Sundarban.

Studies have been conducted on the Bangladesh side of Sundarban regarding tiger and prey. Hubert Hendrichs conducted a three month study in 1971 to identify reasons for man-eating by Sundarban tiger. The initial data collected indicated an association between man-eating behavior amongst tiger and increasing salinity levels, though the project was not completed. The Bangladesh Wildlife Department from a funding by Save the Tiger Fund and the US Fish and Wildlife Service initiated a long term study on tiger ecology and prey availability in February 2005. Another study to asses prey density was conducted in this landscape by Reza *et al.* (2002). However, the most important contribution to information on tiger ecology in this region is an outcome of studies conducted by Khan (2002-2005) and Adam Barlow (2005-2009) in Bangladesh Sundarban. This included monitoring tiger populations in mangrove landscapes (Khan 2004, Barlow *et al.* 2008), designing conservation framework to reduce human-tiger

conflict (Barlow *et al.* 2010) and studying the impact of sea-level rise on Sundarban (Loucks *et al.* 2010).

However, on the Indian side, while several books have been published on this region and man-eating tiger, scientific studies on the tiger are lacking. The inaccessible terrain and the ever present threat from man-eating tigers, makes Sundarban academically and physically challenging to take up rigorous scientific research. The first effort to assess tiger and their prey numbers in this region using reliable scientific methods was made by Karanth and Nichols in mid 1990s, followed by a more recent attempt at understanding tiger ecology using radio-telemetry by Jhala *et al.* (2010).

1.5. Justification of study

Sundarban is designated as a tiger conservation unit (TCU) of level 1 importance and the only one in a mangrove habitat (Dinerstein *et al.* 1997). Very limited information is available on the ecology of tiger inhabiting this area or what measures can be adopted for its long term persistence in this mangrove ecosystem. Studies conducted by Barlow *et al.* (2009) revealed tigers here to be one of the smallest across the entire distribution range. Though not yet diverging into a new subspecies, this population is definitely a distinct ecological unit isolated from other tiger populations exemplifying the evolutionary significance. Through this study I provided information on seasonal home ranges, ranging pattern of tigers in mangrove habitat of the Indian Sundarban.

Improved understanding of the present scale of livestock depredation, human mortality caused by tiger is required for managers to assess the importance of this issue relative to other tiger conservation issues. This study highlights spatial and temporal trends, geographical areas where management intervention is required to mitigate conflict. Equally, without understanding the socio-economic context, which is often the underlying cause of many of the threats, little headway will be made in the development of long-lasting solutions. This information is lacking for most tiger landscapes, and the Sundarban is no exception (Sanderson *et al.* 2006). Support of local people is critical to tiger conservation in human dominated landscape, especially in areas where conflict between the two is significantly high. Thus perception of local people towards tiger and tiger conservation generated thorough this study is crucial in the management and long term protection of tiger.

1.6. Objectives of the Study

1. To study ranging pattern and habitat use of tiger.

2. To quantify livestock losses by tiger predation and identify spatio-temporal patterns in conflict in and around the Tiger Reserve.

3. To document and quantify the geographic distribution of tiger-human incidents and

4. To evaluate the perception and level of tolerance of people living in the vicinity of Tiger Reserve.

1.7. Study Period

The study was conducted from February 2010 to December 2013, covering two seasons annually, i.e summer (January to June) and winter (September to December).

1.8. Organization of the thesis

The thesis is structured into four chapters, each chapter consisting of an introduction of the topic, elaboration of methods and analysis used, results arrived at and discussion of the results and comparisons with earlier studies.

Chapter 1- INTRODUCTION: discusses the ecological aspects of felids, conservation status at the global scale with particular reference to tiger, distribution, threats and present status in India and Sundarban. Additionally it covers major aspects of historic and present status of human-tiger conflict worldwide and in India emphasizing on the past and present scenario in Sundarban.

Chapter 2- STUDY AREA: illustrates the study landscape and provides relevant information about the geography, geology, climate, hydrology, ecological features and socio-economic background of the entire landscape.

Chapter 3- TIGER RANGING PATTERN and HABITAT USE: deals with ranging pattern and movement, habitat use and resource selection by tiger in mangroves highlighting their significance in the context of mitigating conflicts.

Chapter 4- HUMAN-TIGER CONFLICT IN SUNDARBAN: assesses the past and present trends of human mortality by tiger, quantify livestock depredation across peripheral villages, and identifies spatio-temporal patterns of tiger attacks on humans and major drivers of conflict.

Chapter 5- PEOPLE'S PERCETION TOWARDS TIGER: Assesses major drivers influencing perception towards tiger in Sundarban, socio-economics of local people and quantifies dependence of local people on forests.

Chapter 6- CONSERVATION IMPLICATIONS: Highlights the major drivers of human-tiger conflict and provides recommendations for improved conservation of tigers and suggests mitigation measures.

CHAPTER 2
STUDY AREA

2. Introduction

Sundarban is the world's largest contiguous mangrove forest created at the confluence of the deltas of Rivers Brahmaputra, Ganga and Meghna. The delta spreads across the countries of India and Bangladesh covering 80,000 km^2 (Chakrabarti 1992) with 38% of it in India and the remaining in Bangladesh (Mitra 2000). It comprises of mudflats, creeks, tidal channels and an archipelago of about 102 islands of which 54 are inhabited by human population (Bera and Sahay 2010).

To the north of Sundarban are the Himalayas, Rajmahal hills to the west and the Meghalaya plateau and Chittagong hills to the east (Chakrabarti 1992). Geologically this area was carved out in recent times by tidal action and silt deposition and is still under formation. As a result of neotectonic changes the Bengal basin has been tilting eastwards resulting in changes in the flow of River Ganga and subsequently the structure of this vast delta.

The mangrove forests of Sundarban are considered an important barrier to the frequent cyclones emerging from the Bay of Bengal. Some of these can be of intense nature like the cyclone of 1585 which killed about 2,00,000 people while another one in 1688 that killed 60,000 people on the island of Sagar alone (Chakrabarti 1992). The conservation of these mangroves thus becomes essential for not just biodiversity of the region but also as a barrier to reduce the impact of such cyclones which could affect the lives of people living onshore.

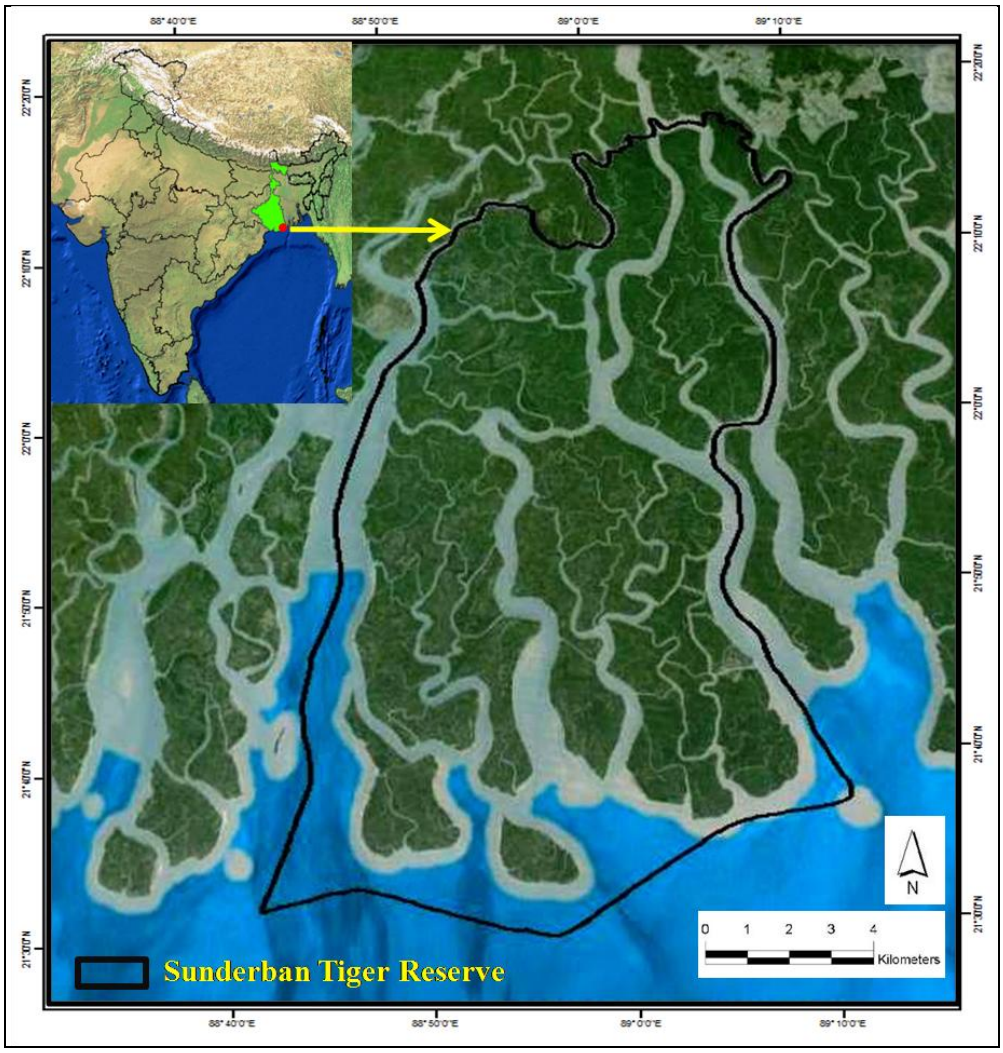
2.1. Location

The Indian part of Sundarban covers about 4,266 km^2 (Sen and Naskar 2003) in the 24 Parganas district of West Bengal, with parts of the region submerged under water. It lies in the biogeographic zone 'Coasts' in the province of 'East Coast' as per Rodgers and Panwar's (1988) Biogeographic classification (Figure 2).

The Protected Area of Sundarban comprises of 2,585 km^2 with a unique ecosystem of which 1,330 km^2 has been designated as the core zone of the Sundarban National Park. River Vidya Malta divides the forest into two Ranges, the western Namkhana Range and the eastern Bashirhat Range (Plate 2.1). The salinity levels vary spatially and temporally in this region with the westward Namkhana area having higher salinity compared to the Bashirhat Range (Chakrabarti 1992). This in turn affects the structure and composition of the flora and fauna in these areas.

The human population density of this region is amongst the highest in the country with 1437.4 persons/ km^2 (Qureshi *et al.* 2006) making biodiversity conservation a challenge, although the Tiger Reserve is free of human settlements.

Figure 2. Map showing the location of Sundarban Tiger Reserve.



2.2. Hydrology

The landscape is characterized by a web of tidal water systems (Plate 2.2). The average tidal amplitude is between 3.5 and 5 meters, with the highest amplitudes in July-August and the lowest in December-January. Of the eight rivers that drain the landscape only the Hugli and Ichamati-Raimangal carry freshwater flow of some significance. Being the moribund part of the lower delta plain of the GBM

system, the Indian Sundarban is experiencing both declining freshwater supplies and net erosion as has been recorded since 1969 (Hazra *et al.* 2002, Hazra 2010).

2.3. Climate

The climate of the region is tropical with high relative humidity between 70 and 88 percent. The mean maximum temperature is 34°C during June and the mean minimum temperature is 11°C during January. Although the region experiences occasional rains through most of the year barring January and February (Chaudhuri and Choudhury 1994), the monsoon period, which occurs between June and October accounts for about 80 percent of the annual precipitation. The Indian Sundarban is prone to extreme storm events which are frequent during the pre-monsoon period, and from September through November. Historical records indicate a high frequency of extreme weather events, such as severe storms or cyclones. There are three aquifer zones here, the shallower one occurs within 60 meter below ground level (bgl) which is mostly brackish. The second zone occurring between 70 and 160 meter (bgl) is also brackish. The third aquifer zone, fresh in nature (sweet water), occurs in the 160 meter to 400 meter zone. The saline water aquifers at the top are separated from the underlying freshwater group of aquifers by a thick clay layer varying in thickness from 4 meter at Gangasagar to 120 meter at Kultali, the general thickness of the intervening clay blanket is between 20 and 50 meter (Sinha Ray 2010).

A pronounced ecological change is evolving in this delta due to huge discharges of untreated domestic and industrial effluents carried by tributary rivers as well as the disposal of contaminated mud from harbour dredging and resulting from the rapid emergence of the Haldia Port Complex, a major oil disembarkment terminal in eastern India. The Sundarban delta has become susceptible to chemical pollutants such as heavy metals, organochlorine pesticides, polychlorinated biphenyls and polycyclic aromatic hydrocarbons which may have changed the estuary's geochemistry and affected the local coastal environment (Sarkar *et al*. 2007, Guzzella *et al*. 2005, Binelli *et al*. 2007). Due to a diversity of inputs such as agricultural runoffs, wastewater and sewage discharges, and agricultural wastes, maximum concentrations of organochlorine pesticide residues were recorded at sites located along the main stream of the Hugli (Ganges) estuary. Among the hexachlorocyclohexane isomers (HCHs) and dichlorodiphenyltrichloroethane i.e. DDTs, β-HCH and DDE predominate. From an eco-toxicological point of view, the impacts of DDT and HCH are much pronounced.

2.4. Conservation Significance

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) in 1987 placed the Indian Sundarban on the World Heritage List for it being an outstanding example of ecological and biological processes in evolution and development of coastal communities of plants and animals and for the

importance of this region for biodiversity conservation. A decade later the Bangladesh part of Sundarban was also added to the same list.

With respect to the tiger, this area is a Tiger Conservation Unit (TCU) of level 1 importance and the only one in a mangrove habitat (Dinerstein *et al.* 1997). However, Sundarban tiger of India and Bangladesh form a single population which is isolated from other tiger populations.

2.5. Vegetation

The vegetation of this region is structured by several factors which include salinity levels, soil composition and structure, silt deposition rates and rates of humus formation. This area is the most important tidal forest in India with about around 35 mangrove species and 117 other halophytic mangrove associates (Qureshi *et al.* 2006). Altogether, about 350 vascular plant species belonging to 254 genera are found here (Chakrabarti 1992). Most plants have unique adaptations like pneumatophores to breath and viviparous germination. Species like *Ceriops*, *Sonneratia apetala*, *Xylocarpus*, *Hertiera*, *Lumnitzera*, *Excoecaria* and *Avicennia* have pnematophores while vivipary is found in *Rhizophora*, *Bruguiera*, *Ceriops*, *Kandelia* (Chaudhuri and Chakrabarti 1989). The dominant plant families of the region are Rhizophoraceae, Verbenaceae and Sonneratiaceae.

Champion and Seth (1968) describe five vegetation types from this region: mangrove scrub, mangrove forest, saltwater mixed forest (*Heritiera*), brackish water mixed forest (*Heritiera*) and palm swamp. Low mangrove areas have

species like *Ceriops*, *Avicennia*, *Excoecaria agallocha*, *Kandelia candel*, *Bruguiera cylindrica*, *Rhizophora sp.*, *Sonneratia sp.*, *Tamarix sp.*, *Aegilops spp.*, while tree mangrove forests have primarily *Rhizophora sp.*, *Sonneratia sp.*, *Bruguiera sp.*, *Xylocarpus sp.*, and *Kandelia candel* (Chaudhuri and Chakrabarti 1989). Saltwater Heritiera forests mainly have *Ceriops*, *Heritiera fomes*, *Excoecaria agallocha* while fresh water Heritiera forests are dominated by *Heritiera* and *Xylocarpus*. On river islands and fresh silt, *Oryza coarctata* is a dominant herbaceous species. Poor soils have species like *Aegialitis rotundifolia* and *Acanthus Ilicifolius* while common palm species are *Phoenix paludosa* and *Nepa sp.*. *Heritiera fomes* or 'Sundari' is the most dominant species in the eastern region and thus gives the name 'Sundarban' to this landscape.

2.6. Fauna

A mixture of fresh and salt water along with the spatial and temporal variations in water levels due to tidal action produce a unique environment for life in this zone with most species being amphibious or aquatic in nature. While estimates of species diversity vary, this region has about 165 species of fish (Dinda 2010), around 163 species of birds (Sen and Naskar 2003), 23 species of molluscs (Dinda 2010), 56 species of reptiles (Dinda 2010), amphibians, phytoplankton, benthic invertebrates and zooplankton. Mangroves provide most of the organic matter on which many of these aquatic species survive, bulk of which comprises of crustaceans (crabs, lobsters, shrimps and prawns). Some *Periophthalmus* and *Boleophthalmus* (mud-skippers) species in the region are also adapted to

climbing trees in order to deal with the fluctuating water levels (Chakrabarti 1992).

Amongst the larger fauna, estuarine crocodile (*Crocodylus porosus*), water monitor (*Varanus salvator*), and three species of terrapin and turtles: northern river terrapin (*Batagur baska*), softshell turtle (*Pelochelys bibroni*), green sea turtle (*Chelonia mydas*), along with the Irrawaddy (*Orcaella brevirostris*) and Gangetic dolphins (*Platanista gangetica gangetica*) are rare and endangered.

However, the flagship of the Sundarban is the tiger (*Panthera tigris*). This is the only such habitat in which tigers are known to survive and lead a more amphibious life than their counterparts in other parts of the world. The tiger is an integral part of Sundarban and partly responsible for the great publicity obtained by this area for two reasons, first, the highest concentration of tigers in the world was believed to exist here and second, for the highest concentration of man-eating tigers in the world. While the former claim is under scientific deliberation, the latter remains a mystery. Local legends mention that about 100 years ago 4,218 people were eaten by tigers in just six years (Montgomery 2008) while historical records indicate that 800 human lives were lost in a span of 20 years in the undivided Sundarban (Chakrabarti 1992). More recent estimates proclaim that on an average 36 lives are lost to tigers on the Indian side of Sundarban each year with only 28.5% of bodies recovered (Chakrabarti 1992). The intensity of human lives lost to tigers is further reiterated through the existence of ‘vaidaba pallis’ or tiger widow villages where every woman in the village has lost a son, father or husband to tigers (Montgomery 2008). Thus, local belief is that the

“unofficial” figures of those killed by tigers can be far higher than the official figures provided by the administration as all deaths are not reported (Montgomery 2008). It is the existence of the tiger that has greatly influenced the local culture of the area with people wearing double faced masks and worshipping deities such as Dakshin Ray, Bara Thakur (Mundu) and Bon Bibi for protection from the tiger and other forest animals.

While mangrove habitats are amongst the most productive ecosystems, most of the productivity is confined to aquatic systems with terrestrial species being low in numbers. Thus, the ability of this region to sustain large mammals is restricted. The main prey of tiger in the region comprises of chital (*Axis axis*), wild pig (*Sus scrofa*) and Rhesus macaque (*Macaca mulatta*) and lesser adjutant (*Leptoptilos javanicus*) (Khan 2008). Most other native fauna of the region which included Javan rhinoceros (*Rhinoceros sondaicus*), swamp deer (*Rucervus duvaucelii*), water buffalo (*Bubalus bubalis*), gaur (*Bos gauras*) and hog deer (*Axis porcinus*) are now extinct from this area (Chakrabarti 1992). The marsh crocodile (*Crocodilus palustris*) also no longer exists in this region.

2.7. Human Colonization and Socio Economic Profile

The Indian Sundarban comprises of 19 community development blocks, with an estimated population of 4.1 million people (Census of India 2001). Forty four percent of the population comprises of schedule caste and tribes, with 85% dependent on agriculture. Other major occupations of the region are fishing, pisciculture, wood cutting and honey collection. The literacy level and per capita

income are significantly below the state average with majority of the people below the poverty line. Human colonisation of this region happened relatively late due to the inhospitable conditions though some people did occupy the area even in 6th century (Chakrabarti 1992).

Present day district of the 24 Parganas was ceded to the East India Company as part of the treaty of 1737 and thereafter became the jagir of Lord Clive (Chaudhuri and Chakrabarti 1989). However, it was only in 1770 that serious efforts were made to reclaim land in this area for agriculture by Claude Russel, the then Collector-General of the district (Bera and Sahay 2010). By 1878-79, 4856 km^2 of this area was designated a Reserved Forest (Bera and Sahay 2010). In 1903, Sir Daniel Mackinnon Hamilton, a Scotsman, bought 40 km^2 of land which included the islands of Rangabelia, Satjelia and Gosaba where he established religious centres, dispensaries and co-operative societies for tribals from the Chotta Nagpur region belonging to tribes like the Bhumij and the Mundas (Chakrabarti 1992, Bera *et al.* 2010).

In 1978, many partition refugees from Bangladesh escaped from the Dandakaranya government resettlement camp in central India and decided to establish themselves at Marichjhanpi in Sundarban, an area that was until then free of human presence and categorised as a Reserved Forest. This act led to violent clashes between the new settlers and the ruling government and resulted in mass deaths, brutality and disease in the region (Ghosh 2004). Socioeconomic profile is not uniform throughout the landscape. This differentiation is due to geographical characteristics, population composition and their background,

access to different sets of resources and subsequent occupational specialization, and the non-uniform pace of socio-economic transformation through the region. The main economic activity in the Sundarban, rain-fed paddy agriculture, is made possible by the construction of earthen embankments to keep brackish tidal water at bay. Historically, in the Sundarban salt-tolerant paddy varieties such as Matla and Hamilton could be cultivated on raised sections of the islands without embankments. However, while searching for the six locally recalled salt-tolerant farmers' paddy varieties, NBPGR informed availability of only two varieties; others developed over centuries are believed to have been lost under the onslaught of “green revolution”.

Poor access to energy services and the consequent lack of opportunities is further compounded by very high population density and poverty, an extremely high proportion of the population (about 34 percent) subsists below the poverty line. This is accompanied by a high dependence on the natural system for biomass and other terrestrial and aquatic resources leading to further degradation of the natural ecosystem. The population as we see it today in the Sundarban is mainly the result of immigration from neighbouring areas. Sections of the population represent first generation immigrants from other areas such as the East Midnapore district in West Bengal and parts of what is now Bangladesh, adjoining the Sundarban. The others are descendants of settlers who arrived during the days of colonial administration. There are two distinct categories apparent among the past settlers. One group came here in search of new opportunities as the frontier was being opened up, while the other group came to

escape oppression in their places of origin. A further category consists of a small group of people of tribal origin from Chotanagpur plateau who were brought to clear forest. This group has remained on the margins of society, and quite literally on the margins of the islands. As of now, the population is more or less evenly balanced between the two major religions, Hinduism and Islam. The two main religious communities have existed side by side in relative harmony for generations largely thanks to the frontier characteristics of the population. Even so, disharmony along communal lines was witnessed sometime in the 1940s (Danda 2007).

In 1973-74, India declared 2,585 km^2 of this area as a Tiger Reserve with Bangladesh following suit, declaring 23.5% of the remaining Sundarban as a Reserved Forest in 1977 by carving out three sanctuaries, viz., Sundarban West, Sundarban East and Sundarban South under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974 (Barlow *et al.* 2008).

Plate 2.1. Sundarban Landscape.

Plate 2.2. A creek in Sundarban Tiger Reserve during low tide.

CHAPTER 3

RANGING PATTERN AND HABITAT USE BY TIGER

3.1. Introduction

Members of many species in the Carnivora exhibit intra-sexual territoriality and maintain territories only with regard to members of their own sex (Powell 1979, 1994, Rogers 1977, 1987). These species exhibit large sexual dimorphism in body size and males are generally polygynous and females are selectively polyandrous. Females raise young without help from males and the large body sizes of males may be considered a cost of reproduction (Seaman 1993). For species that affect food supplies mostly through resource depression i.e. have rapidly renewing food resources such as ripening berries and nuts or prey on animals that become wary when they perceive a predator and later relax, thus intra-sexual territoriality appears to have a minor cost compared to intersexual territoriality because the limiting resource renews. This cost may be imposed on females by males (Powell 1993, 1994).

Home-range size and spacing among wild solitary felids varies both intra and inter-specifically, from exclusive to widely overlapping home ranges for both sexes (Bailey 1993, Eisenberg 1986, Hornocker and Bailey 1986, Kleiman and Eisenberg 1973, Sandell 1989). Sandell (1989) argued that solitary female felids should maintain home ranges just large enough to contain enough prey to meet the energetic demands of reproduction, with exclusive home ranges expected only when resources are distributed evenly both spatially and temporally. Many

studies have documented male felid home-range sizes much larger than expected based on energetic demands, suggesting that other factors such as maximizing breeding opportunities influence male home-range size and degree of exclusivity (Sandell 1989). For solitary felids such as cougars (*Puma concolor)* and leopards (*Panthera pardus)*, either sex may be territorial or have extensively overlapping home ranges, and in at least some studies, spacing patterns have been tied to availability of food resources and breeding opportunities (Bailey 1993, Hopkins *et al*. 1986, Hornocker 1969, Hornocker and Bailey 1986, Logan and Sweanor 2001, Pierce *et al*. 1999, Seidensticker *et al*. 1973, Stander *et al*. 1997). Both species occur in a wide variety of climates and habitats, and a flexible social system likely contributes to their highly adaptable nature.

Animals tend to be territorial when confounded by a limiting resource in short supply, ultimately restraining population growth (Brown 1969). This critical resource stimulates territorial behavior regulating population growth and preventing instability. Though extensive research has been undertaken on population regulation through territoriality (Brown 1969, Fretwell and Lucas 1970, Maynard Smith 1976, Watson and Moss 1970), yet the general conclusion of such theory is that territoriality can regulate populations only proximally. Availability of food resources are inversely related to the size of territory held by individuals of different species (Ebersole 1980, Hixon 1980, Powers and McKee 1994, Saitoh 1991, Schoener 1981).

3.2. Review of Literature

Tigers occupy a wide range of environmental conditions, from the tropical forests of southern Asia to the temperate and boreal forests of the Russian Far East resulting in considerable differences in prey availability (Miquelle *et al*. 1999, Sunquist *et al*. 1999) across habitats, suggesting variable social structure. Studies from Nepal confer that both male and female Bengal tigers maintain largely exclusive home ranges (Smith *et al*. 1987, Sunquist 1981) due to abundant prey base. In contrast, in the Russian Far East prey biomass and tiger densities are an order of magnitude lower (Smirnov and Miquelle 1999, Stephens *et al*. 2006, Sunquist *et al*. 1999), suggesting that spacing patterns may differ considerably. Though majority of studies have concluded that the Amur tigers (*Panthera tigris altaica)* maintain exclusive home ranges (Abramov 1962, Matyushkin 1978, Matyushkin *et al*. 1980, Salkina 1993) and one analysis suggested that home ranges overlap considerably (Bragin 1986). Female philopatry has been documented in many carnivore species, with sub-adult females often inheriting a portion of their natal home range and males generally dispersing longer distances than females.

Dobson (1982) hypothesized that in polygamous species selection for out breeding should result in sub-adult males dispersing farther than females. Smith (1984) concluded that, given male home ranges are generally larger in solitary species; dispersing males would have to move farther than females just to emigrate from their father's home range from the pattern observed for tigers in Nepal. Social instability created by the death of resident males also results in

increased infanticide by immigrating males and reduced reproductive rates (Smith and McDougal 1991, Wielgus *et al*. 2001). Spatial and social structure also affects operational sex ratio (Emlen and Oring 1977) and degree of polygyny, both of which can impact effective population size (Chepko-Sade *et al*. 1987, Clutton-Brock and Harvey 1978, Creel 1998, Lott 1984, Smith and McDougal 1991). Human-induced mortality the most common source of mortality for many large carnivores (Goodrich *et al*. 2008) also has the potential to impact spatial and social structure, and hence, demographic parameters that may affect population viability (Chapron *et al.* 2008, Packer *et al*. 2009).

3.3. Animal Movement

Animal movement is the fundamental process allowing individuals to make choices concerning the exploitation of resources at different spatial scales (e.g. dispersal, foraging) in regard to the environment (Stephens and Krebs 1986, Bell 1991). It is the outcome of varied individual characteristics, such as the internal state, motion and navigation capacity, and a broad range of external factors (Nathan *et al*. 2008). Turchin (1998) defined individual movements as “the process by which individual organisms are displaced in space over time”. Thus movement is fundamental to individual and population dynamics, allowing individuals to meet their basic requirements. Basic needs of movement include gaining energy, seeking safety, learning, and reproducing (e.g. searching for mates, food, escaping from predator, avoidance of intra-specific competition and

inbreeding) (Nathan *et al*. 2008). Movement strategies pertaining to survival and reproduction are inherently driven by natural selection (Fahrig 2007).

This is therefore a key process, influencing the overall fitness of mobile individuals (Schooley and Wiens 2003). Movement enables individuals to respond to heterogeneous and variable environments, according to their requirements. Mobile animals make seasonal migrations when constrained by food and climatic conditions. At a small spatial scale, with patchy food resources, animals may move from low-quality patches (e.g. after depletion of the patch) to high-quality patches of the landscape. Quality of a same habitat (or habitat patch) might be perceived differentially according to individual requirements by animals. Food resources and refuge (e.g. protection from heat or predators) are often spatially disconnected, leading animals to make trade-offs between habitat types, according to their activity and requirements. Viewed along a broad spectrum animal movement and habitat selection are intimately linked, movements being the key mechanism underlying the habitat selection pattern.

3.4. Habitat Use

Resource selection by animals to particular environmental characteristics is a behavioral response which is often a hierarchical process (Horne *et al*. 2008). Different environmental factors influence establishment of a home range within a landscape at diverse scales and therefore animal-landscape relationships should be examined across a range of scales (Johnson 1980, Anderson *et al*. 2005, Boyce 2006). Habitat use by animals is the proportion of movements within

diverse habitat types defined as trajectories through space and time (Aebischer *et al*. 1993). Animal location data approximate the trajectory by sampling it at discrete intervals. Evenly distributed sampling effort across little used habitat types ensures proper representation by estimating proportion of the movement trajectory in each habitat (Aebischer *et al*. 1993). Resource selection being a scale-dependent hierarchical process of behavioral responses to environmental factors ensures identification of habitat types requiring management interventions for conservation.

Sundarban is the only mangrove habitat in the distribution range of tiger and very limited information exists on ecology of tigers inhabiting them and what measures should be taken to conserve them. Though anecdotal information on observation of tigers (secondary signs along channel banks in different mangrove communities exists in natural history records and published literature (Khan 2004), yet detailed studies on resource selection and habitat use by tigers constitute a research gap. Through this present study I examined habitat use by radio-collared individuals in Sundarban Tiger Reserve.

In home range selection, the proportional occurrence of resources within the estimated home range boundaries may be used to characterize use (Aebischer *et al*. 1993). The appropriate size and shape of the area to consider for defining use depends on the scale of study, patch sizes, variable types and biology of the animal under study.

3.5. Radio Telemetry

Understanding the organization of animals in space and time is a central question of ecology. The dynamics of a population are directly linked to the spatial arrangement and movements of individuals caused by internal or external pressures on the population. Animal space use and movements are best understood through direct observation. Although this method may allow locations to be precisely recorded, it is very labor intensive and the potential to influence the animal's behavior is high, often resulting in a biased estimate of distribution patterns. With animals that are wide-ranging or difficult to find, direct observation may be impractical. In the absence of direct observation, radio telemetry has filled an important gap. Whether radio telemetry is used on animals that are wide ranging and difficult to study, or simply for convenience, the data generated are well suited for investigating space use and movement patterns of animals.

Radio transmitters provide convenient and cost-effective means of remotely monitoring the physiology, movements, resource selection and demographics of wild animals. For animals which are elusive, solitary and difficult to observe in the wild especially large carnivores inhabiting dense woodlands, radio-telemetry as a tool is indispensible to gather information on their secretive lives. The Global Positioning System (GPS) collars or Satellite collars on tigers can be used to estimate density, population, and movement, as has been done in other parts of the tiger's range (Sunquist 1981, Smith *et al*. 1987, Smith 1993, Smith *et al*. 1998). Tracking individual tigers can also help to understand tiger movement, and their likelihood to cross certain habitat features (Smith 1993, Smith *et al*.

1998). For certain habitat types, telemetry offers insight into these aspects of tiger ecology that other methodologies, such as secondary sign surveys and camera-trapping, cannot always provide (Sunquist 1981, Smith 1993, Chundawat *et al*. 1999, Miquelle *et al*. 1999, Karanth and Sunquist 2000, Kerley *et al*. 2003, Goodriche *et al*. 2005). However, despite its benefits, telemetry studies have only been published from six (8%) of the 76 Tiger Conservation Landscape (TCL), with work from Nepal and Russia contributing the majority of information (Seidensticker 1976, Sunquist 1981, Smith *et al*. 1987, Smith 1993, Kotwal and Gopal 1995, Chundawat *et al*. 1999, Miquelle *et al*. 1999, Karanth and Sunquist 2000, Kerley *et al*. 2003, Goodrich *et al*. 2005, 2008). More telemetry studies across the tiger's range would add information that could improve the long-term prospects for the survival of this species.

3.6. Methodology

3.6.1. Home range, habitat use and activity pattern of tigers

Intriguing facts on the socio-biology of elusive carnivores can only be inferred through use of invasive techniques such as radio telemetry, which can be otherwise be extremely difficult or resource intensive to obtain (Jhala *et al*. 2004). Thus four tigers were radio-collared in Sundarban Tiger Reserve between February and May 2010 (Plate 3.1. and Plate 3.2.). These included 1 adult female and 3 adult males. Satellite collars (Vectronics IRIDIUM) were deployed on all the four individuals. The tigers were trapped in cages using live baits

(goats) and tranquilized using 2.5 mg/kg Ketamine and 1 mg/kg Xylazene administered intra muscularly using a blow pipe (Kreeger 1996). A protocol for anesthetizing and evaluating body measurements was developed (Appendix 1). The radio-collars (Vectronics IRIDIUM) weighed less than 1% of the body weight of the tiger.

3.6.2. Data Collection: Radio Telemetry

The satellite collars were programmed to transmit GPS fixes every three hours which was downloaded remotely via internet access. On an average 20-25 transmitted GPS fixes were downloaded every day whenever it was possible to get internet access. Once collar was activated the GPS fixes were downloaded via UHF (Ultra High Frequency) based ground download facility. The collars transmitted fixes for the entire duration of 24 hours a day. Tracking and then downloading the data within a close proximity of the individual was extremely difficult in the mangroves due to inaccessibility of narrow channels especially during low tide. There was irregularity in fixes for 7224 male tiger due to technical failure of satellite transmission and battery drainage.

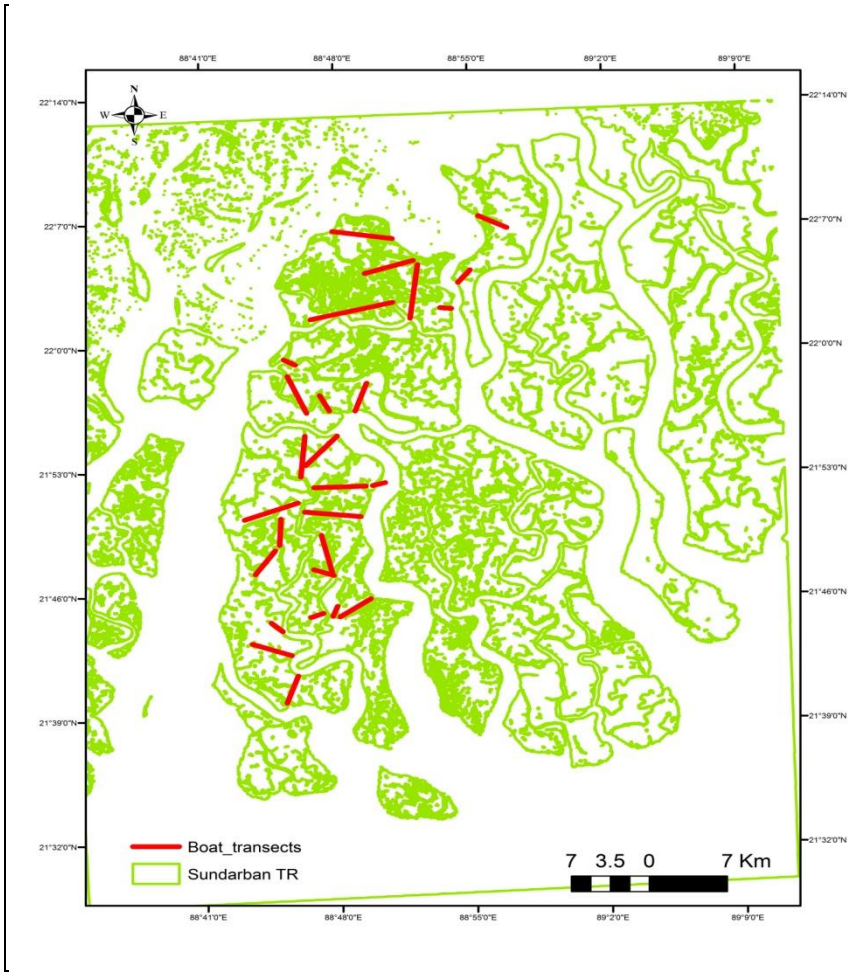
3.6.3. Relative Abundance: Estimation of prey

Due to ever present threat from man-eating tigers and difficulty of walking inside the mangroves it was not possible to conduct ground surveys, hence the channel banks were surveyed for recording data on relative abundance of predators and prey. Due to the unique nature of mangrove ecosystem and tidal fluctuations the

entire area was submerged under water twice a day during high tide. This left me with a window of six hours every day to conduct surveys, three hours after setting of low tide and three hours after setting of high tide when the banks were completely exposed for observing signs deposited by animals. Tide timings shifted every day by half an hour during Neap Tide Phase and more than an hour during Spring Tide Phase. Thus transects were conducted irrespective of the time of day, primarily in response to the daily shift in the tidal pattern.

Within the intensive study area, boat transects (n = 34) of five to ten kilometers in length were conducted between February and November 2010, totaling an effort of 248.16 kilometers. GPS coordinates along with type of mangrove, slope of the bank and width of the upper and lower bank were noted for each sign encountered. The locations were recorded using GARMIN© 72 GPS unit. Data on major vegetation types were also collected for each transect at every 400 meters interval. Anthropogenic pressure and dependence of local people were also quantified by observing indirect signs such as human footprints, fishing and crab collection evidence such as presence of wooden poles, bamboos along channel banks. Direct sighting of fishermen and crab collectors encountered were also noted down for every transect.

Figure 3.1 Location of boat transects (n=34) carried out within Intensive Study Area of Sundarban Tiger Reserve.



3.7. Data Analysis

3.7.1. Defining Home Range

Burt (1943:351) first defined "home range" as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young". The concept of home range since the proposed definition has been redefined or criticized by several authors (Mohr 1947, Jewell 1966, Baker 1978, Hansteen *et*

al. 1997). White and Garrot (1990) pointed two inherent problems with the original definition, including use of the ambiguous term "normal" and the inadequacy of not specifying a temporal component. Morris (1988) proposed home range to be a concept rather than an entity and defined it as the extent of area with a defined probability of occurrence of an animal during a specified time period. Hayne (1949) introduced the concept of "center of activity" referring to the intensity of use in various parts of the home range. Subsequently, the term center of activity was replaced by the term core area (Hodder *et al*. 1998).

3.7.2. Autocorrelation

An inherent assumption in most existing probabilistic estimators of home range is that location data used to estimate the home range are independent (Dunn and Gipson 1977). Swihart and Slade (1985) suggested that autocorrelation exists when locations at time (*t)* are dependent on the animal's location at time (t-1). Assuming a fixed time between relocations, auto-correlated datasets are created when (1) the animal has too little time to move away, (2) the animal simply does not move between consecutive observations, or (3) the animal periodically returns to a previously used portion of its range (Hansteen *et al*. 1997). The main assumption related to the effects of autocorrelation on home range estimates is that ‘n’ observations that are auto correlated yield less information than do ‘n’ independent observations (Swihart and Slade 1985). That is, when data are auto correlated, the distance moved between consecutive observations decreases, resulting in a lower proportion of the home range traversed and an

underestimation of home range size. In contrast, independent data allow the animal enough time to move throughout its home range, thus yielding more information about an animal's movement patterns (Swihart and Slade 1985). I had programmed collars to transmit and record GPS fixes at regular 3 hours interval, thus negating the effects of auto-correlation on the dataset.

3.7.3. Sample size requirements for estimating home range

There is a statistical sample size, whereby home range estimators perform better with increasing number of data points (Seaman *et al*. 1999). Increasingly accurate estimates of home range are generally obtained with more data points as home range size increases to an asymptote (Swihart and Slade 1985, Seaman *et al*. 1999). The effect of sample size (n) on the accuracy of home range estimates is further related to the duration between observations. Though number of observations improves accuracy of estimates yet observations with small sampling intervals contributes little in refining the estimates (Swihart and Slade 1985b). Therefore, there is an unavoidable trade-off between sampling interval and sample size (Hansteen *et al*. 1997). In theory, home range size estimates reach an asymptote when an adequate sample size is reached (S. Harris *et al*. 1990). The minimum sample size is attained when the area estimates do not increase as more locations are added. To determine adequacy of radio-locations necessary to represent home range size, I examined 100% MCP home ranges of each radio-collared tiger using area accumulation plot (also

referred to as incremental area analysis). Home range size was plotted against the number of locations used; with sample size regarded as adequate when the accumulation plot reached an asymptote (Harris *et al*. 1990, Kernohan *et al*. 2001).

3.7.4. Home range estimators

Quantifying an animal's home range is an act of using data about the animal's use of space to deduce the animal's cognitive map of its home (Peters 1978). While advances in improving definitions of home range in recent years have been few e.g. Kernohan *et al*. (2001), advances in the methods used to estimate this elusive concept have been considerable (reviews in Macdonald *et al*. 1980, Harris *et al*. 1990, Powell 2000, Kenward *et al*. 2001, Kernohan *et al*. 2001, Walter *et al*. 2011). Increase in available computing power have allowed ecologists to use increasingly sophisticated methods to estimate home-range use for reviews refer to (Worton 1987, Harris *et al*. 1990, White and Garrot 1990, Powell 2000, Hemson *et al*. 2005, Millspaugh *et al*. 2006, Laver and Kelly 2008, Horne *et al*. 2008) with no consensus for any single technique. I used two non-parametric home range estimators: (a) Minimum Convex Polygon (b) Fixed Kernel contour (Worton 1989). A minimum Convex Polygon (MCP) home range is the area contained within the smallest possible convex polygon joining the outermost location of an animal movement (Mohr 1947). This is conceptually simple, easy to draw, reflects the exploratory behavior of animals, most widely used and comparable between studies (Worton 1987, White and Garrot 1990,

Harris *et al*. 1990). The main disadvantages of the MCP method are that it is sensitive to the number of radio locations used (Anderson 1982), it provides no indication of the intensity with which an animal uses different parts of its range, and home range size is strongly influenced by the peripheral locations (van Winkle 1975, Powell 1987, White and Garrot 1980, Seaman 1993, Kenward *et al*. 2001). To remove the effect of exploratory movements, outlying fixes were removed from the calculated MCPs. I also computed 50% Fixed Kernels indicating core areas of home ranges for all tigers.

Recent advances in home range modeling have used contouring methods for estimating probability density distributions (Dixon and Chapman 1980, Worton 1989). Kernel density estimation (KDE) is widely viewed as the most reliable contouring method currently used in ecology (Powell 2000, Kernohan *et al*. 2001) and was first adapted for animal home range analysis by Bruce Worton (Worton 1989) from a technique devised to estimate complex distributions from small samples (Silverman 1986). KDE creates isopleths of intensity of home-range utilization (e.g. 95%) by calculating the mean influence of data points at a series of grid intersections. Two major subdivisions of the general kernel technique are the fixed and adaptive kernel methods (Worton 1989). With the fixed kernel method the same bandwidth is used over the entire evaluation area while with the adaptive kernel method a local bandwidth is selected for each observation (Kernohan *et al*. 2001). Despite the close relationship of fixed and kernel methods, the adaptive kernel estimators performed slightly worse than the fixed kernel estimators, apparently through overestimation of peripheral use (Seaman

1993, Seaman and Powell 1996, Seaman *et al*. 1999). Therefore in the present study I calculated home ranges using Fixed Kernels (FK) also called Utilization Distribution (UD) methods. I used Hawth's Tool (Beyer 2004) in ArcGIS 9.3 (ESRI, Redlands, CA: Environmental Systems Research Institute, USA) to calculate MCP and Fixed Kernel home ranges.

3.7.5. Core Area Estimation

Core has been defined as particular areas of an animal's home range which are more important than others. A core is therefore used more heavily than the apparent clumps of heavy use that occur from uniform random use of space within a home range and may not be strictly determined by home range area (Powell 2000). Most define core area as the smallest area with an arbitrary probability of use e.g. 89% of authors defined core area by the 50% KDE isopleths (Laver and Kelly 2008). Given that different processes underlie space use patterns for different individuals and species, it is probably not valid to assume that an arbitrary rule will adequately define a core area. Rather, methods used to delineate animal space use patterns should have logic (Samuel *et al*. 1985). Therefore, I used area/probability curves over specific core-area definitions because the method is objective and based on the spatial distribution of telemetry locations (Powell 2000). The null expectation was uniform use of all regions within a home range, represented as a linear relationship between the percentage of total home-range area and the probability isopleths. Area/probability curves are typically concave, indicating clustered use of space

(Bingham and Noon 1997, Seaman and Powell 1990, Burdett *et al*. 2007). I used fixed kernel home ranges with isopleths at 5% increments from 5% to 100% (Powell 2000). I created area/probability curves by plotting the home range area within each isopleths as a function of the isopleths. The point at which inflection of line (slope) changed was identified as the core area (Powell 2000).

3.7.6. Movement of tiger

Distance moved between two successive locations were estimated by using Hawth's Tool in ArcGIS 9.3 (Rodgers and Kie 2010). For each day, the distances between subsequent GPS fixes were added up to calculate total distance travelled. I categorized 24 hours into interval of three hours each and calculated average distance travelled by tigers.

3.7.7. Channels crossed by tiger

Out of 2500 Km^2 of the Tiger Reserve 1600 Km^2 comprises of land and the rest water. Channels of diverse width classes, from the mighty Bay of Bengal on the southern tip to innumerable narrow creeks 20 to 50 meters in width intersects this mangrove ecosystem. Rivers such as Matla, Raimangal, Harinbhanga, Goasaba, Kalindi, Bidyadhari over five to eight kilometers width at certain stretches borders the Tiger Reserve separating islands and acting as temporary barriers for frequent animal movement. Tigers are reported to cross channels regularly, moving across islands in search of mate and prey. I was interested to examine

the frequency of crossing and evaluate if there was a preference for certain width class of channels by tigers. I classified channels into five broad categories, 30 to 50 meters, 50 to 100 meters, 100 to 150 meters, 150 to 200 meters and more than 200 meters.

Paths with at least 12 fixes per day (12AM-12PM continuous sessions) were selected from the intensive radio-collaring data of three individual tigers. Individual Paths were overlaid on digitized Google Earth Pro and LandSAT 30 m resolution imagery to calculate number and width of channel crossings per day. Ninety five percent confidence limits (Upper and Lower Limits) were calculated to evaluate range of width of channels crossed. Considering all radio locations of these three collared tigers a common Minimum Convex Polygon was created in Arc GIS 9.3 (Rodgers and Kie 2010). Pure random walk model within Hawths Tool was used in ArcGIS 9.3 (Animal Movement CRW Models), (Rodgers and Kie 2010) to generate random paths. For each original path five random paths were created using random points generated within the home range of three radio-collared individuals (Figure 3.9). Numbers of steps were kept constant to 15 per path with an average step length to reduce variability in length of random paths. Turning angle and step length distribution was assumed to be random with a uniform distribution.

3.7.8. Effect of Tidal Phase on ranging pattern

Lunar Calendars were referred from local newspapers and available literature to check effect of tides on ranging pattern of tigers. Distance travelled during spring and neap tide phase was compared by combining data of all radio-collared individuals. Due to unavailability of tide charts and absence of a permanent station in Sundarban it was not possible to draw inference on effect of daily tidal fluctuations.

3.7.9. Resource selection and habitat use

Habitat selection was examined by comparing use and availability of habitat types within the study area using the Neu Method (Neu *et al*. 1974). The Neu method is a straightforward application of the χ^2 goodness-of-fit test, and is usually used to compare observed counts of animals in each habitat with the counts expected if habitats were used in proportion to their availability. The method involves the calculation of confidence intervals (Bonferroni Z-statistic) around the expected proportions to determine whether the observed proportion of usage in each habitat is significantly different from expected. The usage of a particular habitat type was defined as the ratio between animal locations in each habitat type and the total number of locations recorded in the study area. Expected usage of a habitat type was defined as the ratio of the area of the particular habitat type to the total area of the study site. Due to the small sample size (n = 3), I pooled data for all tiger individuals. Due to irregularity in GPS fixes

of different individual tigers, only 100 locations were considered for each individual with an average of one to two locations per day depending on the number of tracking days. The area occupied by 7825 Male was not sampled, since its home range was in Bangladesh Sundarban (Figure 3.5) and thus was excluded from the analysis.

Mapping of vegetation types was done within this present study by laying 15 m x 15 m circular plots (n= 145) at every 400 meters of the Tiger Reserve between February and June 2010. Major tree species, herbs and shrubs within these plots were enumerated. Remotely sensed data of Landsat-5-ETM + imagery (30M resolution) for the month of February 2010 Geo coded False Color Composite (FCC) on 1:50,000 scales was used for entire Sundarban Tiger Reserve and different color tones for 30 classes were extracted. The color classes were merged depending on the similarity in vegetation types based on field collected vegetation data. The map was first improved using supervised maximum likelihood classifier to incorporate unclassified and misclassified data. Five vegetation types were mapped and finalized with 80% accuracy (Figure 3.16).

I used ordinary Kriging to estimate prey (chital, wild pig), tiger and human usage probabilities in non-sampled areas based on boat transects conducted across the sampled area. Grids of 5 Km^2 were overlaid on the intensive study area for interpolation. Kriging is a geo-statistical interpolation technique (Cressie 1993, Banerjee *et al*. 2004) that permits inferences about a parameter of interest (in my case, the probability of use) in non-sampled areas by using information available in sampled locations and accounting for uncertainty as the distance between

spatial locations increases. The approach produces a semivariogram that describes the spatial correlation between the points. Several models are available for fitting a semivariogram, such as spherical, circular, exponential, Gaussian and linear. Based on the Akaike's information criterion (AIC), I fitted the Gaussian model to the observed data, using the Kriging Interpolator in ArcGIS 9.3 Spatial Analyst Tool (ESRI 2006). Maps were generated based on the usage probabilities for the intensive study area within Sundarban Tiger Reserve (Figure 3.16-3.19).

Table 3.1 Major vegetation types within Sundarban Tiger Reserve.

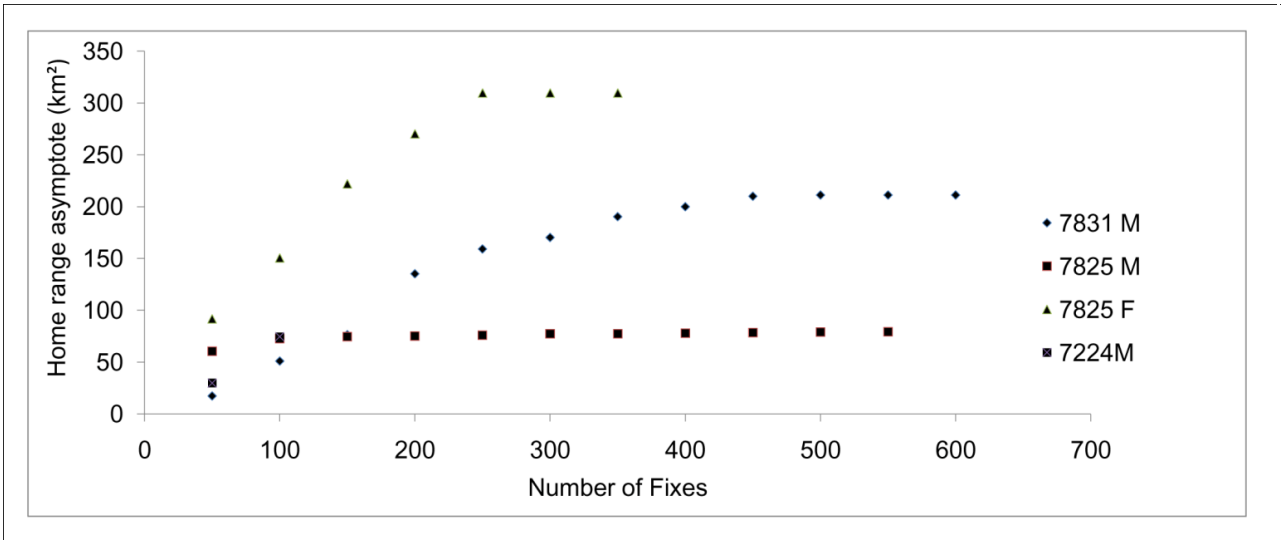
Vegetation Type	Characteristics
Water	Major channels and water bodies within the tiger reserve
Phoenix	*Phoenix paludosa* dominated habitat, occurs along high ground compared to other mangrove species, major association with *Exocoeceria*
Ceriops	*Ceriops decandra*, short stunted shrub like mangrove, most dominant vegetation type, major association with Exocoeceria
Avicennia	*Avicennia* sps. grows along periphery and channel banks in low lying islands, associated with *Sonneratia* sps.

3.8. Results

3.8.1. Sample size adequacy for home range analysis

The home ranges of individual tigers stabilized and reached an asymptote at different sample sizes (range 100 - 500) reflecting exploratory movements and distinctive socio-biology of individuals (Figure 3.2). The overall home ranges reached an asymptote at 337 fixes.

Figure 3.2 Stabilization of 100% MCP Home Ranges of radio-collared tigers (n=4) against GPS fixes in Sundarban Tiger Reserve.



3.8.2. Effect of autocorrelation

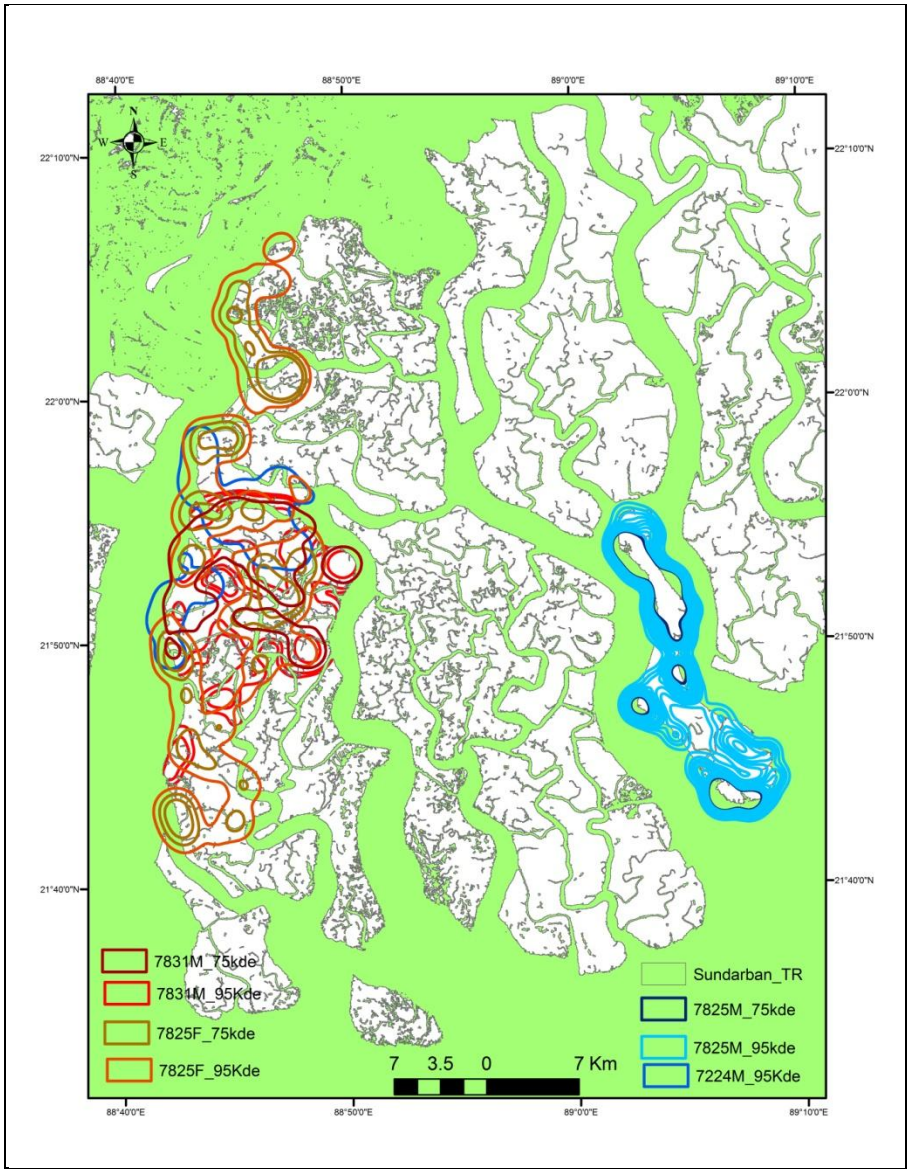
Radio-collared tigers frequently covered a maximum distance of 7-8 km per hour in the Sundarbans. Assuming the average home range size and shape to be equivalent of an approximate circle, I estimated a diameter of 14 km for the collared tigers. Thus within an hour there was a random chance of a tiger to

move from one corner to the centroid or any where within the home range. Thus a gap of 1 hr between fixes was sufficient to negate autocorrelation and asume independence of locations in the datset as well reduce substantial loss of ecological information (de Solla *et al.* 1999).

3.8.3. Home ranges of tigers

A mean of 1367 (SE 963.93) locations (range 643 – 2532, n = 3 tigers) were used in each home range analysis (Table 3.2). The number of tracking days for individual tigers varied from 59 to 176. The estimated average tiger home range (95% FK) size was 195.76 km² (SE 60.34) (range 166.1 - 239.9 km²). The overall home range (95% MCP) of male tigers was 136.98 km² (SE 23.05) (n = 2) (Table 3.2). The lone tigress had a larger home range both using MCP and FK as compared to the male tigers.

Figure 3.3 Home range (95% & 75% Fixed Kernels) of (n=4) radio-collared tigers in Sundarban Tiger Reserve.



The Sonaga tigress 7825F was captured from Sonaga village near Bidya Range Office of West range on 22nd February 2010, radio-collared and released near Netidhopani camp in West range (Store Khali) on 24th February. She dropped her

collar on 21st April 2010 at Dhonar Khal near Dobanki camp in Sajnekhali Range. She was trapped near the northwestern part of the Tiger Reserve and soon after radio-collaring travelled all the way south towards Bay of Bengal and finally heading back towards the village from where she was captured. The male tiger 7825M was captured from Malmelia village of Basirhat range on 20th May 2010, radio-collared and released nearby on 22nd May 2010. The animal weighed 108 kgs, was blind in the right eye and bore signs of territorial fight on the head and left rear leg. This tiger subsequently moved into Bangladesh and settled in Talpatti Island and continued to use the entire Island till its satellite signal stopped transmitting on 4th August 2010. It was not possible to ground track this tiger through VHF signal since the animal was in Bangladesh. The third tiger Netidhopani Male 7831 M weighed around 97 kg, was captured near Netidhopani camp on 20th May 2010, radio-collared and released near the fresh water pond in Netidhopani camp. This tiger was recaptured on 3rd October 2010 and the collar was replaced since the satellite status showed that one of its batteries had drained. This male tiger was tracked till November 2010 with the help of a hand held directional 3-element Yagi directional antennae with radio receivers (HABIT receiver model HR 2600 and Vectronics GPS Plus Handheld Terminal Unit) via boats. The 7224 Male tiger was captured near Netidhopani Camp on 21st March 2010 and released near Pirkhali 7 compartment. The tiger was tracked till mid April before the collar stopped transmitting probably due to exhaustion of battery.

Table 3.2 Home Ranges of Radio-collared Tigers (N=3) as determined by different estimators in Sundarban Tiger Reserve.

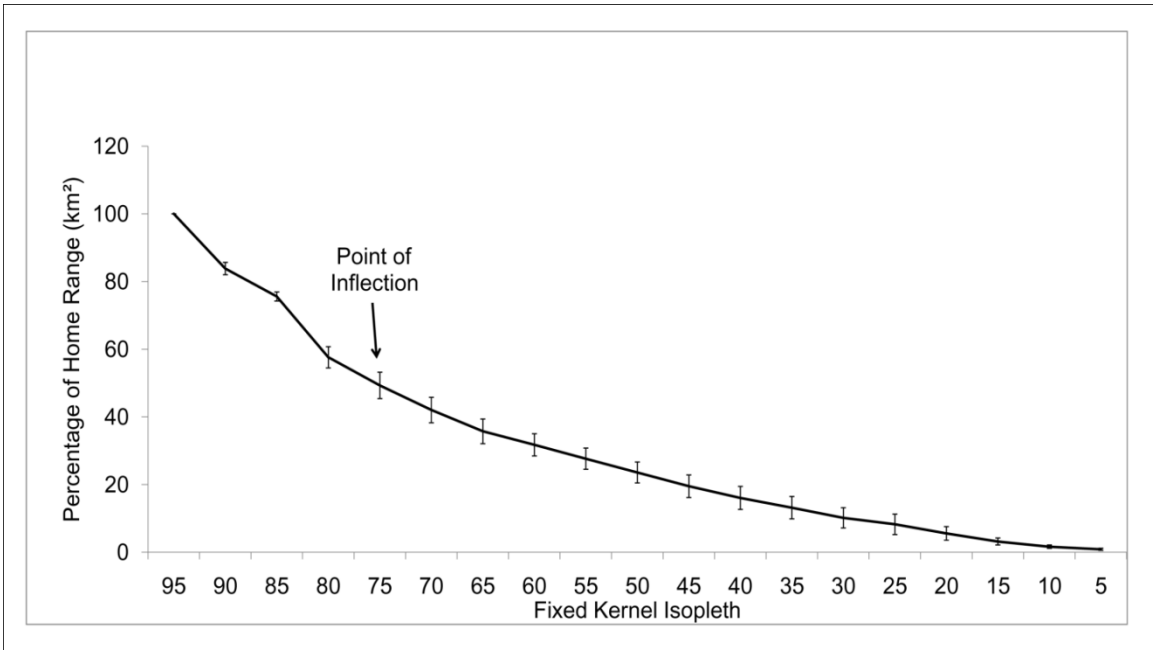
Tigers	100% MCP km²	95% MCP km²	95% FK km²	75% FK km²	Total Number of Tracking Days	Total Fixes
7825 Female	336.8	309.67	191.31	79.46	59	643
7825 Male	120.73	79.29	60.97	32.76	76	928
7831 Male	211.39	153.85	159.09	83.78	176	2532
*7224 Male	92.94	78.62	68.7	33.44	18	122
Mean	213.71	180.94	137.12	65.33	103.6	1368
Standard Error	115.43	67.87	39.19	19.31	59.84	963.93

*Not used for estimating Home Range as sampling duration was too small. Data used for other analysis like activity pattern, habitat use and movement.

3.8.4. Core Area estimation

The point of inflection in the graph of the home range size vs. Fixed Kernel isopleths suggested that at 75% FK, the home range area reduction with decreasing fixed kernel isopleths decreased (Figure 3.4). Hence the average core area of tigers was estimated to be 65.33 (SE 19.31) km² (Table 3.2)

Figure 3.4 Probability Curve estimation of core area of activity of radio-collared tigers in Sundarban.



3.8.5. Distance moved by tigers

The average distance moved per day was 5.43 (SE 0.93) with range as 0.1- 23 km. There was no significant difference between daily distances moved by individual tigers (One way Anova, F = 1.675, df = 3, p value = 0.174). An average of 746 fixes (SE 421) and 47 days (SE 22) were used for enumerating the distance travelled (Table 3.3).

Table 3.3 Daily movement pattern of radio-collared tigers (N=4) in Sundarban Tiger Reserve.

Individual Id	Mean Distance (km)	Number of days	Total Fixes
7224 Male	8.12	3	39
7825 Female	4.86	27	349
7825 Male	3.80	49	641
7831 Male	4.95	110	1957
Mean	5.43	47.25	746.5
Standard Error	0.93	22.93	421.80

Tigers were observed to move more during the early hours of dawn, day and afternoon with a distinct heightened movement between 7AM and 10AM. For an hourly interval, the highest distance moved was 595.25 meters during 7 AM and the lowest being 31.58 meters during 7 PM (Figure 3.5) per day with a peak around 4PM in the afternoon. Tigers travelled an average of 5.06 km (SE 0.47) during neap tide phase and 4.43 km (SE 0.40) during spring tide phase per day (Figure 3.6) with no significant difference observed between these two tide phases (Paired t test t = -1.193, df = 3, P = 0.319).

Figure 3.5 Distance moved by radio-collared tigers (n=4) during different time zones in Sundarban Tiger Reserve.

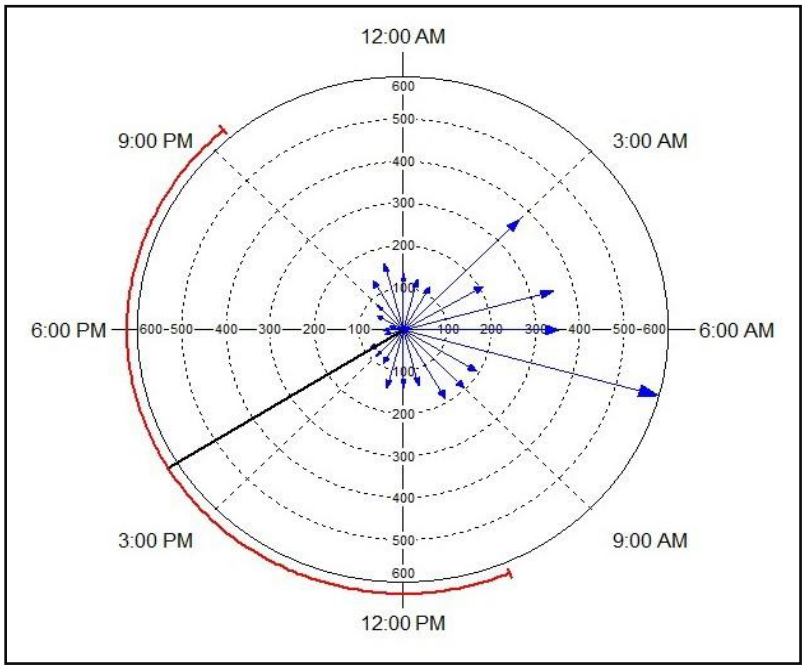


Figure 3.6 Distance moved during Spring and Neap tide phase by radio-collared tigers (n=4) in Sundarban Tiger Reserve.

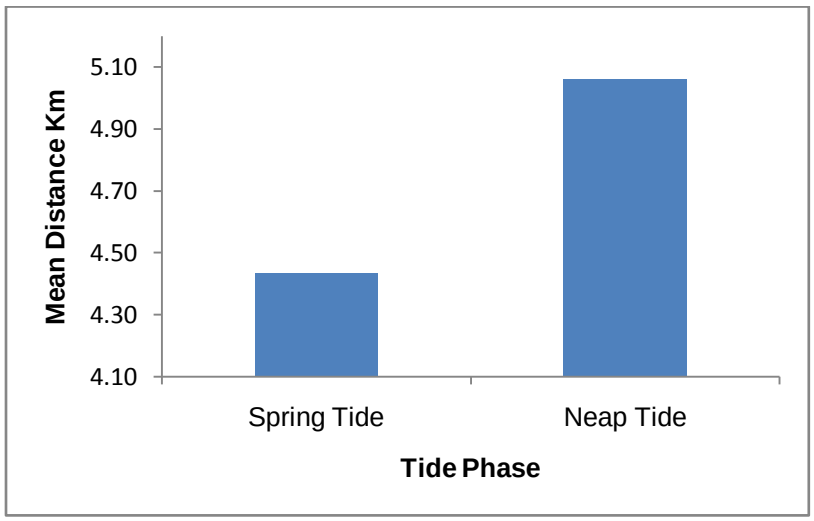
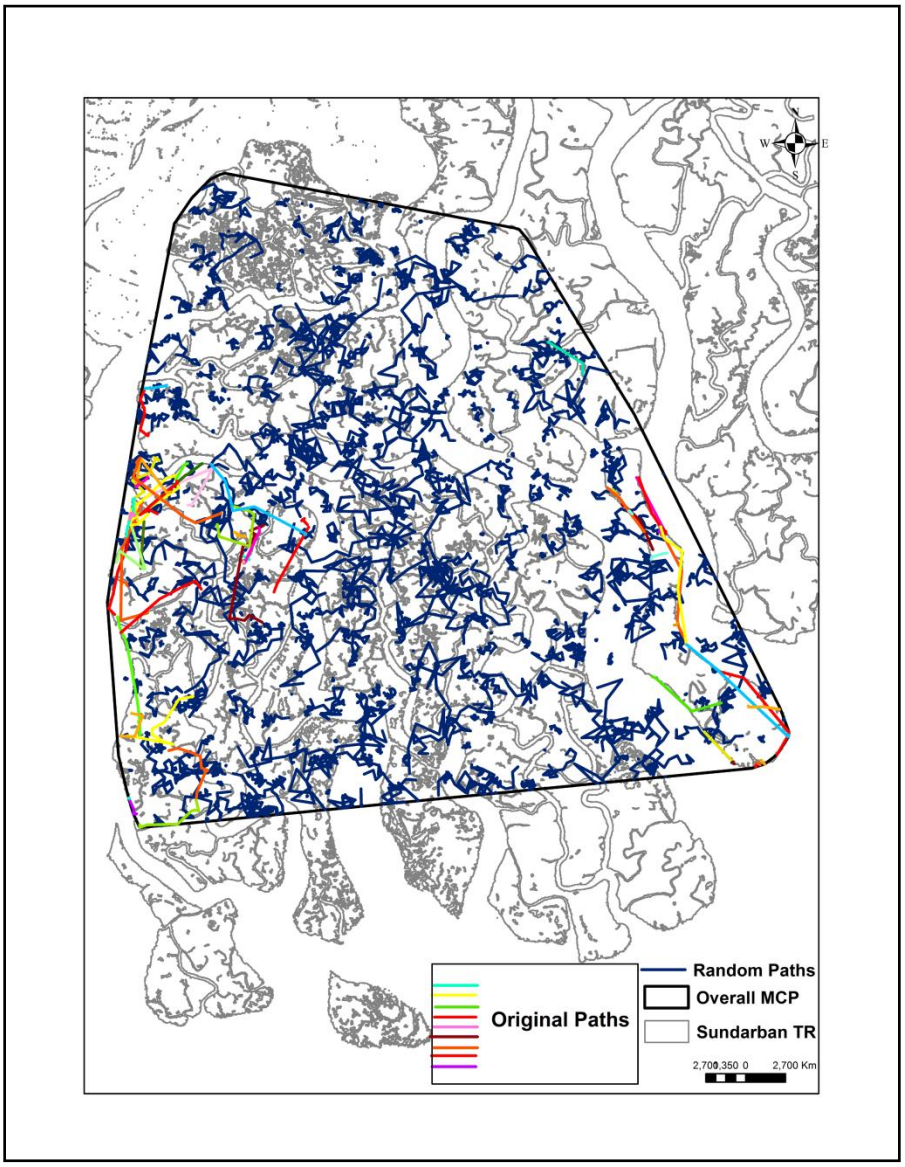


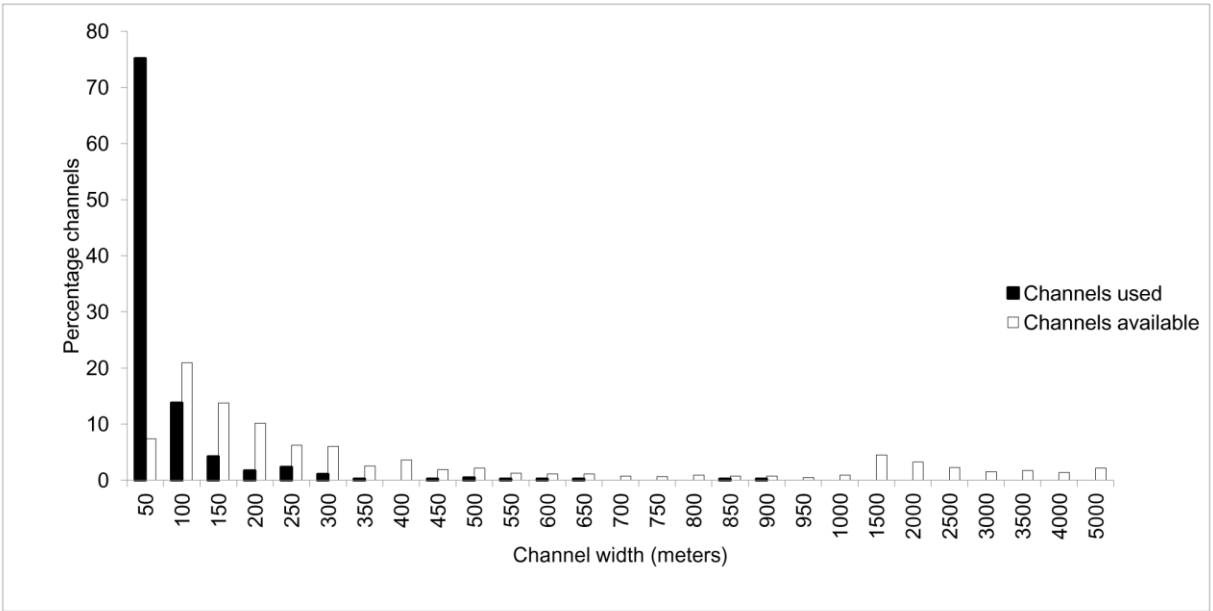
Figure 3.7 Daily Tiger Paths (n = 189) and simulated random paths (n= 674) from (n=4) radio-collared tigers overlaid on the Google Earth Image of the study area of Sundarban Tiger Reserve.



3.8.6. Channels crossed by tigers

Channels within 100 to 350 meters in width were crossed by tigers according to their availability. Channel width more than 400 meters were avoided by tigers (Figure 3.8). The mean number of channels crossed by tigers per day was 5.19 with SE 0.99. There was no significant difference observed in mean number of channels crossed by individual tigers (*F*= 0.963, df = 3, P = 0.441). There was a significant difference in the width of channels crossed by tigers as compared to their availability (χ^2=182.55, df = 26, P < 0.05) (Figure 3.11).

Figure 3.8 Availability and use of different width class of channels by radio-collared tigers (N=4) in Sundarban Tiger Reserve.



Ninety five percent Confidence limits (Upper Confidence Limit and Lower Confidence Limit) of width of channels encountered within random paths was

calculated and compared with original paths of tigers. Mean width of channel crossed within random paths was computed as 674.37 (SE 39.11) meters with a UCL of 751 meters and LCL of 597.73 meters whereas for original paths, the mean width of channel crossed was 52.85 (SE 4.07) with a UCL of 60.83 and LCL of 44.86 meters (Figure 3.9).

Figure 3.9 Mean width of channel crossed by radio-collared tigers (n=4) in Sundarban Tiger Reserve.

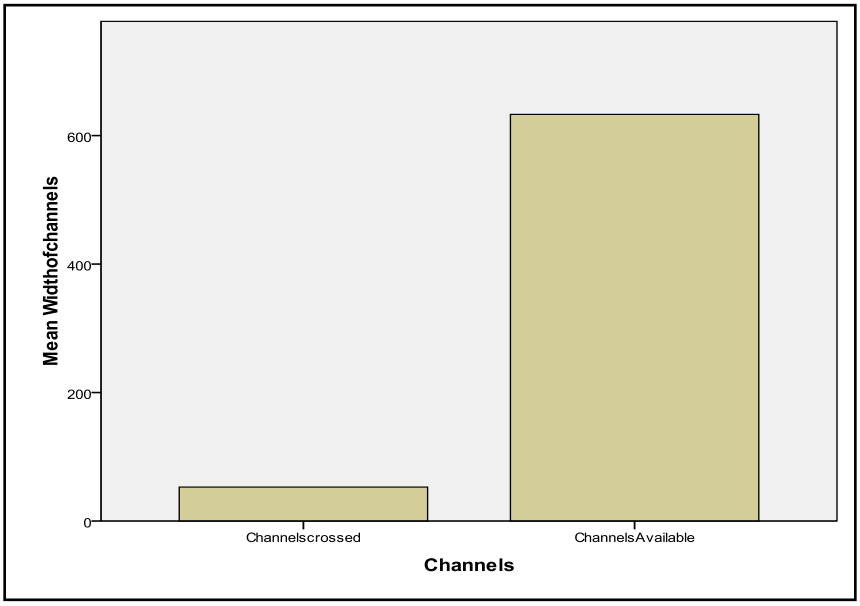
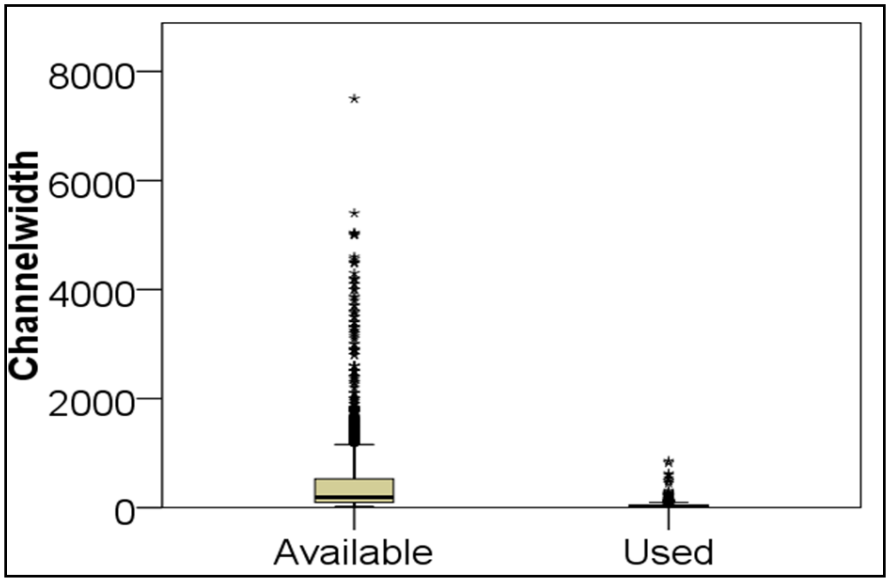


Figure 3.10 Availability and Use of different width of channels by radio-collared tigers.



3.8.7. Habitat use by tigers

The χ^2 test rejected the null hypothesis of no habitat preference by tigers in the Sundarbans (χ^2= 43.31, df = 4, $p < 0.05$). Results of Bonferroni Confidence Interval showed that tigers preferred *Avicennia* patches whereas *Phoenix* and *Ceriops* habitat were used according to their availability. Though *Avicennia* was preferred, yet 50% of the locations were in *Phoenix*, followed by 20% within *Ceriops* dominated patches signifying their importance as critical habitat for tigers in mangroves (Figure 3.12). There was an avoidance observed for water in the overall preferred habitat use (Table 3.4). Ivlev's Index also supported preference for *Avicennia* and *Phoenix* dominated habitats by tigers in the mangrove forests of Sundarban (Figure 3.11).

Table 3.4 Preference for different habitat types by tiger (n=4) in Sundarban Tiger Reserve as shown by Bonferroni Confidence Intervals.

Resource	Proportion		Available	Preferred/Avoided	P value
	Lower	Upper			
Dry barren land	0.041	0.1082	0.0756	Used according to availability	P > 0.05
Phoenix	0.4395	0.5672	0.4446	Used according to availability	P > 0.05
Avicennia	0.1168	0.2115	0.0699	Preferred	P < 0.05
Ceriops	0.1503	0.2528	0.2001	Used according to availability	P > 0.05
Water	0.0269	0.0858	0.2098	Avoided	P < 0.05

Figure 3.11 Preference for habitat type by tigers in Sundarban Tiger Reserve as shown by Ivlev's Index.

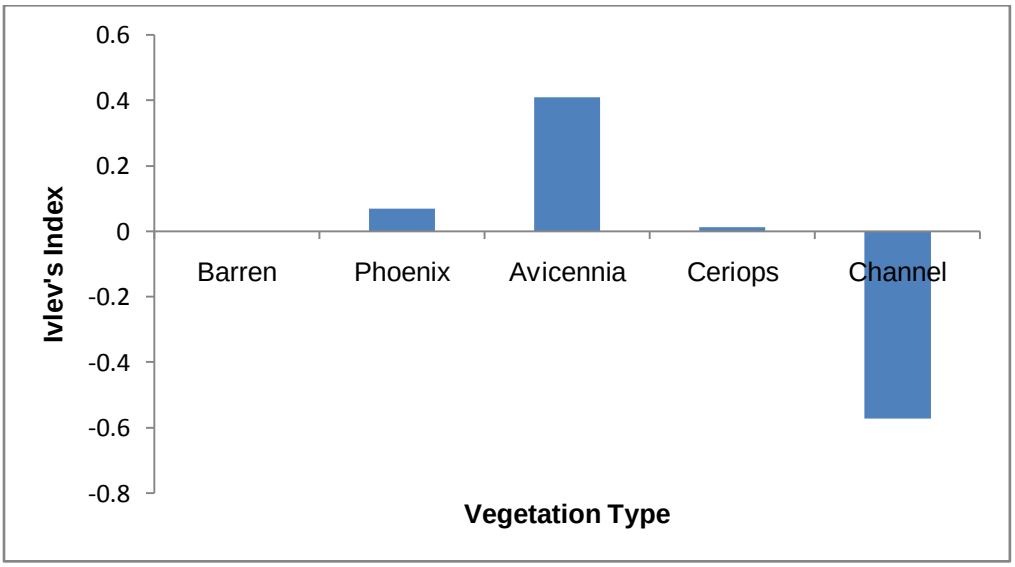


Figure 3.12 Proportion of locations of radio-collared tigers within different vegetation types in Sundarban Tiger Reserve.

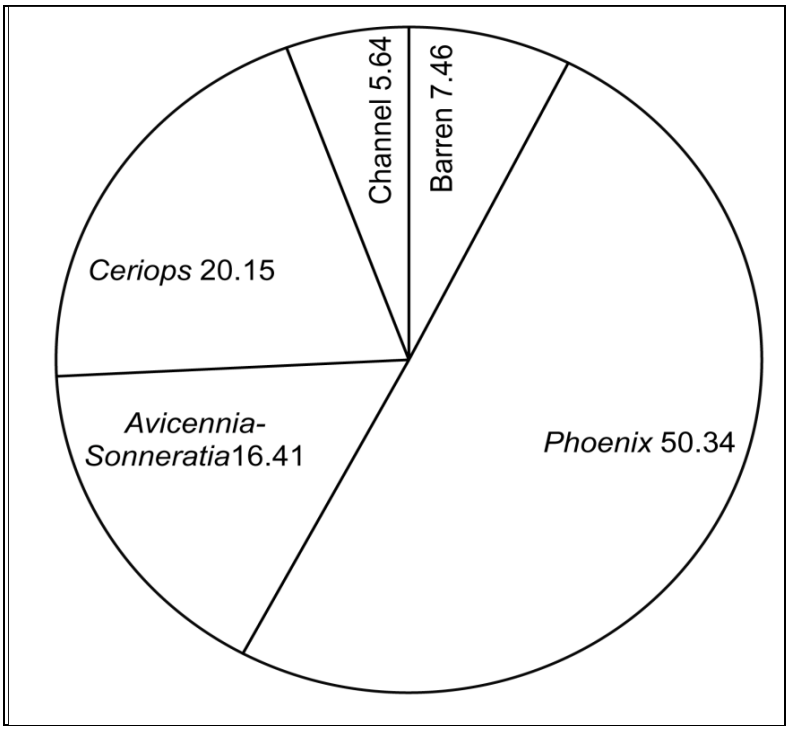
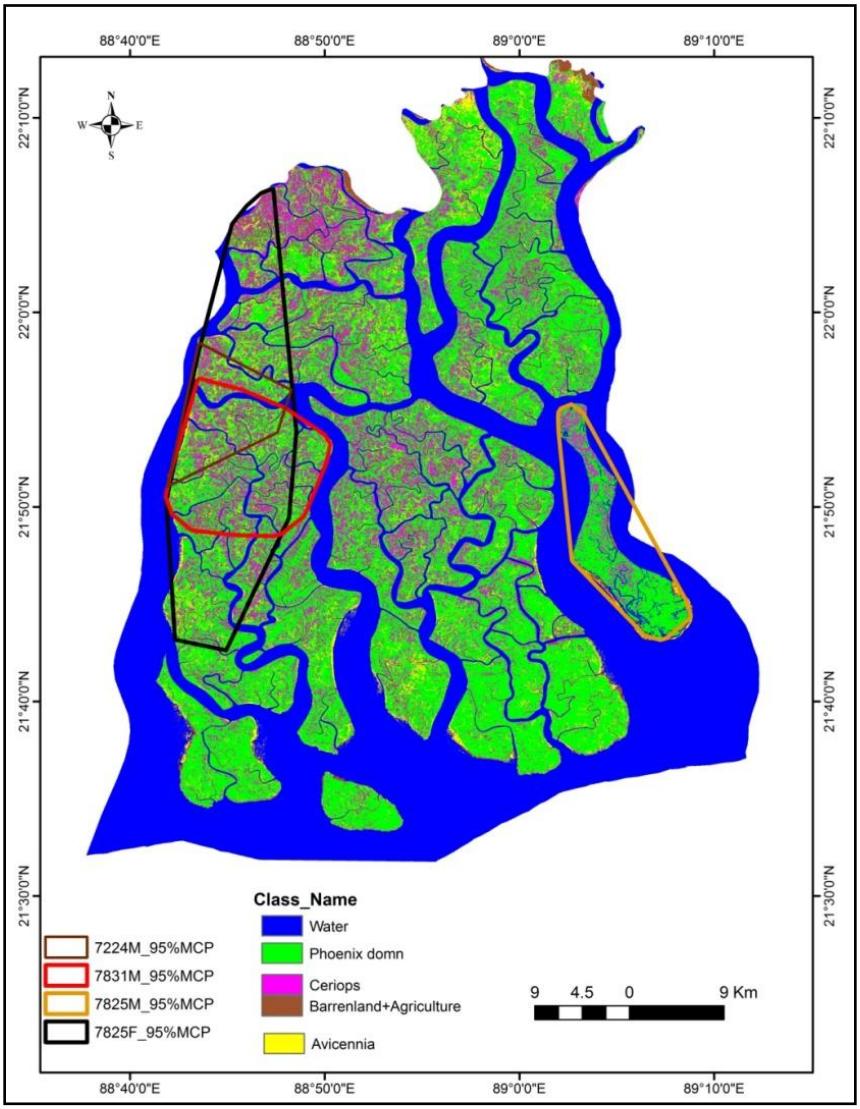


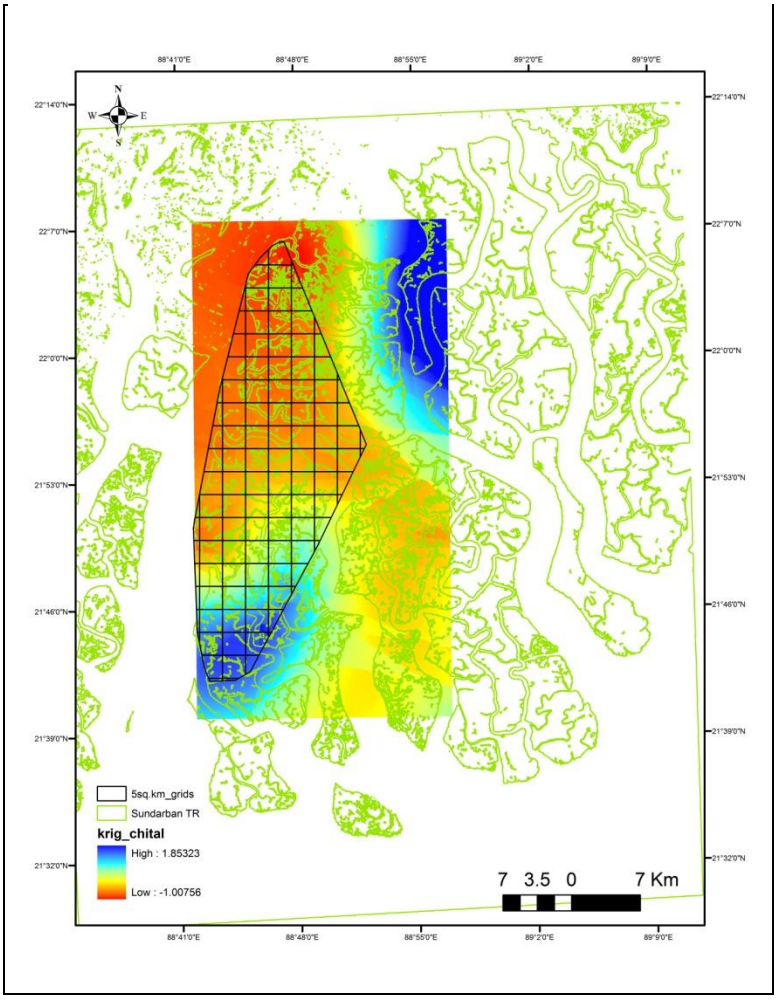
Figure 3.13 Home Ranges (95% MCP) of (n= 4) tigers plotted on Vegetation Map of Sundarban Tiger Reserve.



3.8.8. Relative abundance of prey species

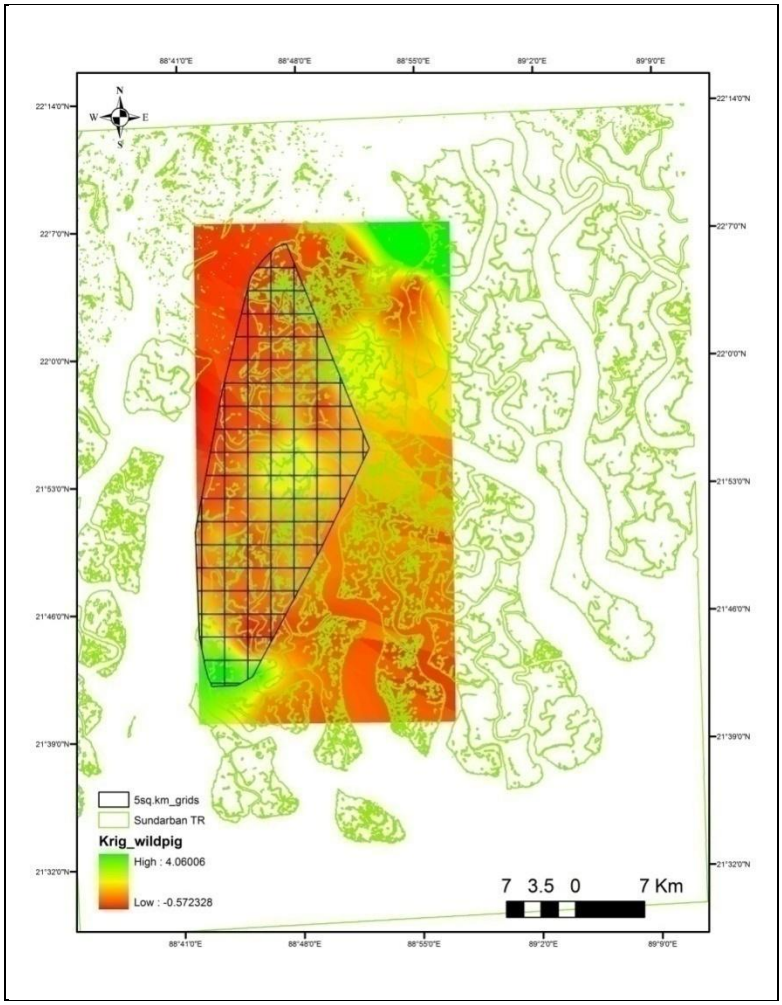
The overall encounter rate for chital sign was 1.92 per kilometer with a total of 477 signs recorded during the surveys (Figure 3.14).

Figure 3.14 Kriging based Grid wise Interpolation Map for chital use within overall home range of radio-collared tigers (n=3) in Sundarban Tiger Reserve.



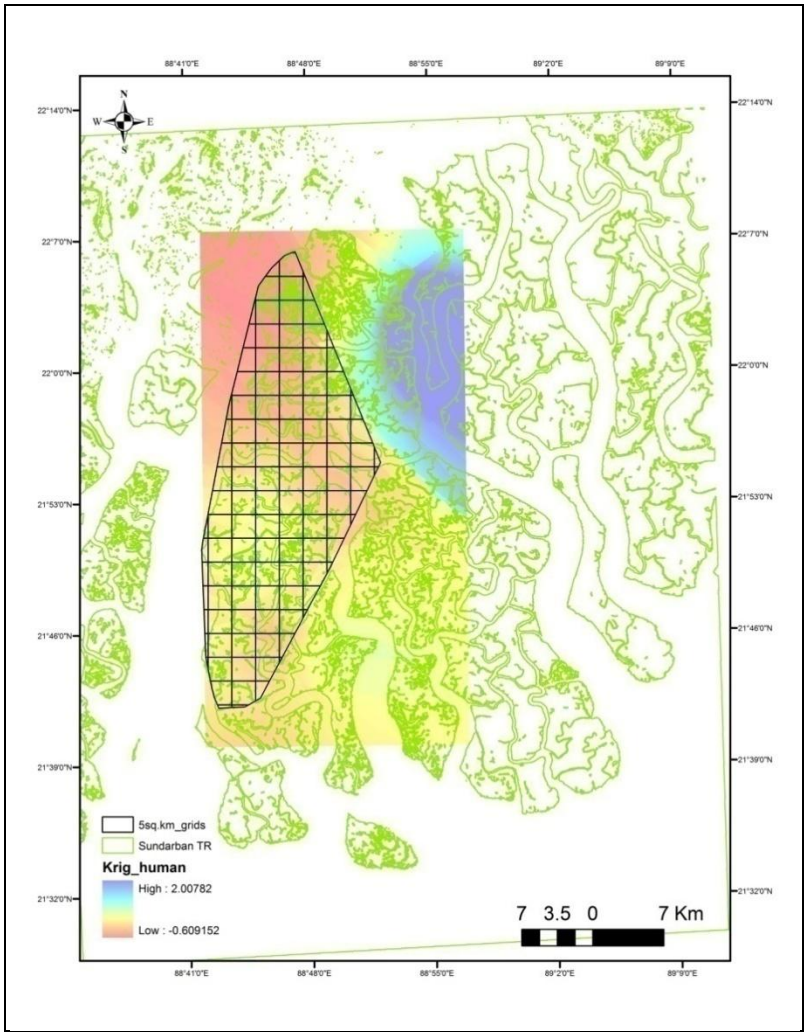
The encounter rate per kilometer for wild pig sign was 0.26 with a total number of 65 signs detected during the surveys (Figure 3.15).

Figure 3.15 Kriging based Grid wise Interpolation map for wild pig use within overall home range of radio-collared tiger (n =3) in Sundarban Tiger Reserve.



The encounter rate per kilometer for human sign was 0.56 with a total of 138 signs recorded during the surveys (Figure 3.16).

Figure 3.16 Kriging based Interpolation Map of human use within overall home range of radio-collared tigers (n = 3) in Sundarban Tiger Reserve.



The overall maps prepared based on boat transects carried out, showed low chital and wild pig presence within the home ranges of radio-collared tigers.

Human usage was low too within the home ranges, being part of the core area with restriction on access imposed by the forest department.

Table 3.5 Mean home range size of different sub-species of tiger from Nepal, Bangladesh, India, Indonesia and Russia.

Place	Method	HR Adult Male (n) km²	HR Adult Female (n) km²	Reference
Chitwan (Nepal)	RT (MCP)	54.1 (2)	16 (3)	Sunquist 1981, 2010
Panna (India)	RT (MCP)	188.6 (2)	42.2 (4)	Chundawat *et al.* 2002
Nagarahole (India)	RT (MCP)	25.7 (1)	16.5 (1)	Karanth and Sunquist 1995
Sikhote-Alin (Russia)	RT (MCP)	1385 (6)	390 (14)	Goodrich *et al.* 2010
Kanha (India)	RT (MCP)	102 (2)	10.5 (4)	Sharma *et al.* 2010
Sariska (India)	RT (MCP)	168.6 (1)	202.4 (2)	Sankar *et al.* 2010
Ranthambore (India)	RT (MCP)	46.1 (4)	20.1 (2)	Jhala *et al.* 2010
Pench (India)	RT (MCP)	55.1 (1)	44 (1)	Majumdar *et al.* 2012
Nagpur (India)	RT (MCP)	NA	726 (1)	Athreya *et al.* 2014
Indonesia	RT (MCP)	236 (4)	NA	Obrien *et al.* 2003
Sundarban (Bangladesh)	RT (MCP)	NA	12.3 (2)	Barlow *et al.* 2011
Sundarban (India)	RT (MCP)	NA	44 (1)	Sharma *et al.* 2011
Sundarban (India)	RT (MCP)	141.7 (3)	336.8 (1)	Present Study 2014

RT= Radio-telemetry, MCP= Minimum Convex Polygon

3.9. Discussion

The high frequency of locations together with the results of the home range asymptote curves as observed during the present study suggested that they were effectively estimated, but it is possible that the full home ranges were not ascertained due to the limited longevity of the collars. Male Tigers maintain exclusive home ranges, with little overlap between males encompassing home ranges of several females (Sunquist 1981). Females maintain home ranges large enough to meet the energetic demands of reproduction and are often philopatric, settling in areas close to their natal site (Smith *et al.* 1987). Size of home ranges shows an inverse relationship with abundance of prey. The smallest ranges reported are from tropical deciduous, forests and resource rich grasslands of India that have high primary productivity and support high ungulate abundance and diversity.

The home range for tiger, as small as 25 km² for males and 10.5 km² for females from Nagarahole (Karanth and Sunquist 1995) and Kanha (Sharma *et al.* 2010) have been reported (Tabel 3.5). The largest home range of tiger's 1385 km² for males and 390 km² for females are reported from the Russian FarEast, an artifact of low prey abundance (Goodrich *et al.* 2010). Range size of Sundarban tigers were between these two extremes and suggests higher resource availability compared to the Russian Far East but lower than that of deciduous forests. This study showed that tiger range sizes are much larger than reported from Bangladesh Sundarban (Barlow *et al*. 2011) suggestive of a low tiger

density in the Indian side. Tiger range sizes as low as 16.5 km² are reported for females from tropical deciduous forests of Nagarahole, India (Karanth and Sunquist 1995) and alluvial floodplains of Chitwan, Nepal (Sunquist 1981, Smith *et al*. 1987, Karanth and Sunquist 2000). The radio-collared tigress in Sundarban, during the present study, was a dispersing individual captured on the edge of the mangrove forest near a village. She had a home range of 329.9 km² (95% MCP) which is comparable to home range of a collared tigress 726 km² (95% MCP) in a human dominated landscape near Nagpur, Maharashtra (Athreya *et al*. 2014). The Sundarban tigress travelled a distance of 120 kilometers in 27 days from the day of her release till she dropped her collar in early April 2010. Earlier telemetry studies have shown that breeding tigers are territorial with an average home range size of 12.3 km² in Bangladesh Sundarban (Barlow *et al*. 2011), 40 km² in Indian Sundarban (Sharma *et al*. 2011). The male 7825 captured from one of the peripheral villages on the northern part of the Tiger Reserve during the present study crossed the kilometer wide Harinbhanga River in early June 2010 and settled in Talpatti island of Bangladesh, where he remained for two months till the collar remained operational, suggesting that tigers preferred not to cross wide water channels yet these were not barrier to dispersal. The tiger population of India and Bangladesh Sundarbans is a single continuous population and trans-boundary conservation between the two countries is vital for long term population persistence.

The mean distance moved by tigers per day in the present study was comparatively more than that as reported by Barlow *et al.* (2009) from Bangladesh (3.6 km/day), Panna (1.4 km/day) (Chundawat *et al.* 1999) and Chitwan (2.4 km/day) (Sunquist 1981). This could be attributed to the large number of GPS fixes received from the Satellite collars compared to limited fixes obtained using VHF collars in previous studies. Though there was no significant difference in distance travelled by tigers during different time zones, yet maximum distance moved were recorded during the day and afternoon. Tigers are crepuscular and nocturnal, an adaptation to evade confrontation with humans in majority of landscapes where they co-exist (Inskip and Zimmerman 2011). Sundarban Tigers are probably the least persecuted tiger's in the world and therefore do not fear people. This seems to be the reason for diurnal activity which coincides with the activity of their prey, the spotted deer. Majority of the human kills by tigers were recorded in the daytime between 8 AM and 12 PM (Khan, 2004; Chakrabarti, 1992) including 39% of human-tiger conflict incidents in the present study. Thus, diurnal movement pattern of tigers in Sundarban seems to be a major factor resulting in fatal attacks on humans. Similar findings were reported by Khan (2004) and Chakrabarti (1992). Diurnal movement pattern of tigers in Sundarban seems to be a major factor in humans kills recorded during the day.

The entire Indian Sundarban comprises of 52 islands crisscrossed by innumerable water bodies of varying widths locally referred to as `khals', hence

tigers routinely commute between islands either in search of prey or patrolling territories. Jaguars are also reported to move between islands in the Pantanal crossing water bodies and rivers (Rabinowitz 1986). Tigers routinely commute between islands either in search of prey or patrolling territories with an average of 5.19 channels crossed per day and a mean width of 54 meters (SE 4.1). Though channels of more than 400 meters in width were avoided and seldom crossed, yet banks of these wide channels were intensively patrolled by tigers suggestive of well guarded territories. A high proportion of human kills occurred in proximity of areas with 30 to 50 meter width channels (Chapter 4). Tigers rarely do cross over to peripheral villages separated from the Reserved Forests by a kilometer wide or more in width channels. There are records from 1900 to 1922, which suggests that tigers swum across 29 Km of the Hooghly river, and that one tiger might have crossed 10-56 Km of open water, depending on where it started (Garga 1947).

Barlow *et al.* (2009) stated that tigers in the Sundarban are smaller in size as compared to mainland tiger populations of India, South East Asia and Russian FarEast. Crossing channels and maneuvering between islands ideally burns a lot of body fat exhausting considerable energy reserves leading to lean, muscular and agile tigers. Over a period of time natural selection seems to have favored survival of smaller and lighter individuals with increased fitness to inhabit these islands. The study area experienced an average of 6 hours of high and 6 hours of low tide twice a day. Tidal cycle plays significant role in the daily life of

terrestrial fauna, especially in a mangrove ecosystem but due to limitations of data it was not possible to infer on its effect on movement pattern of tigers. Spring tide comprises of 8 days with extreme tidal fluctuations and severe water currents as compared to 6 days of Neap tide phase when currents are milder and tidal fluctuations were found minimal. Radio-collared tigers moved more during Neap tide phase as compared to Spring tide phase in the study area. Currents are milder during neap tide phase compared to strong currents during spring tide, substantial dry land area remains exposed allowing tigers to explore between islands.

I used Neu *et al.* (1974) approach to assess habitat preference in place of more recent methods such as compositional analysis (Aebischer *et al*.1993). This is because Neu *et al.* (1974) is more robust for smaller samples while the recent methods require more than six individuals. *Phoenix* and *Ceriops* patches were used according to their availability, though there is a preference shown for *Avicennia* patches. *Sonneratia* and *Avicennia* patches grow along periphery of channel banks in relatively low lying islands, with regular tidal water inundation. A study of chital using telemetry (Dey 2004), documented ungulates to exhibit habitat preference for *Sonneratia*, *Avicennia* and *Exocoeceria* dominated patches in the Sundarbans. They provide enhanced visibility and ease of movement for hunting prey compared to dense *Ceriops*, *Exocoeceria* and *Phoenix* patches. Tigers spend a considerable time frequenting these places likely in pursuit of their primary prey. *Phoenix* dominated patches, provide dry ground to seek

refuge from extremes of tidal fluctuations, growing in areas with relatively higher ground. Chakrabarti (1984) and Choudhury and Sanyal (1985) reported tigers to have a preference for *Phoenix paludosa* and *Sonneratia-Avicennia* mixed stands in the Indian Sundarban which is similar to the present findings. Based on encounter rate of pugmarks, Khan (2004) reported that tigers do not have a significant preference for certain habitat types in the Bangaldesh Sundarban. Thus minimum human disturbance and intrusion should be permitted by the Forest Department within these habitat types in order to reduce human-tiger conflicts.

The Sundarban Tiger Population is of global importance for the conservation of the species due to the size of the contiguous habitat and the unique adaptations of the tigers that inhabit these mangrove forests. In spite of only four tigers which could be radio-collared and monitored this study contributes by enhancing our understanding aspects of tiger ecology in this unique habitat. Sundarban tigers are primarily diurnal and prefer certain habitat types. This information can be used to minimize human-tiger conflict which is a major impediment to tiger conservation in this region.

Plate 3.1. Radio-collared tigress in Sundarban Tiger Reserve.

Plate 3.2. Radio-collaring a male tiger in Sundarban Tiger Reserve.

CHAPTER 4
HUMAN-TIGER CONFLICT IN SUNDARBAN TIGER RESERVE

4.1. Introduction

Large carnivores such as tigers (*Panthera tigris*), often present unique challenges to wildlife managers, frequently killing livestock and attacking humans (Treves *et al*. 2002, Patterson *et al*. 2004, Packer *et al*. 2005, Woodroffe *et al*. 2005, Kolowski and Holekamp 2006, Holmern *et al*. 2007). Being apex predators they play vital role in regulating natural ecosystems and generate public support too as flagship species of conservation (Linkie and Christie 2007). South Asia harbors the highest densities of tigers (McDougal 1977, Smith *et al*. 1987, Karanth *et al*. 2004, Barlow *et al*. 2009) and also has the largest number of man-eating cases (McDougal 1987, Khan, 1987, Singh 1993, Corbett 2005). Man-eating has been documented throughout the tiger's range, including the far east of Russia, Southeast Asia, Sunda Islands and South Asia (McDougal 1987, Miquelle *et al*. 2005).

Tigers are k-selected with low reproductive potential requiring abundant large prey (Smith *et al*. 1987, 1998) and extensive habitats often overlapping with humans (Sunquist 1981, Smith *et al*. 1987, 1998). With the rising human population and resources required to sustain them, vast stretches of wild lands have been fragmented and cleared to make way for agriculture. As a consequence, the geographic distribution range of tigers has been reduced to <7 % of its historical distribution (Dinerstein *et al*. 2007), three sub-species of tigers have gone extinct (Seidensticker 1987). Rapid encroachment and habitat

fragmentation has reduced tigers to occupy isolated small pockets surrounded by seas of human civilization (Smith *et al*. 1998). As documented through several ecological studies conducted over a decade tiger densities are somehow positively correlated to prey densities, primarily large ungulates (Karanth and Sunquist 1995, 2000, Karanth and Nichols 1998, Karanth *et al*. 2004).

Humans have hunted ungulate species (mainly deer and pig) since the last 40,000 years, mainly for subsistence thus directly exterminating prey base to sustain tiger populations (Corlett 2007). Prey depletion has surfaced as one of the primary reason for local extinction of tigers in the past 100 years (Karanth and Stith 1999). Declines in natural prey persuaded tigers to predate on livestock and occasional humans. In retaliation local people have poisoned, hunted down tigers to avenge personal and economic losses. Therefore, human-tiger conflict is a major threat to the continued survival of tiger, reducing their numbers and generating negative attitude to their conservation. With only three thousand odd tigers surviving in the wild these factors could be decisive in shaping their future existence. The goal of this present study is to enhance understanding and ultimately recommend strategies to reduce human-tiger conflicts.

4.2. Review of Literature

Human–tiger conflict

Human tiger conflict can be grouped into three categories: tiger attacks on humans, tiger attacks on domestic animals and tigers that approach human-

dominated areas. Tigers might attack people as prey, but most commonly attack people defensively to protect their cubs or themselves, particularly when wounded by people (McDougal 1987, Gurung *et al*. 2008, Goodrich *et al*. 2010). Tigers usually attack domestic animals as prey, most commonly in areas where wild prey has been depleted. When tigers enter human-dominated areas, it is not a conflict per se, but such events might be a precursor to conflict and receive considerable attention from local people, who often request intervention from government authorities and hence, are considered human-tiger conflict (Nugraha and Sugardjito 2009, Goodrich *et al*. 2010). Depredations on domestic animals are the most common type of human-tiger conflict. Tigers readily kill livestock and dogs in areas where wild prey are depleted, usually due to hunting, habitat degradation and competition with livestock (Madhusudan and Karanth 2002, Miquelle *et al*. 2005, Johnson *et al*. 2006, Wang and MacDonald 2006, Sangay and Vernes 2008, Nugraha and Sugardjito 2009). Typically livestock make up a very small portion of the tiger's diet and most tigers avoid livestock altogether (Sunquist 1981, Miquelle *et al*. 1996, Stoen and Wegge 1996, Karanth 2003, Andheria *et al*. 2007). However, in extreme situations, losses might reach as high as 12% of local herds and 17% of annual household income (Madhusudan 2003, Wang and MacDonald 2006, Sangay and Vernes 2008), and livestock can make up over 25% of the tiger's diet (Wang and MacDonald 2009).

Sangay *et al*. (2008) examined the predation activity throughout Bhutan by tiger (*Panthera tigris*), common leopard (*Panthera pardus*), snow leopard (*Uncia*

uncia) and Himalayan black bear (*Ursus thibetanus*) on a variety of livestock types using data gathered over two years (2003–2005) of a compensation scheme for livestock losses. Leopards killed significantly more livestock (70% of all kills), than tigers (19%), bears (8%) and snow leopards (2%). About 50% of livestock killing were of cattle, and about 33% were of horses, with tigers, leopards and snow leopards killing a significantly greater proportion of horses than predicted from availability. Examination of cattle kills showed that leopards killed a significantly greater proportion of smaller prey (e.g. calves), whereas tigers killed a significantly greater proportion of larger prey (e.g. bulls). Overall, livestock predation was greatest in summer and autumn which corresponded with a peak in cropping agriculture; livestock are turned out to pasture and forest during the cropping season, and subsequently, are less well guarded than at other times.

Johnson *et al*. (2006) examined the effects of human–carnivore conflict on tiger and prey abundance and distribution in the Nam Et-Phou Louey National Protected Area on the Lao–Vietnam border. The relative abundance of large ungulates was low throughout whereas that of small prey was significantly higher where human density was lower. Tiger abundance was significantly lower where human population and disturbance were greater. Three factors, commercial poaching associated with livestock grazing, followed by prey depletion and competition between large carnivores, were likely responsible for tiger abundance and distribution. Findings from a study conducted in Bangladesh

Sundarban by Denzau *et al*. (2010) revealed that high level of disturbance by forest resource users seems to provoke man-eating behavior among tigers. About 91% of resource extractors had expressed positive response in favor of their interest to be involved with alternative jobs. Gurung (2008) investigated the ecological and sociological aspects of human-killing in the central lowlands of Nepal. Thirty-six tigers killed 88 people from 1979 to 2006. Most (66%) kills were made within 1 km of forest edge but equally in degraded and intact forests. An equal number of male and female tigers killed humans and 56% of tigers that were examined had physical deformities. The trend of human deaths increased significantly from an average of 1.2 (SE 1.2) persons per year prior to 1998 to 7.2 (SE 6.9) per year from 1998 to 2006. This difference was primarily to a tenfold increase in killing in the buffer zone since 1998 because of forest restoration. Nearly half the people killed were grass/fodder collectors.

Goodrich *et al*. (2011) examined data from wild Amur tigers to establish a baseline for degree of canine breakage in wild tigers not involved in conflict, tested for sex and age-related patterns in canine breakage, and estimated impacts on survival and reproduction. He further compared canine breakage in research tigers to that in tigers captured or killed in human tiger conflict situations and concluded that broken canines do not usually represent a serious health issue and are usually not related to conflict. Similar results have been found for lions and the trend may be true for other large cats and carnivores as well (Patterson *et al*. 2003).

Unlike other tiger populations, tigers of Sundarban are held responsible for a considerable number of human deaths annually (Montgomery 1995, Karanth 2000). The Sundarban is home to some of the highest level of tiger-human conflict in the world (Blanford 1891, Siddiqui and Choudhury 1987, Chakrabarti 1992), probably because many people are dependent on the natural resources of the Sundarban. This high level of human activity does not create a suitable habitat situation for tigers (Griffith and van Schaik 1993). Man-eating as reported from other parts of the tiger's distribution range is primarily an outcome of old age or injury, making tigers incapable of catching wild prey (Mountfort 1969, Nowell and Jackson 1996). Blanford (1891) notes the death of 4,218 people due to tiger attacks over a six-year period from 1860 to 1866 in Sundarban (Bangladesh and Indian Sundarban). Thus keeping in perspective the intensity of conflict since historic times I was interested in identifying the key drivers and suggest mitigation actions which the park authorities should find feasible to implement.

Predation risk modeling is rapidly emerging as a quantitative tool with applications for mitigating human-carnivore conflict. By correlating environmental conditions at sites with previous kill records, these models predict probability of carnivore attacks on prey known as predation risk. Hunting behavior of a predator is governed by its movement pattern and hunting mode with respect to spatial attributes and consequentially shape the way that prey move and utilize space (Schmitz 2005, Atwood *et al.* 2009). Predation risk from stalking predators like large cats can depend on topography, land-use, vegetation structure, human

presence, and the density of both predators and prey (Atwood *et al.* 2009, Kissling *et al.* 2009, Valeix *et al*. 2009, Karanth *et al*. 2012, Loarie *et al.* 2013, Zarco-Gonzalez *et al.* 2013). Heterogeneity of these landscape variables directly impact hunting success, favoring attributes where prey is easy to detect, catch or encounter thus making certain areas hotspots of predation (Balme *et al.* 2007, Laundre *et al.* 2009, Gorini *et al.* 2012). Species utilize landscape features differently by spatial scale and select resources through a hierarchical decision-making process (Senft *et al.* 1987, Wiens and Milne 1989, Levin 1992, Creel and Winnie Jr. 2005). Thus through this study I investigated the effects of model structure on predation risk models of carnivore attacks on humans in the mangrove forests of Sundarban.

4.3. Methodology

4.3.1. Field Data Collection

Forest department records, published literature and newspaper archives were compiled and examined to gather information on human-tiger conflict for the past 47 years (1963-2013). Family members of tiger victims were interviewed across different villages to authenticate information on reported human killing by tigers. Places where tigers have killed humans in the past few years (2008-2013) were visited either accompanied by local people, companion of the tiger victim, family member or forest personnel who had inquired about the ground reality of the incidents. Areas which were inaccessible by boats due to narrow width of channels were left out of the surveys. I collected data on vegetation type, width of

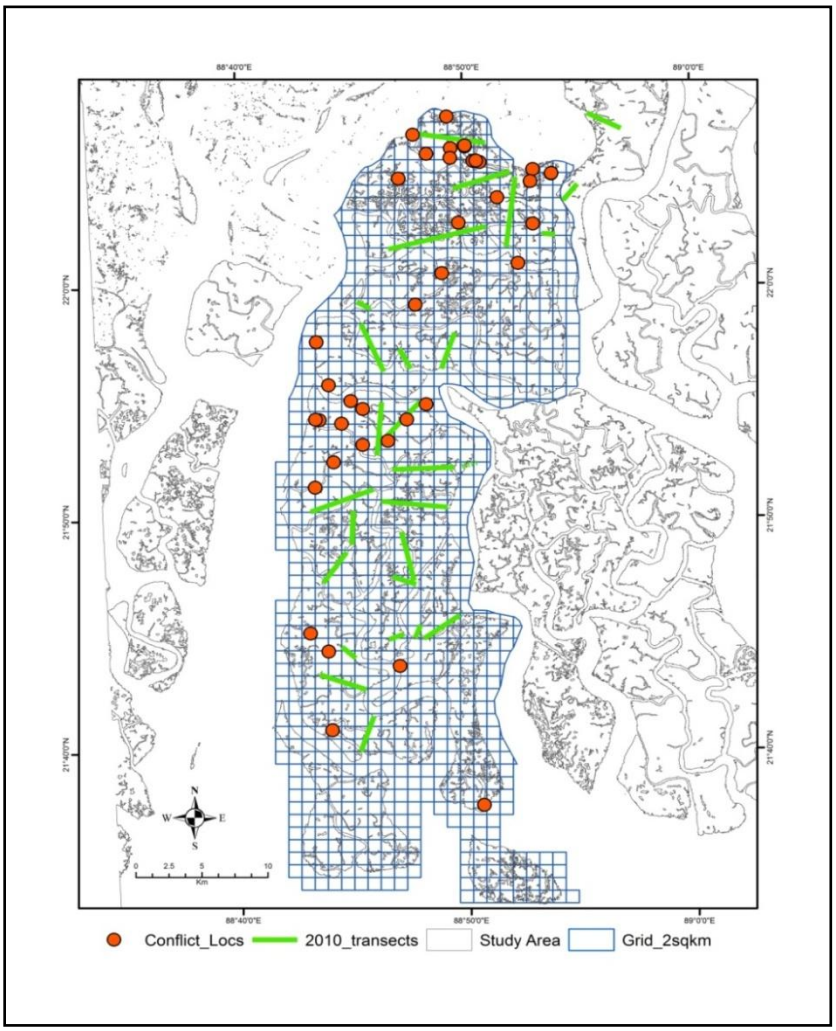
channel, GPS location and other relevant information of each individual site (N=29) within Sajnekhali Wildlife Sanctuary and West Range of the Tiger Reserve between 2010 and 2013. It was not feasible to collect data on human kills throughout the Tiger Reserve due to unreliable information and lack of observers, family members, forest staff who had witnessed or at least visited the site. Primarily the victim, family members of the victim and the local people (only when the victim or his/her family was unwilling to cooperate) were informally interviewed to obtain the details about the demographic profile of the victim, human activity patterns during tiger attacks and a brief description about the attack event (location, time, nature, body parts attacked, people accompanying etc.). All the attacks sites surveyed and people interviewed involved fatal interactions claiming victim's life instantaneously. Almost all attacks on humans were deliberate as gathered from the interviews.

The intensive area within which data on human kills were collected was stratified into 1x1 Km^2 (2 sq.km) grids for gathering information pertaining to habitat and ecological variables (Figure 4.1). Due to ever present threat from man-eating tigers and difficulty of walking inside the mangroves it was not possible to conduct ground surveys, hence the channel banks were surveyed when exposed during low tide. Due to the unique nature of mangrove ecosystem and tidal fluctuations the entire area was submerged under water twice a day during high tide. This left me with a window of six hours every day to conduct surveys, three hours after setting of low tide and three hours after setting of high tide when the

banks were completely exposed for observing signs deposited by animals. Within the intensive study area, boat transects (N= 34) of five to ten kilometers in length were conducted between February 2010 and April 2010. GPS coordinates along with type of mangrove, slope of the bank and width of the upper and lower bank were noted for each sign encountered. The locations were recorded using GARMIN© 72 GPS unit. Data on major vegetation types were collected for each transect at every 400 meters interval. Anthropogenic pressure and dependence of local people on forest resources such as fishing and crab collection were also quantified along each transect.

I checked Forest Department registers, compiled records of livestock depredation and straying incidents by tigers between 1998 and 2010 in peripheral villages of the Tiger Reserve in order to evaluate seasonal and temporal variation of livestock depredation.

Figure 4.1 Map of Intensive Study Area within Sundarban Tiger Reserve with superimposed (1x1 km²) grids and conflict locations.



4.3.2. Analysis

I used chi-square analysis (α = 0.05) (Zar 2010) to compare tiger attack events between seasons, months of the year, time of the day and different demography classes. Conflict information was collected on a presence/absence basis within the intensive study area with a grid having a conflict incident recorded as '1' and

‘0’ if absent. Records were converted into digital data in GIS using program Arc GIS (Environmental Systems Research Institute, Redlands, CA, USA), and were stored on the base map prepared for Sundarban Tiger Reserve. A total of five macro habitat characteristics and variables were considered for the analysis (Table 4.1). Anthropogenic variables (distance from villages) and human intensity of use within grids, prey encounter rates such as chital and wild pig, tiger signs, Normalized Differential Vegetation Index (NDVI) and hydrological variables such as length of different width of channels within individual grids were also recorded. These variables were selected based on field knowledge and information on human-tiger conflict from published literature (Khan 2004, Barlow *et al*. 2009).

4.3.3. Vegetation Map

Mapping of vegetation types was done during the present study by laying 15m x 15m circular plots (n = 145) at every 400 meters of the Tiger Reserve between February and June 2010. Major tree species, ground cover and shrubs within these plots were enumerated. Remotely sensed data of Landsat-5-ETM + imagery (30M resolution) for the month of February 2010 Geo coded False Color Composite (FCC) on 1:50,000 scale was used for entire Sundarban Tiger Reserve and different color tones for 30 classes were prepared. The color classes were merged depending on the similarity in vegetation types based field collected data. The map was first improved using supervised maximum likelihood classifier to incorporate unclassified and misclassified data. Six vegetation types were identified and finalized with 80% accuracy. Area occupied by each

vegetation type was extracted grid wise (1x1 km²) from the vegetation map using Arc GIS 9.3.

4.3.4. Distance from village

All village locations were recorded using Global Positioning System (GPS) during the field work. The locations were then digitized and Euclidian distance was calculated for each grid center from the nearest village.

4.3.5. Relative abundance of prey and human use

I used ordinary kriging to estimate prey (chital, wild pig), tiger and human usage probabilities in non-sampled areas based on boat transects (n = 34) conducted across the sampled area. Kriging is a geostatistical interpolation technique that permits inferences about a parameter of interest (i.e. the probability of use) in non-sampled areas by using information available in sampled locations and accounting for uncertainty as the distance between spatial locations increases. The approach produces a semivariogram that describes the spatial correlation between the points. Based on the Akaike's information criterion (AIC), I fitted the Gaussian model to the observed data, using the Kriging Interpolator in Arc GIS 9.3 Spatial Analyst Tool (Rodgers and Kie 2010). Maps were generated based on the usage probabilities for the intensive study area within Sundarban Tiger Reserve.

4.3.6. Channels

Based on Google Earth and LandSAT 30 m resolution imagery (February 2010), a map with creeks/channels demarcated within Sundarban Tiger Reserve was prepared using Arc GIS 9.3 (ESRI Redlands USA). Channels were categorized as 30 to 50 meters, 50 to 100 meters, 100 to 150 meters, 150 to 200 meters and > 200 meters in width respectively (Table 4.1). Within the superimposed grids of 1x1km^2 all channels from 30 to 50 meters to more than 200 meters in width along with their respective lengths were enumerated in Arc GIS 9.3.

The tiger attack data was analyzed to arrive at spatial-temporal pattern of such attacks. I used chi-square analysis ($\alpha = 0.05$) (Zar 2010) to compare attack events between seasons, months of the year, time of the day and different age classes of tiger victims. A total of 15 predictor variables (independent variables) were selected based on their ecological importance. I composed histograms to check for difference between predictor variables within sites with no conflict and conflict records in SPSS 17.0 (Figure 4.17). To explore interrelatedness of individual predictor variables, I computed Pearson correlation coefficients (Zar 2010) in SPSS ver. 17.0 (Table 4.2). The independent variables were selected based on their ecological importance and correlation values (Table 4.2). I selected thirty random subsets of 58 grids, without conflict records (absence) from the overall dataset and compared with 29 grids with conflict record (presence) and performed binary logistic regressions using SPSS 17.0 (SPSS Inc., Chicago, Illinois) to identify significant drivers of conflict. Dependent variable was coded as 0 = no conflict and 1 = conflict for the regression equations. I

averaged the beta-coefficients of all the variables from the models to arrive at an overall model output. A logistic regression model allows us to establish a relationship between a binary outcome variable and a group of predictor variables. Based on the average beta coefficient values for all the predictor variables, I computed probability of conflict for each single grid of 2 km^2. Using these probability values I prepared a conflict risk map for the intensive study area in Arc GIS 9.3 (Rodgers and Kie 2010).

Table 4.1 List of variables used in regression analysis.

Variables	Variable types	Data Source
Prey information	Chital	Boat transect data 2010
	Wild pig	
	Monitor lizard	
	Rhesus Macaque	
Human disturbance	Fishing and Crab collection	Boat transect data 2010-2013,interviews of fishermen 2010-2013
	Honey collection	
Predator information	Tiger	Boat transects 2010
Hydrological information	30 to 50 meters channel	Wildlife Institute of India, GIS cell
	50 to 100 meters channel	
	100 to 150 meters channel	
	150 to 200 meters channel	
	200 meters	

4.4. Results

4.4.1. Past and present trend of human deaths

From existing published literature and Forest Department records, I compared past and present scenario of human-tiger interactions in Sundarban. The mean number of human casualties to tiger attacks between 1963 and 1978 and 1985 and 2000, in Sundarban Tiger Reserve were 35 (SE 3.15) (Chakrabarti 1978) and 18 (SE 3.4) (Forest Department Records) respectively. Between 2001 and 2013 the average human mortality came down to 6.7 (SE 1.04). There were no records for the years 2005 and 2006, hence they were excluded while calculating the mean. There was a significant difference in the number of human deaths between these three periods (χ^2= 20.39, df = 2, $p < 0.05$). A total of 80 tiger attack events on humans have been recorded between January 2001 and December 2013 (Forest department record and survey of villages) out of which 95% were fatal claiming the victim's life, only in 5% of the cases people were admitted to hospital with mild to medium mauling. There was no significant difference in human deaths between the years 2001 and 2013, with the highest in 2002 (n = 14) followed by nine in 2009 respectively (χ^2= 17.56, df = 10, $p > 0.05$).

4.4.2. Condition of tiger victims

Out of 80 attacks information on 62 cases could be gathered from interviewing local people and checking Forest Department records. There was significant difference observed in the nature of fatal attacks with 65% cases where body

was not recovered, 20% when body was recovered by either family members, companions or forest officials, 3% when victim died on way to hospital, 2% died after being admitted to hospital and rest 9% survived after nursing injuries sustained ($\chi^2 = 136.9$, df = 4, $p < 0.05$). Only 5% of the attacks were reported inside the villages, rest 95% were reported from within the Protected Area.

Figure 4.2 Year-wise variation of human kills by tigers in Sundarban Tiger Reserve between 1963 and 1978.

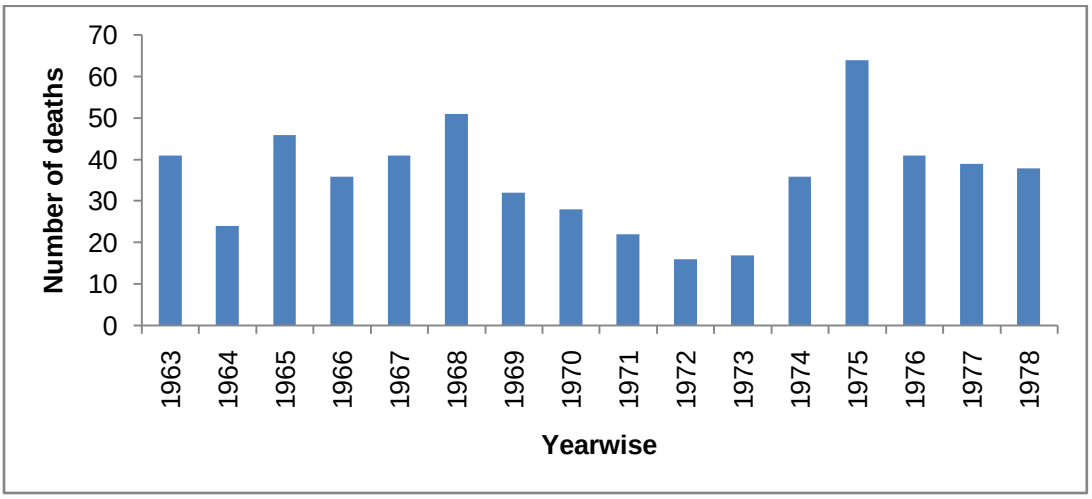


Figure 4.3 Year-wise variation of human kills by tigers in Sundarban Tiger Reserve between 1985 and 2000.

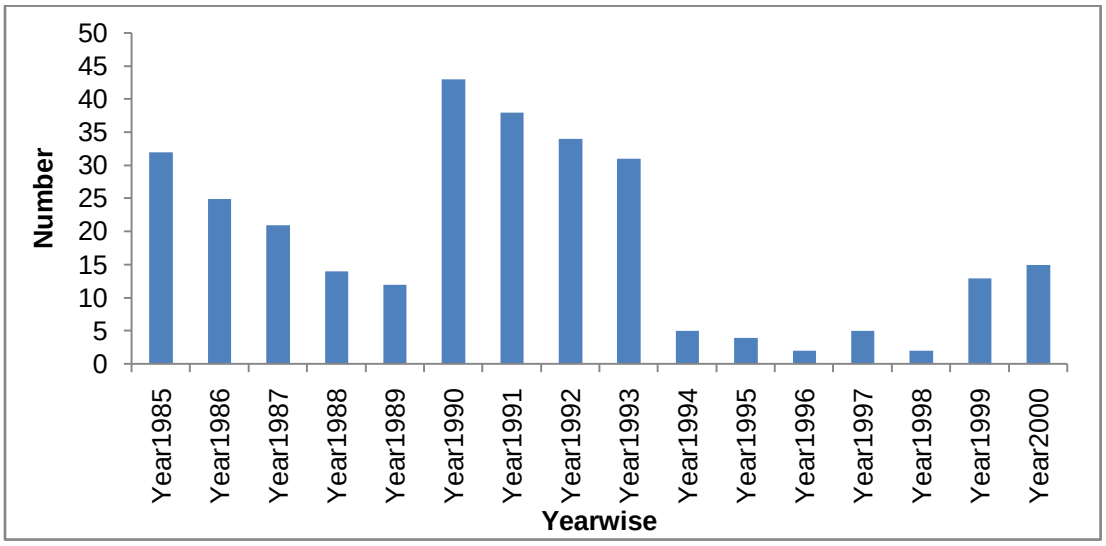
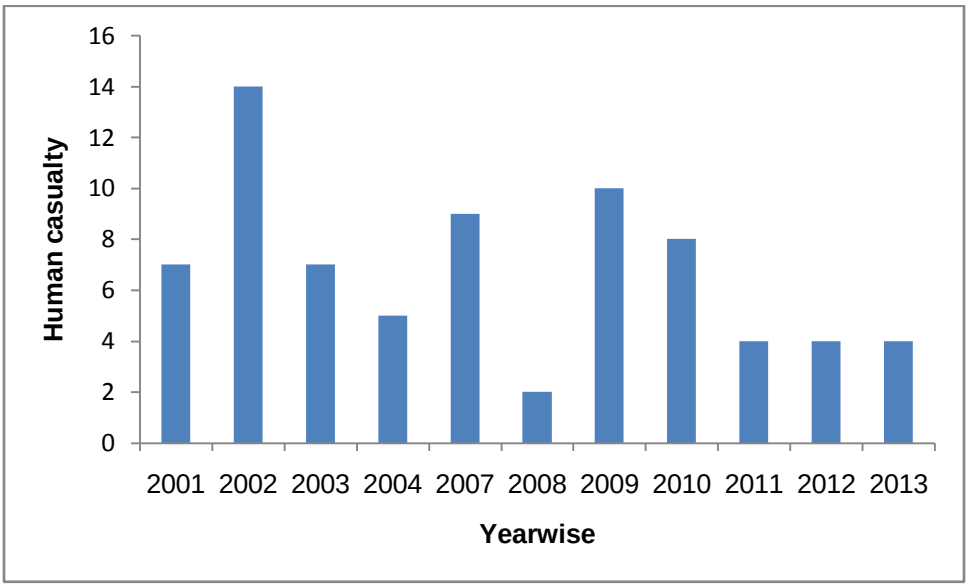


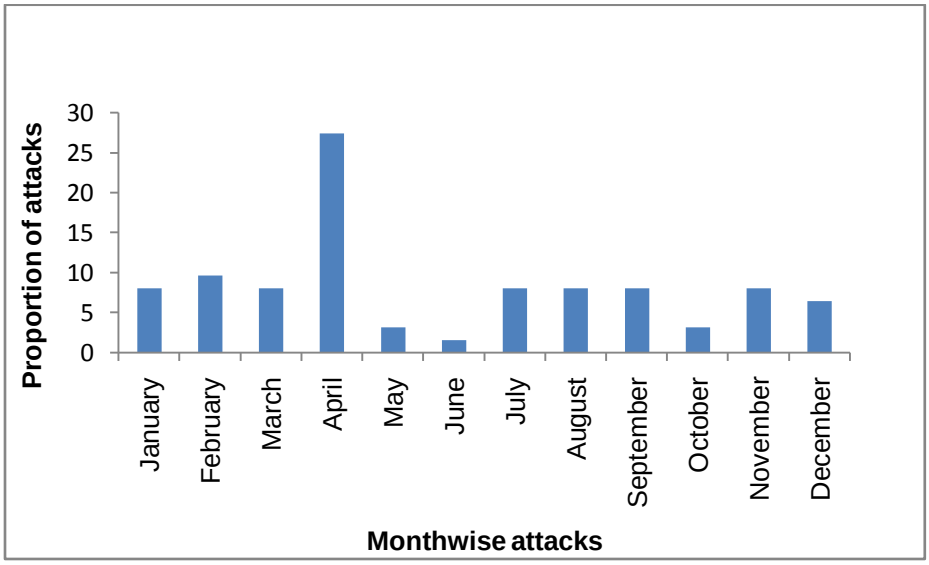
Figure 4.4 Year-wise variation in human kills by tigers in Sundarban Tiger Reserve between 2001 and 2013.



4.4.3. Seasonal and temporal variation in tiger attacks on humans

Tiger attacks varied across seasons with the majority of attack events recorded in April (27%) followed by winter months November, December, January and February (31%) (Figure 4.5) (χ^2 = 52.97, df = 11, $p < 0.05$). Monsoon months (July, August and September) recorded 24% of the incidents. Thirty two percent of the attacks were recorded between 2 and 5 PM, 24% in the morning between 5 and 8 AM and 19% between 8 and 11 AM (χ^2 = 87.31, df = 7, $p < 0.05$). Among the administrative blocks of Sundarban Tiger Reserve, Chamta recorded 24%, Pirkhali 21%, Chandkhali 15% and Netidhopani 13% of the conflict incidents (χ^2 = 64.48, df = 9, $p < 0.05$).

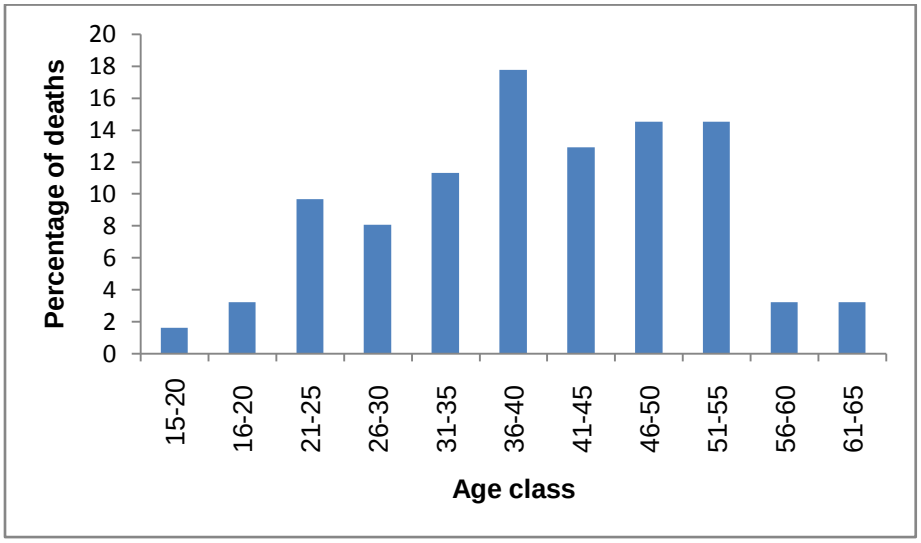
Figure 4.5 Seasonal patterns of human kills by tigers in Sundarban Tiger Reserve between 2001 and 2013.



4.4.4. Age and profession of tiger victims

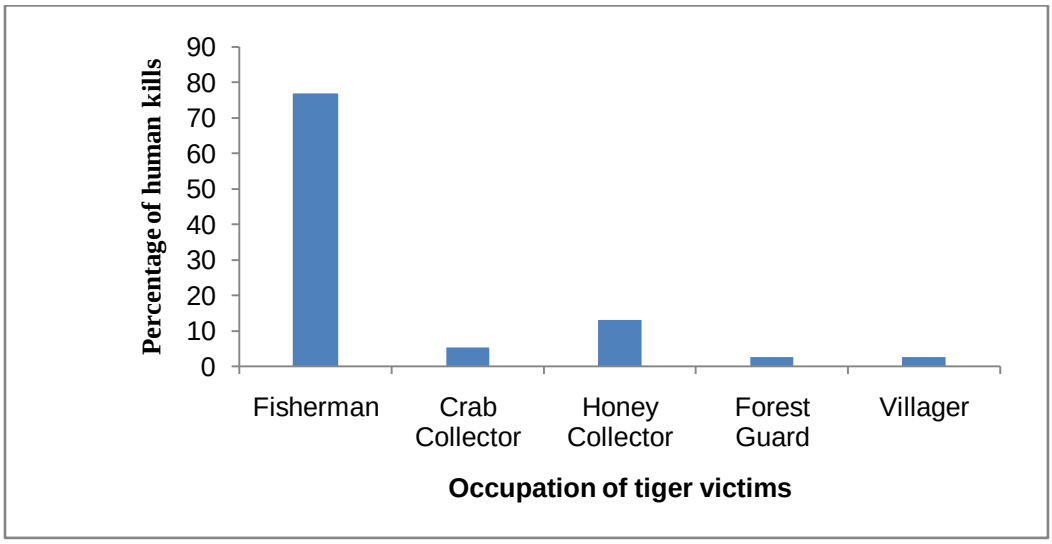
Most of the tiger victims were middle aged, with the average age being 39.9 years (SE 9.3) (Figure 4.6).

Figure 4.6 Age class variation in humans killed by tiger attacks in Sundarban Tiger Reserve between 2001 and 2013.



Majority of the humans killed by tigers were dependent on forests, 77% fishermen, 13% honey collectors, 6% crab collectors and rest 2% forest personnel, 2% villagers (Figure 4.7) (χ^2=.6, df=4, $p < 0.05$).

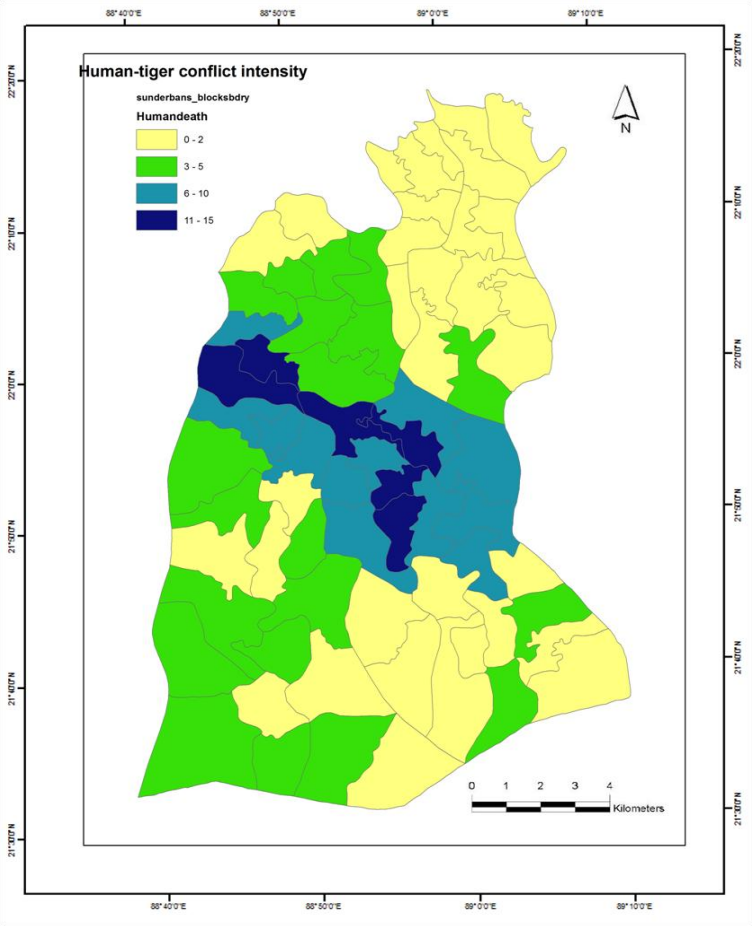
Figure 4.7 Occupation of tiger victims in Sundarban Tiger Reserve.



4.4.5. Spatial extent of human-tiger conflict incidents

There seems to be a clustering of human kills by tigers along the central (eastern and western) part of the Tiger Reserve (Figure 4.18). Conflict intensity was low on the northern and southern tip of the Tiger Reserve. The southern tip is flanked by the Bay of Bengal and Northern tip by hard boundaries i.e. peripheral villages. Thirty three percent of the victims were standing along the edge of the bank, 21% were collecting firewood inside the forest, 18% were arranging fishing line along the bank, 9% catching crabs, 9% resting inside boats, 6% catching fish with hand net and rest 4% were attacked inside the forest while collecting honey (χ^2 =.704, df=5, $p < 0.05$).

Figure 4.8 Spatial extents of human-tiger conflict incidents in Sundarban Tiger Reserve between 2001 and 2013.



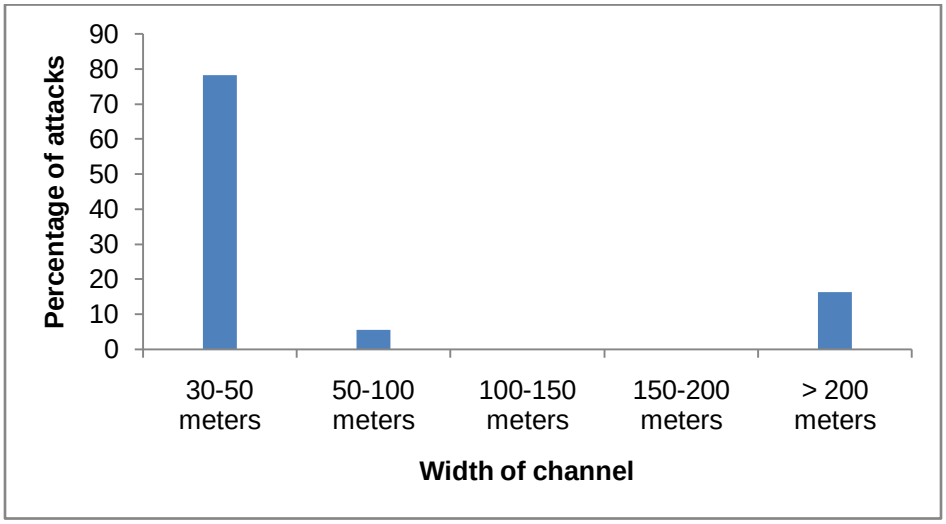
4.4.6. Characteristic of tiger attacks on humans

Majority of the humans were attacked from the rear 60%, 30% face on, 8% from top of the river bank and rest 2% from the side ($\chi^2 = 82.72$, df = 3, $p < 0.05$). Chakrabarti (1978) also reports similar trend of attack in Sundarban during 1970's. Based on records of killed (n = 98) and injured (n = 25) humans, Khan (2004) reported that 92% of the killed people had neck-head bites as the initial

form of attack and 67% of the injured humans did not have neck-head bites in Bangladesh Sundarban. It probably indicates that neck-head bite from rear is the principal stalking and hunting technique of tigers attacking humans. Thirty four percent of the victims attacked were defenseless, 31% had axe or machete, 31% of the group members had axe or machete, only in 4% of the cases firearms were present (only with forest personals) (χ^2 =.5, df=2, $p < 0.05$).

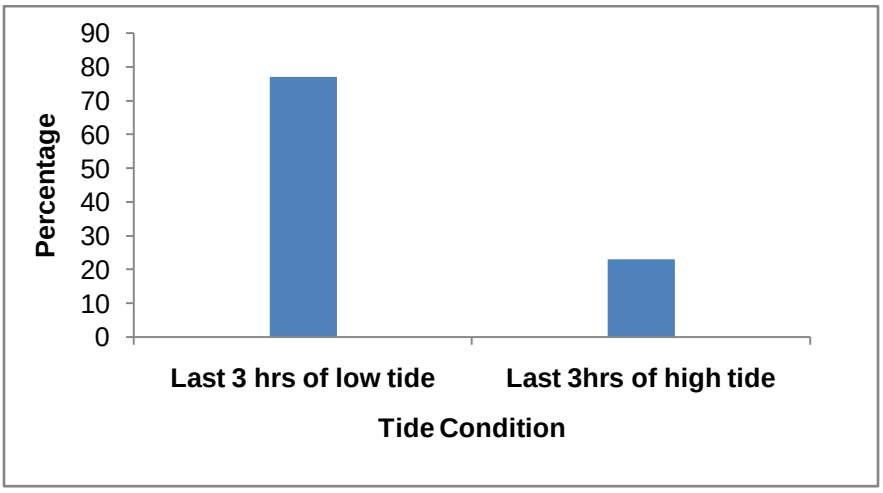
Channels of width 30 to 100 meters were present in 84% of the conflict sites, whereas 16% occurred near channels more than 200 meters in width (Figure 4.9).

Figure 4.9 Variation in channel widths of tiger attack sites in Sundarban Tiger Reserve between 2001 and 2013.



Seventy seven percent of the incidents occurred during last three hours of low tide, 23% in last 3 hours of high tide (Figure 4.10) ($\chi^2 = 29.16$, df = 1, $p < 0.05$).

Figure 4.10 Tide condition during tiger attacks on humans in Sundarban Tiger Reserve.



The average group composition of fishermen killed were 5 (SD 1.7) range (2-8), for honey collectors it was 12 (SD 1.9) range (10-14).

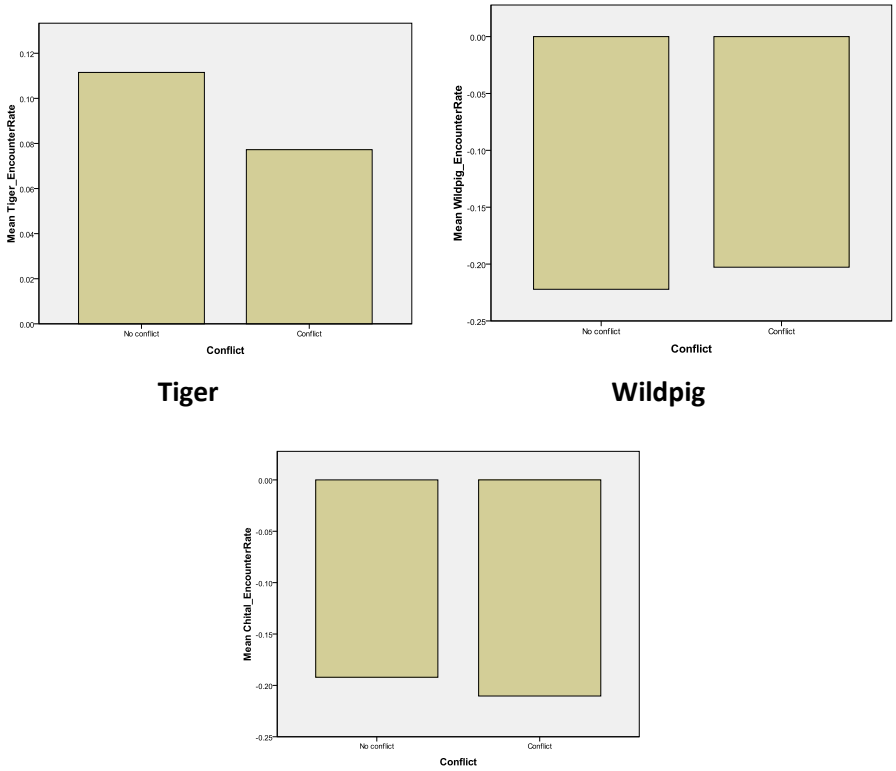
4.4.7. Attributes of conflict sites

Predictor variables

Out of the 15 predictor variables *Avicennia* and *Ceriops* patches and length of 30 to 50 meter, 50 to 100 meter, 100 to 150 meter, 150 to 200 meter width channels were comparatively higher within conflict sites. *Phoenix* vegetation patches and length of more than 200 meter width channels were higher within non-conflict

sites compared to conflict sites. Relative abundance of tiger, wild pig and chital and human usage were similar within both sites (Figure 4.11).

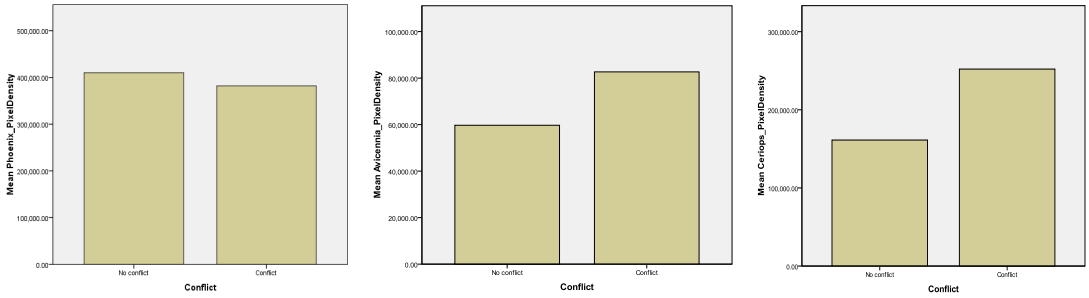
Figure 4.11 Tiger and Prey Encounter Rates (Kriging based z values) within No Conflict and Conflict Zones.



Tiger **Wildpig**

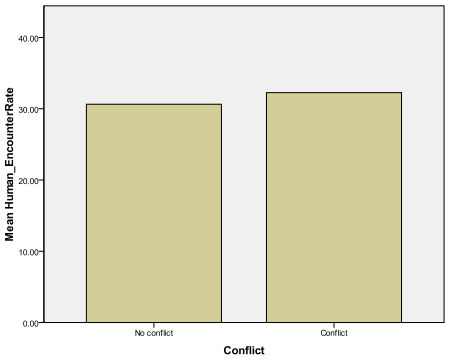
Chital

Cover (Phoenix, Avicennia and Ceriops species pixel density) within No Conflict and Conflict Zones)



Phoenix **Avicennia** **Ceriops**

Human Intensity of use (Kriging based Score) within No Conflict and Conflict Zones

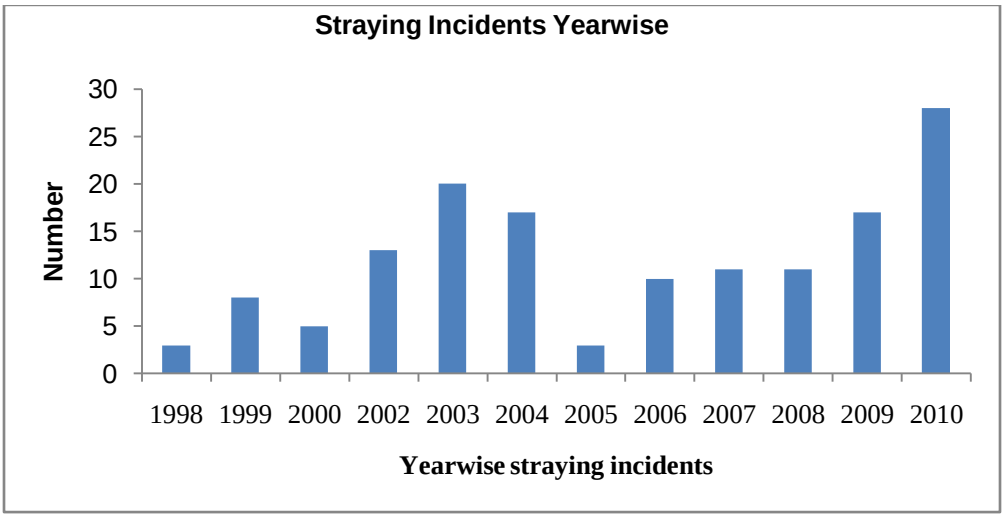


Human Encounter Rate

4.4.8. Seasonal and temporal variation in straying incidents and livestock depredation by tigers

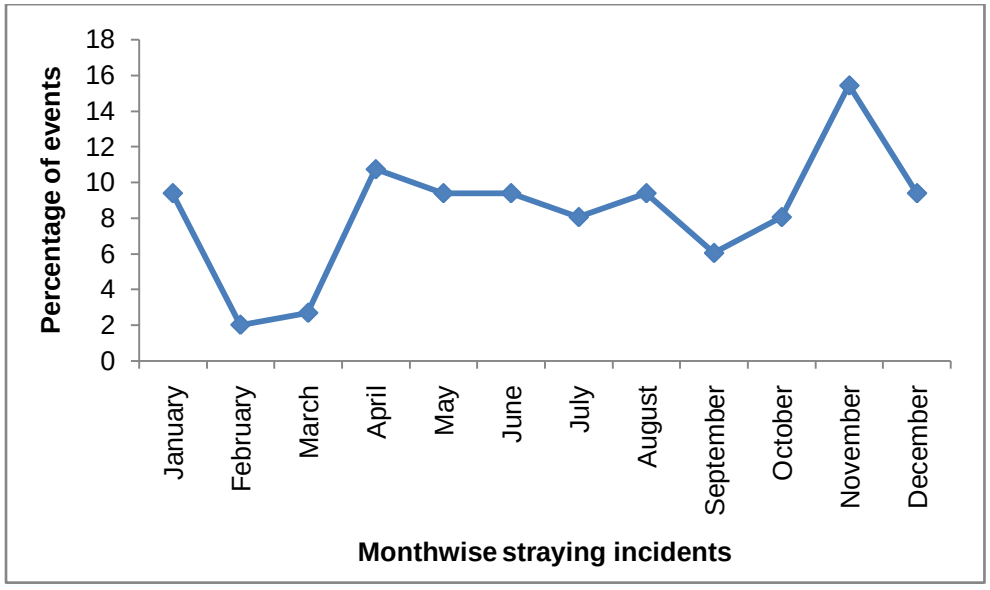
On an average tigers strayed 12.4 times per year (SE 0.3) during the period between 1998 and 2010 in peripheral villages of the tiger reserve (Figure 4.12) (Plate 4.1).

Figure 4.12 Straying incidents of tigers in peripheral villages between 1998 and 2010.



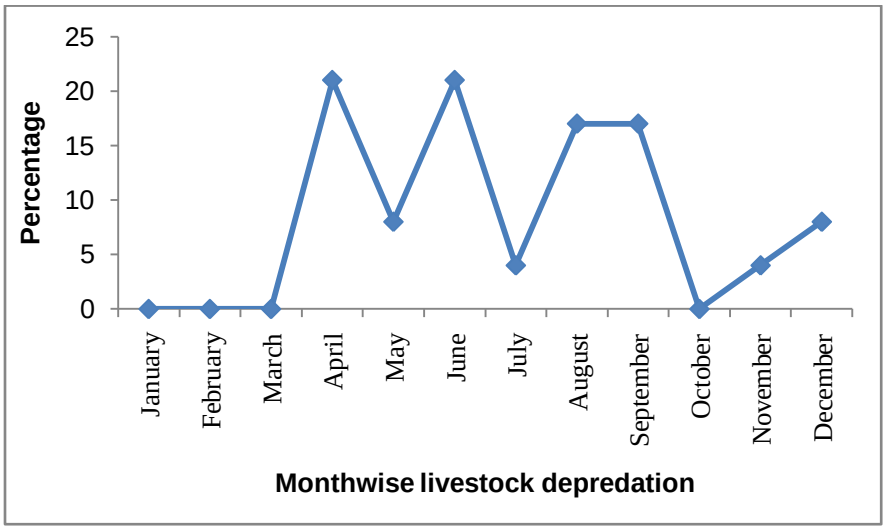
In winter tigers were recorded to stray (35%), summer (29%) and rest (23%) during monsoon months (Figure 4.13) (χ^2 = 16.69, df = 11, p > 0.05). There was no significant seasonal variation in straying incidents of tigers (Plate 4.2).

Figure 4.13 Seasonal variation in straying incidents of tigers along peripheral villages of Sundarban Tiger Reserve between 1998 and 2010.



During 1998 and 2010 tigers killed on an average 3 goats (SE 0.4) and 2 cows (SE 0.2) per year. Fifty percent livestock kills were recorded in summer (April to June) and 38% during monsoon (July-September) ($\chi^2 = 94.4$, df = 11, $p < 0.05$) (Figure 4.14).

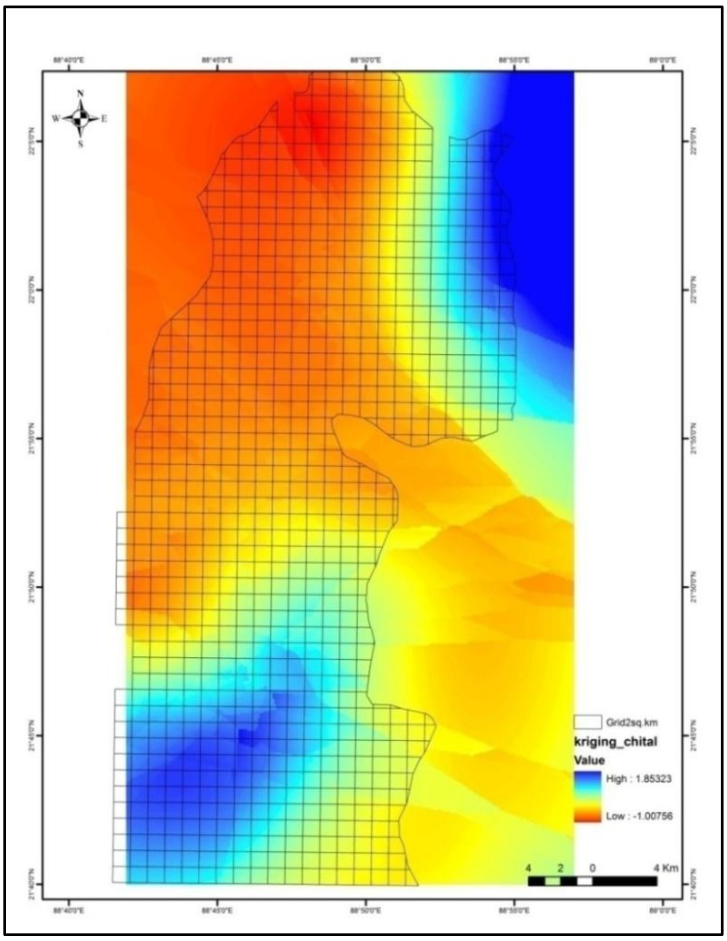
Figure 4.14 Seasonal Variation in livestock depredation by tigers across peripheral villages of Sundarban between 1998 and 2010.



4.4.9. Relative Abundance of prey and human use within conflict sites

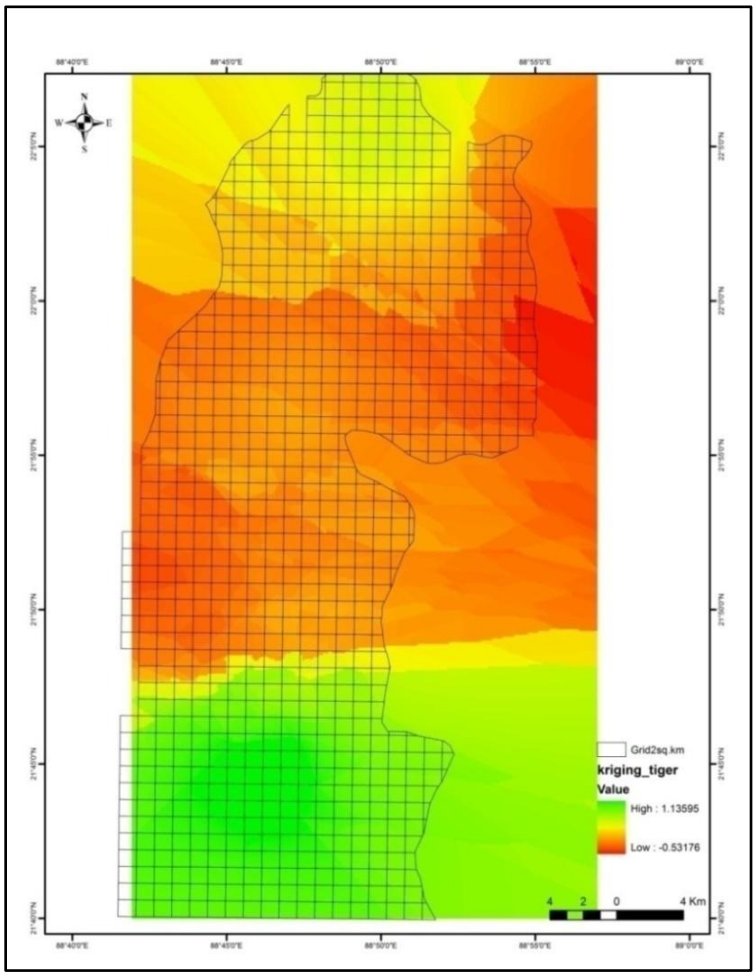
Boat transects of 248.16 kilometers in length were carried out within the intensive study area in 2010. The overall encounter rate for chital sign was 1.92 per kilometer with a total of 477 signs recorded during the surveys (Figure 4.15).

Figure 4.15 Kriging based map for chital distribution within the intensive study area.



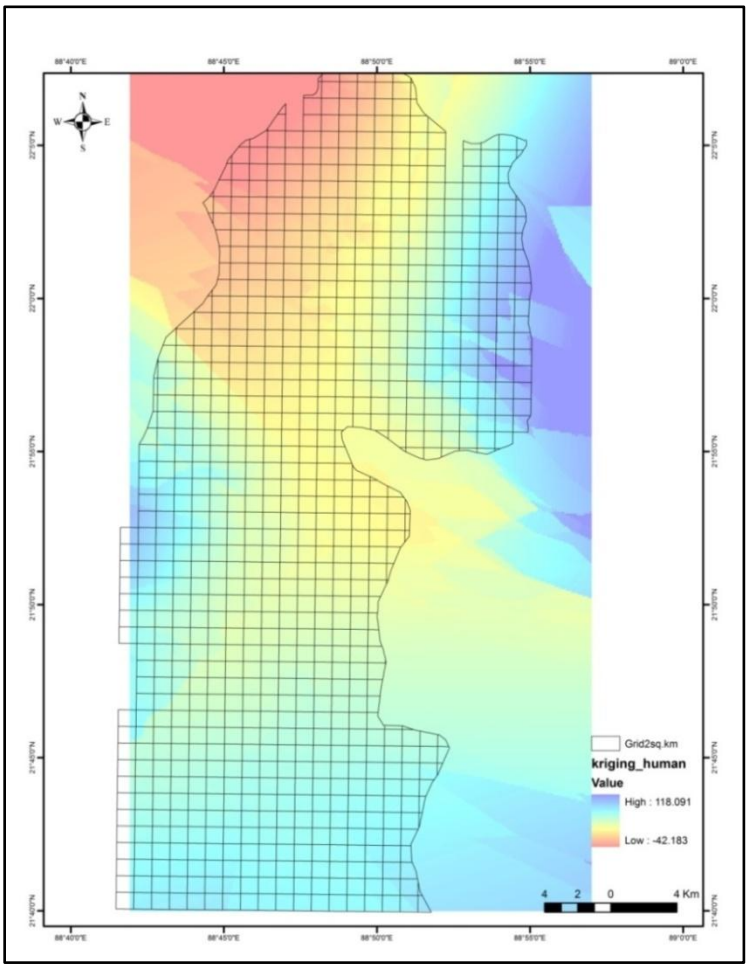
The overall encounter rate for tiger signs was 0.43 per km with a total of 107 signs recorded for 248.16 km of boat transects (Figure 4.16).

Figure 4.16 Kriging based interpolation map for tiger intensity of use within the Intensive Study Area.



The encounter rate per kilometer for human sign was 0.56 with a total of 138 signs recorded during the surveys (Figure 4.17).

Figure 4.17 Kriging based Interpolation map of human use within the Intensive Study Area.



The encounter rate per kilometer for wild pig sign was 0.26 with a total number of 65 signs detected during the surveys.

Figure 4.18 Kriging based interpolation map for wild pig within the Intensive Study Area.

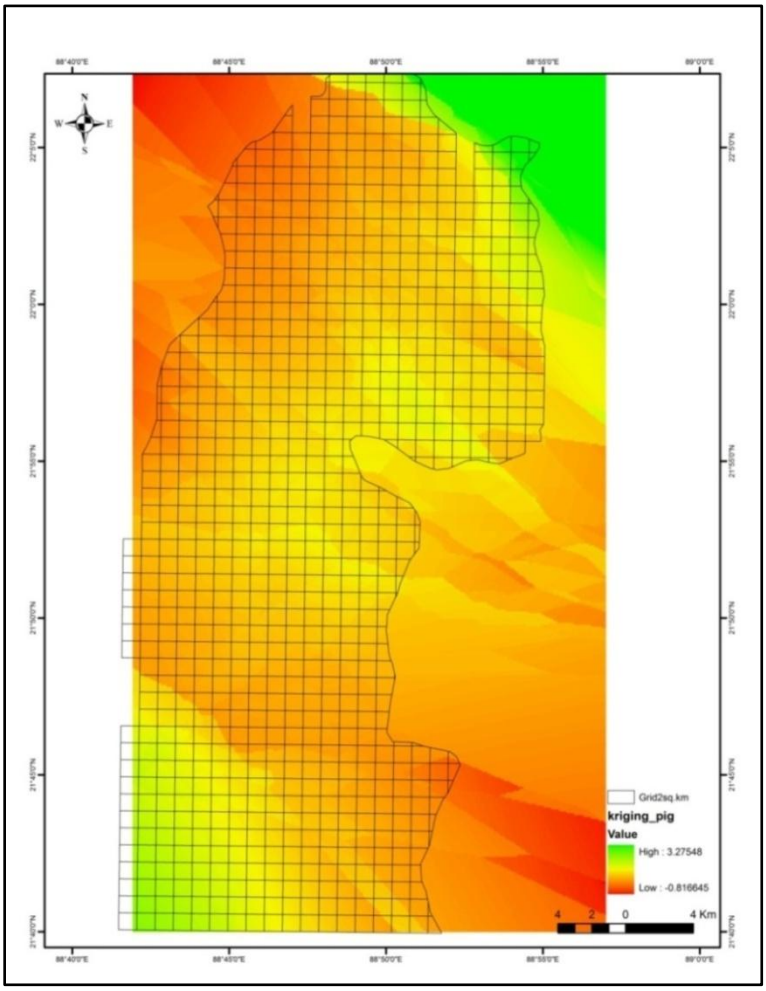


Table 4.2. Pearson correlation coefficients for variables considered for binary logistic regression.

	Ch	Wp	T	H	NH	B	P	Av	C	W	DV	NDVI	30_ 50 m	50_ 100m	100_ 150 m	150_ 200 m	> 200 m
Ch	1	.543**	.504**	.693**	0.032	-0.065	-0.043	-.093**	-.114**	.078*	-0.029	-.108**	-.082*	.086*	0.001	-0.038	0.052
Wp	.543**	1	.096**	.361**	0.054	-.067*	-.098**	-.070*	-.136**	.135**	0.008	-0.063	-.067*	0.039	-0.001	0.049	.096**
T	.504**	.096**	1	.193**	0.038	-0.043	0.019	-.078*	-0.027	0.03	0.044	.087*	-.117**	0.006	-0.041	0.018	-0.022
H	.693**	.361**	.193**	1	0.022	-0.066	-0.025	0.012	-.131**	0.063	-.106**	-0.065	-0.059	0.044	-0.005	-0.064	0.065
NH	0.032	0.054	0.038	0.022	1	-.128**	-.197**	-.130**	-.144**	-0.028	-0.023	-0.017	-.069*	0.004	-0.023	-0.016	0.006
B	-0.065	-.067*	-0.043	-0.066	-.128**	1	.143**	.131**	.724**	-.439**	-.068*	-.097**	.262**	.289**	.140**	.098**	-.156**
P	-0.043	-.098**	0.019	-0.025	-.197**	.143**	1	.242**	.320**	-.717**	0.008	0.03	.254**	-0.026	0.045	0.049	-.272**
Av	-.093**	-.070*	-.078*	0.012	-.130**	.131**	.242**	1	.137**	-.261**	-0.058	0.003	.074*	-0.054	0.049	-0.031	-.076*
C	-.114**	-.136**	-0.027	-.131**	-.144**	.724**	.320**	.137**	1	-.617**	-.089**	-.070*	.297**	.247**	.184**	.128**	-.274**
W	.078*	.135**	0.03	0.063	-0.028	-.439**	-.717**	-.261**	-.617**	1	0.02	0.05	-.281**	-.143**	-.109**	-.097**	.396**
DV	-0.029	0.008	0.044	-.106**	-0.023	-.068*	0.008	-0.058	-.089**	0.02	1	-0.039	-.085*	-0.013	-0.005	0.064	0.007
NDVI	-.108**	-0.063	.087*	-0.065	-0.017	-.097**	0.03	0.003	-.070*	0.05	-0.039	1	-0.003	-.099**	-0.016	-0.062	-0.027
30_50m	-.082*	-.067*	-.117**	-0.059	-.069*	.262**	.254**	.074*	.297**	-.281**	-.085*	-0.003	1	0.062	0.017	-0.024	-.254**
50_100m	.086*	0.039	0.006	0.044	0.004	.289**	-0.026	-0.054	.247**	-.143**	-0.013	-.099**	0.062	1	0.066	0.016	-.129**
100_150m	0.001	-0.001	-0.041	-0.005	-0.023	.140**	0.045	0.049	.184**	-.109**	-0.005	-0.016	0.017	0.066	1	.074*	-.115**
150_200m	-0.038	0.049	0.018	-0.064	-0.016	.098**	0.049	-0.031	.128**	-.097**	0.064	-0.062	-0.024	0.016	.074*	1	-.125**
200 m	0.052	.096**	-0.022	0.065	0.006	-.156**	-.272**	-.076*	-.274**	.396**	0.007	-0.027	-.254**		-.115**	-.125**	1

****.** Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).
Abbreviation of variables used: Ch-Chital, Wp-Wild pig, T-Tiger, H-Human, NH-Non-habitat, B-Barren, P-Phoenix, Av-Avicennia, C-Ceriops, W-Water, DV-Distance to village, NDVI-Normalized Difference Vegetation Index: m-meters.

4.4.10. Effect of different ecological variables and overall model selection

Out of the 30 binary logistic regression performed and 15 predictor variables used, six were significant ($p < 0.05$) in predicting probability of conflict (Table 4.3). The best model was selected based on the overall average of the beta coefficients of predictor variables (Table 4.3). Human-tiger conflict risk was highest in *Avicennia* species and *Ceriops* species dominated patches, being relatively open with high visibility and moderate to dense cover essential for stalking and unexpected attacks. Dense *Phoenix paludosa* dominated patches were negatively related to conflict risk probability. Human usage was directly proportional to conflict risk probability especially within sites with presence of 50 to 100 and 100 to 150 meter width of channels. Medium to moderate width of channels were prone to high conflict risk owing to presence of wide banks allowing tiger's to move freely before delivering fatal attacks.

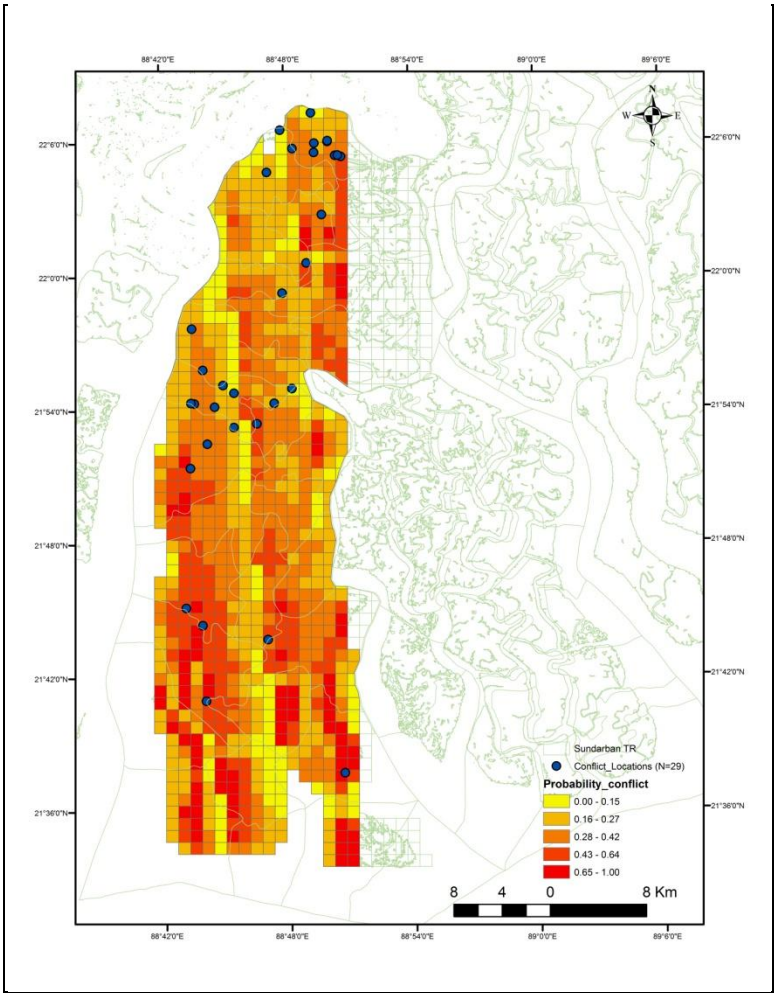
Table 4.3. Averaged beta coefficient values of predictor variables derived from Binary Logistic Regression for conflict risk analysis.

Variable	Beta-coefficient	Wald	df	Sig
Avicennia	0.49 (SE 0.12)	3.96 (SE 1.02)	1	0.039
Ceriops	0.58 (SE 0.18)	5.06 (SE 1.94)	1	0.021
Phoenix	-0.024 (SE 0.11)	0.149 (SE 0.68)	1	0.001
Human	0.20845 (SE 0.19)	1.278 (SE 1.17)	1	0.046
50 to 100 meter channel	0.11 (SE 0.20)	0.65 (SE 1.13)	1	0.015
150 to 200 meter channel	0.26 (SE 0.17)	1.793 (SE 1.19)	1	0.06
Constant	-.807 (SE 0.03)	9.95 (SE 0.56)	1	0.002

4.4.11. Human-tiger conflict Risk Map

Predation risk maps from spatially explicit models offered an additional location-specific perspective on human kills by tigers (Figure 4.19). Maps visually showed a patchy probability of high conflict risk with absence of definite clusters or hot spots of predation. High risk sites were noticeable within the core area of the reserve far away from the peripheral villages. Small swathes of high risk were observed on the south-western, southern and north eastern part of the intensive study area. On the contrary northern and western portion had low conflict risk probability being closer to human habitation and high water traffic. Relatively undisturbed areas resource rich for fishes and crabs and frequented by fishermen with moderate to dense cover favored tiger attacks.

Figure 4.19 Human-tiger conflict Risk Map on 2 km² scale in the Intensive Study Area of Sundarban Tiger Reserve.



4.5. Discussion

Felids with an average body mass of more than 50 kg show a propensity to attack humans, the most notorious being leopard, lion and tiger (Inskip and Zimmermann 2009). Attacks by puma and jaguar are rare (Beier 1991, Perovic and Herra´n 1998, Quigley and Herrero 2005, Altrichter 2006), and no report exists of snow leopards or cheetahs attacking humans. Though attacks have

gone down primarily due to declining felid populations (Nowell and Jackson 1996, Treves and Naughton 1999), yet in few pockets of Asian and African countries attacks are still common (Thirgood *et al*. 2005). For example, attacks by lions increased considerably in Tanzania between 1990 and 2005 (Packer *et al*. 2005), attacks by pumas has also been reported in the USA and Canada in recent decades (Beier 1991). It is not only humans subjected to fatal attacks but felids too as retaliatory killings are responsible for 47% of cheetah (Marker *et al*. 2003), 46% of Eurasian lynx (Andre´n *et al*. 2006) and up to 50% of tiger mortality (Miquelle *et al*. 2005). Brechin (2003) states that 39% of respondents in Belize have hunted cats in retaliation for livestock depredation, 88% of ranchers interviewed in the Brazilian Pantanal believe that jaguars are shot by ranchers to prevent cattle losses (Zimmermann *et al*. 2005), and 14% of herders interviewed in four Mongolian regions have hunted snow leopards (Allen *et al*. 2002). In India felids mostly involved with attacks on humans are leopards and tigers as has been documented through several studies (Goyal 2001, Athreya *et al*. 2007, 2011, Sawarkar 1986, Sanyal 1987).

Human-tiger conflict has been documented across much of the tiger's distributional range but the conflict is more severe in the Indian sub-continent (McDougal 1987), where tigers and humans densities are relatively high compared to other tiger range countries. Human-killing and retaliatory tiger-killing in the Sundarban of India and Bangladesh is an example of human-tiger conflict at its most extreme. Human-killing by tigers produce unnecessary human misery

and economic stress, while tigers that enter villages are often killed in return (Gani 2002). Management aimed at reducing this conflict will require building a solid information base (Loe and Roskaft 2004). The current study compare trends of conflict between the past and present scenario and identified drivers of conflict, in conjunction with assessing local people's perception towards tigers (Chapter 5). Thus the findings will play substantial role in mitigating future tiger-human conflicts in this region.

From 1978 to 1997, an average of 7.1 human deaths/year with an overall total of 146 people was reported to be killed by tigers on the island of Sumatra (Nyhus and Tilson 2004). Human-tiger conflict is also a serious conservation issue in Nepal, where 88 people were killed in Chitwan during 1976-2006, and the rate of human killing increased from 1.2 human deaths/year between 1976 and 1997 to 7.2 human deaths/year during 1998 - 2006 (Gurung *et al*. 2008). A total of 7,833 human deaths from tiger attacks were recorded in the Sundarban of India and Bangladesh, between 1860 and 2006. Majority (54%) of the cases i.e. 4,218 deaths, were recorded from a six year period 1860 to 1866, giving an average of 703 human deaths/year for that period (Blanford 1891). According to Barlow 2008, the Indian side had a greater mean number of human deaths/year (mean = 30, SD = 15.2, range 4-64) compared to Bangladesh (mean = 22, SD = 16.6, range 0-96) between 1881 and 2006.

Compared to the past trend of 35-18 deaths annually between 1970's and 2000, it has reduced drastically to 6.7 in the Indian side in the last 13 years. This seems to be an artifact of the decline in number of people dependent on forests as compared to the past. In 1960's to 1990's vast areas of the Tiger Reserve, then Reserved Forests were accessible and open to public for felling timber by laying out coupes, cutting leaves of *Nypa fruticans* and *Phoenix paludosa*, unregulated harvesting of fish, crabs and honey. Kalyan Chakrabarti (1992) states that 35,330 people worked in the forest annually, of which 4,580 were timber and firewood workers, 24,900 fishermen,1,350 honey collectors and 4,500 from other professions. Today there are around 10,000-15,000 people dependent annually on Indian Sundarban for livelihood out of which hardly 500 are involved with honey collection, rest being fishermen and crab collectors (Field Director, Sundarban Tiger Reserve Pers. Communication). Nine hundred and twenty three boat license permits (BLC) were issued by the Sundarban Tiger Reserve authorities in the last few years to the BLC owners at the rate of Rs 5 per person per week, for a period of 42 days. Beyond 42 days, fishermen are supposed to pay Rs 6 per person per week (for the first four weeks), Rs 10 per person per week (for the next two weeks) and, for periods beyond that, the amount is Rs 15 per person per week was charged. The permits are also applicable for the crab fishers, who are charged Rs 10 per gear per trip (Government of India 2006, Annual Report STR).

Tigers are known to drag the body of human victims for a considerable distance inside mangroves (local respondents, forest personnel Pers. Comm.), Khan (2004) states that the mean dragged distance was 1.3 kilometers within a range of 15 meter to 8 kilometer from the initial spot of attack. Thus on a majority, human bodies were not being recovered after tiger attacks due to inaccessibility inside the mangroves in the present study. Chakrabarti (1978) also reported that only 28.5% of the victims' bodies could be recovered after tiger attacks in the Indian Sundarban in the 1970's. Ninety five percent of tiger attacks on humans occurred inside the Protected Area of Sundarban with only a minority recorded in villages. In the Terai floodplains of Nepal, most human deaths occurred within 1 km of the forest edge because of the intensity of human use as compared to the forest interior. Similarly, all tigers that came into villages were impaired and killed people that they encountered near the forest edge (Gurung *et al*. 2008). Nyhus and Tilson (2004) found increased tiger attacks in suboptimal habitats near forest edges in Sumatra. In the Russian Fareast majority of the tiger-human interactions took place inside remote forested areas followed by villages (Goodrich *et al*. 2011). The intensity of human use was higher in Sundarban as compared to the other tiger habitats resulting in majority of attacks within Protected Area.

In the present study there was a significant seasonal variation in number of humans killed, with the highest recorded during April, which is similar to findings of Khan (2004), Denzau *et al*. (2010) and Chakrabarti (1978, 1992). Owing to an annual closure and prohibition in fishing and honey collection between June and

August imposed by the Forest Department, people congregate in large numbers in April inside the forests, majority being fishermen and honey collectors. This seems to have contributed for majority of tiger attacks in April. Thus there seems to be a positive correlation of seasonal habitat use by humans and tigers in the Sundarban which is similar to findings of Barlow *et al*. (2008). In the Russian Fareast majority of attacks on people and livestock were recorded during harsh winters (Goodrich *et al*. 2011). Hunting season occurs in late fall through winter, resulting in an increase in number of people in the forest and an increase in tiger–human encounters in Russia (Miquelle *et al*. 2005). In Tanzania majority of lion attacks on humans were recorded in March and October when people were busy guarding their crops in the monsoon (Nyahongo and Røskaf 2011). In Terai flood plains of Nepal there were no significant seasonal variation observed in tiger attacks on humans (Gurung *et al*. 2008).

During the present study it was observed that attack on humans was mostly diurnal and during early morning hours between 5 and 8 AM and 2 and 5 PM, the time when people are busy harvesting fish and crabs. Though tidal cycles play a major role in harvesting fish, yet majority of the catch is made during the day. Similar trend was reported by Khan (2004) from Bangladesh where 95% of people were attacked during daytime when they were at work in the forest or in a narrow creek. People spend the night mainly on the boat in the middle of the river or in a protective house or ‘machan’ (house above the ground), and hence they are relatively safe at night. Chakrabarti (1978), Chowdhury and Sanyal (1985)

also reported that man-eating incidents took place between 7 and 9 AM, 3 and 5 PM and around 11 PM in Indian Sundarban during 1970's-1980's which is similar to findings of the present study. Lion attacks in Tanzania on humans were mostly during night (Packer *et al*. 2007) and by leopards in Maharashtra during dusk and dawn (Athreya *et al*. 2007). In Sumatra majority of tiger attacks on humans were reported during the day followed by early morning and late afternoon (Nyhus and Tilson 2004). Though carnivores are crepuscular and nocturnal as reported from studies across the world (Gittleman 1996), yet diurnal nature of attack on humans in Sundarban somehow seems an aberration from the established findings.

It was observed that during the present study the average age of tiger victim was 40 years which is similar to findings of Khan (2004), where 73% of the people attacked were in the 30 to 50 years age category in Bangladesh. Chakrabarti (1992) also reported that middle aged men between 35 and 45 years constituted 80% of the human casualty figures in Indian Sundarban. The average age of tiger victim near Chitwan National Park, Nepal was 36 years (Gurung *et al*. 2008) which is similar to the findings of the present study. Occupation wise considerable majority (96%) of the tiger victims in Sundarban were dependent on forests with 77% being fishermen and rest 19% comprising of crab and honey collectors. Khan (2004) also reported that 45% fishermen and 35% woodcutters to be killed by tigers in Bangladesh. Fishermen use a wide variety of techniques to harvest fish, the most vulnerable ones to tiger attacks being Khalpatta and

Chorpata jal (Stakenet) along mouth of small creeks and along river banks. In Chitwan Nepal majority of people killed by tigers were attacked while collecting fodder and grass for their livestock (Gurung *et al*. 2008). Eighty four percent of the human deaths occurred near narrow channels with 30 to 100 meters in width. Majority of the attacks were recorded during last three hours of low tide, when water currents are minimal and mudflats of channels exposed. During low tide when water recedes, these channels are separated from forests by soft, slosh like mud at places. Thus it acts as a support base for tigers to attack humans off guard, busy collecting fish and firewood. Though water is not a deterrent to tigers in the Sundarban, yet exposed areas and minimum water flow provides optimal condition for tigers to range across the islands.

Livestock depredation in the peripheral villages of Indian Sundarban was comparatively lower than the mean of 73 per year as recorded by Rahman *et al*. (2009) for Bangladesh. This might be because of low livestock holding in the Indian side due to limitations of fodder required for stall feeding to support livestock. Tigers killed 59% goats, 36% cows and 5% dogs in the Indian side whereas 52% cows, 32% goats, 13% dogs, and 2% buffaloes on the Bangladesh side (Rahman *et al*. 2009). Tigers killed cattle and yak according to their availability, but more horses and fewer sheep than expected in Bhutan (Sangay and Vernes 2008), in the Russian Fareast 63% dogs (*Canis lupus familiaris*) were killed, followed by cows (*Bos primigenius*) 17%, horses (*Equus ferus*) 12%, sheep (*Ovis aries*) 6%, and ‘farmed’ sika deer (*Cervus Nippon*) 4% (Goodrich *et*

al. 2011). Between 1978 and 1998 tigers killed 43% livestock in general, 40% goats, 10% cows and water buffalo, 3% dogs and horses respectively in Sumatra (Nyhus and Tilson 2004). Majority of livestock kills were in summer and monsoon when tidal fluctuation are at their extreme with frequent cyclones and rise in water levels making native prey difficult to catch. In Russia, depredation was most common in winter, and most depredations occurred in villages because Amur tigers were more stressed physically due to intense cold, deep snow, and in some cases, lower prey availability, particularly of small prey that are easily captured and hence important to sick or wounded animals (Goodrich *et al*. 2011). Other studies have found depredation to be greatest in seasons when livestock were free-ranging and not in villages (Johnson *et al*. 2006, Li *et al*. 2009, Sangay and Vernes 2008).

Tigers in the Sundarban, somehow consider humans as natural prey which might be attributed to a combination of factors. Historically tigers were not frequently persecuted here as prevalent across parts of Mughal and British India, probably because of inaccessibility, threat from sea-pirates and remoteness of the region. Fear of guns and subsequently humans never existed here which might have made these tigers bolder and less shy than their mainland counterparts over the course of time. Colonization of these islands is also relatively recent dating back to a few centuries, thus prolonged isolation from humans somehow seems to be another major reason for their aggressive behavior towards humans. Prey encounter rates were similar between conflict and non-conflict zones during the

present study and do not seem to be a major driver of conflict. Cover provided by *Avicennia* and *Ceriops* patches seems optimal for tiger attacks on humans. Narrow channels with 30 to 50 and 50 to 100 meters in width were higher within conflict sites, which eventually dry up during low tide providing open ground to move across islands. It is this river and land interface which plays a critical role for tigers attacking vulnerable humans.

The human-tiger conflict in the Sundarban needs an urgent solution, to ease the agnostic feeling prevalent among the local people which might eventually lead to retaliatory killings and local extinction of tiger. The most promising solution seems to treat tiger victims instantaneously and reduce risk of deaths due to lack of timely aid. Medical Emergency Mobile Units should be set up along conflict prone sites especially during April and May. Family members of tiger victims should be provided adequate compensation, financial loans and educational scholarships to ensure stability and hassle free progress in life. Village tiger response units can be mobilized from the local youth in cooperation with the Forest Department to efficiently resolve human-tiger conflicts. Awareness programs and campaigns for local inhabitants should be taken up by the forest department and local NGO's to prioritize threats and plausible reasons of tiger attacks on humans to reduce intensity of human tiger conflict.

Plate 4.1. A tigress caught inside a village on the periphery of Sundarban Tiger Reserve.

Plate 4.2. A tiger caught from the peripheral village being released back into the forest.

CHAPTER 5
Attitude, perception and level of tolerance of people towards tigers living in the vicinity of Sundarban Tiger Reserve

5.1. Introduction

Large Carnivores occupying the apex of trophic level are k-selected occurring at low densities with large home ranges (Schaller 1996). Thus to support viable population of large carnivores, vast stretches of habitat are required (Bixby 1992). Large home range and wide ranging pattern, dietary requirements draw carnivores into recurrent competition with humans sharing similar resources (Schaller 1996). Diverse socio-economical and bio-political scenarios across varied land use patterns in landscapes, harboring large carnivores escalates human-wildlife conflicts (Wang and Macdonald 2006, Macdonald and Sillero-Zubiri 2002). Such conflicts tend to be controversial when resources damaged have economic value and the predator involved legally protected (Thirgood *et al.* 2000). Situations with fatal attacks claiming human lives results into retaliatory killings, engendering negative attitude towards large carnivores (Sillero-Zubiri and Laurenson 2001). A rigorous theoretical framework integrating understanding of socio-economics, dependence on forest based resources, competitive interaction and requirement of prey and predators is limited despite growing relevance of conflicts worldwide (Conover 2002). Thus a holistic approach addressing the concerned issues becomes essential for policy making and successful management of the isolated tiger population of Sundarban.

5.2. Review of literature

Humans have a dynamic relationship with carnivores, few events are sufficient to affect people's attitudes and shape their future interactions with particular species (Beedel and Rehman 1999, Conover 2002, Woodroffe *et al.* 2005). People base their perceptions and attitudes not only upon facts and personal experiences, but also upon a myriad of factors such as wider societal experiences, cultural norms, expectations and beliefs. These social factors can play an extremely important role in human–wildlife conflict, yet are rarely considered. Animals play important roles in folk-lore in almost all cultures, and attitudes towards species can be substantially influenced by such means. These perceptions of certain species as innately evil or harmful mean that even if wildlife damage is entirely mitigated, residual fear and antagonism can lead to continued persecution nonetheless. Therefore, certain species can be imbued with human characteristics that elicit far more hostility than their actual actions do, highlighting again the complexities of human attitudes towards animals.

Large carnivores widely acclaimed for inflicting damage on valuable resources especially livestock and occasionally human lives are thus prone to revenge killings, shaping negative perception towards their future persistence in human-dominated landscapes (Naughton-Treves 1998, Treves and Karanth 2003, Linkie and Christie 2007, Inskip and Zimmermann 2009, Nyhus and Sumianto 2000, Riley and Decker 2000, Naughton-Treves *et al*. 2003, Bagchi and Mishra 2006). Conversely people with positive attitude tend to be more accepting of conservation or management actions that enable survival of viable carnivore

populations (Andersone and Ozolins 2004, Kaczensk *et al*. 2004). Accordingly, understanding and addressing local people's attitudes and behavior toward human-wildlife conflicts blending both social and ecological aspects are vital to successful conservation of many species and has been a major research focus (Wang *et al*. 2006, Palmeira *et al*. 2008, Ogra 2009).

Identifying and quantification of the actual level of damage inflicted by conflict is the first step of conflict management (Caughley and Sinclair 1994). Though losses might not be economically significant on a regional scale, yet for the affected household it is damaging or at least perceived to be so (Mishra 1997). Thus understanding the economic burden of induced conflict on local peoples' lives and their perception towards conservation are central to combating the problem. People who endure conflict and feel they are unsuccessful in ameliorating the problem are likely to be more inclined to retaliate (Mills and Hofer 1998). Public attitudes are generally assumed to be more positive in areas where carnivores are absent (Zimmermann *et al*. 2001) or in areas where coexistence have been prevalent since historical times (Boitani 1995). While attitudes might be favorable in a large portion of today's urban population, locally the old conflicts still might exist with marginalized communities sharing resources with large carnivores. Their direct involvement and regular interactions makes them wary of damage to livestock and game, increased costs and working efforts, foreign involvement and new restrictions (Kaczensky 2003).

Though eventually people do learn to coexist with large carnivores, yet periodic losses ignite the dwindling fear and hatred which seldom change over time. This

could have been attributed to the human fear psychology (bio-phobic or bio-philic) and peoples' concern about their own safety and health (Røskaft *et al*. 2003). However; ethical, cultural and traditional values and beliefs of the communities towards wildlife and particular species as well as political representations of the species could be the most important socio-ecological factors governing such perceptions ultimately shaping the outcome of human-wildlife conflicts (Mishra 1997, Naughton-Treves *et al*. 2003).

Tiger-human conflicts have already contributed to the decline and extinction of two sub-species i.e. Bali tiger (*Panthera tigris balica*) and Javan tiger (*Panthera tigris sondaica*) (Hoogerwerf 1970, Seidensticker 1987b) and there is an urgent need to characterize and develop measures to reduce these conflicts (Nowell and Jackson 1996, Woodroffe and Ginsberg 1998, Linnell *et al.* 1999). Examining the social aspect of tiger conservation requires investigating the values and behavioral intentions held by people whose interests may conflict with tiger presence. Social theory suggests that "attitude [as] a function of individuals' beliefs and is expected to be related to his intensions" (Fishbein and Ajzen 1975). This theory details that individual views of an object such as tigers, are arranged in a hierarchy of cognitions. Ashraft (1994) defines cognition as "collection of mental processes and activities used in perceiving, remembering, thinking, and understanding as well as the act of using these processes". The cognitive hierarchy structure is like an inverted pyramid. At the foundation of this cognition hierarchy are fundamental values. These values are very few in number and difficult to change. Built on this value are patterns of basic beliefs or

value orientation, attitudes, norms, behavioral intensions and behaviors (Rokeach 1973, Homer and Kahle 1988, Fulton *et al*. 1996). Higher order cognitions such as behavior are many and are changing constantly. In this cognitive hierarchy lower order constructs are the best predictor of next higher order constructs (Fishbein and Middlestadt 1995, Schultz and Zelezny 1999, Betsch *et al*. 2001). For example, measure of tiger's values people hold will be the best predictor for attitudes towards tigers. Additionally, in this hierarchical cognition attitudes mediate the influence of value orientations on behavioral intentions (Vaske and Donnelly 1998, Manfredo *et al*. 1999). For example, conservation value of tiger's predicts people's attitude towards tiger conservation, and the conservation attitude towards tigers fully mediates the relationship between conservation value of tiger and behavioral intention towards tiger conservation. Therefore, it is critical to understand wildlife value orientation that forms the basic foundation explaining the human behavior related to wildlife.

Thus keeping in perspective the intensity of conflict since historic times, I hypothesized that perception of local people towards tigers in Sundarbans will be determined by several factors such as dependence on forests, occupation and socio-economic conditions. To understand these factors shaping public perception I carried out questionnaire surveys across peripheral villages interviewing people of different age classes and profession.

5.3. Methodology

5.3.1. Field Method

A closed and open ended structured questionnaire (Bath 1987, Bernard 1995) was administered to 411 respondents across 19 peripheral villages of Sundarban Tiger Reserve (Figure 5.1) between 2011 and 2013 to get an overview of the socio-economic conditions of the people, occupational patterns in the area and attitude towards tigers (Plate 5.2). All respondents were above 18 years and were questioned only when they were willing to answer the questions and participate in the survey. Opinion and attitudes towards tigers and wildlife conservation in general was assumed to vary based on economic losses due to livestock depredation and death of a person in the neighborhood. The villages were categorized into three classes, according to the intensity of conflict (loss of human lives and livestock depredation by tigers) (i) Low, (ii) Medium and (iii) High (Table 5.1).

This ensured uniform, unbiased representation of respondents from three different categories of villages. I was accompanied by one or two local residents during majority of the interviews, to ensure a certain level of comfort while conversing with respondents and also to authenticate the information gathered. Interviews were conducted in vernacular language in an informal way to acquire desired information. The questionnaire survey was primarily conducted by the same research team members to maintain uniformity and reduce individual biasness in scoring of the answers. A family was treated as the basic unit for the

purpose of this study, with only one respondent from a family being interviewed. The respondent was treated as a representative of the family unit.

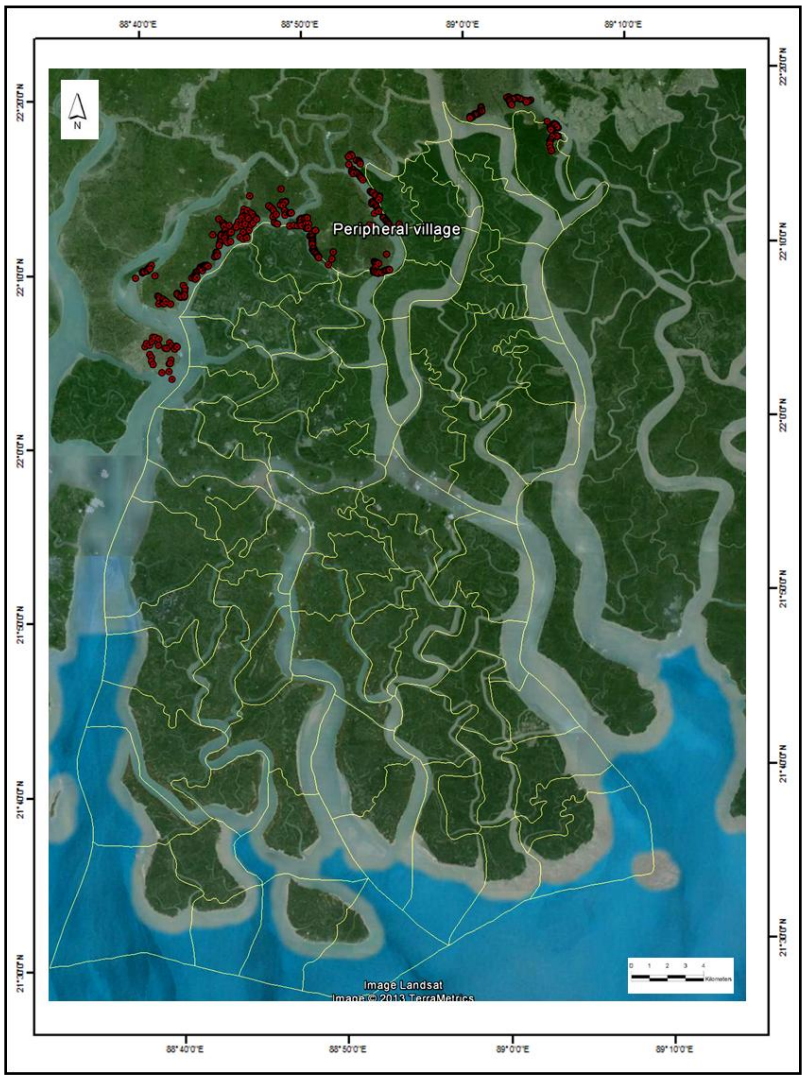
Table 5.1 Names of villages (N=19) categorized into low, medium and high conflict zones for carrying out questionnaire surveys (N=411).

Serial Number	Criteria of Selection(High/Medium/Low) Based on human deaths & annual livestock loss to tigers (1-4=low, 5-7=medium > 7 high)	Annual conflict 2001-2012 (livestock and human casualty)	Name of village N=411 Households in 19 villages
1	Low	2	Pakhirala
2	Medium	6	Dulki
3	Medium	5	Sonagaon
4	Medium	5	Bally
5	Low	2	Bijoynagar
6	Low	2	Amlamethi
7	Low	1	Mathurakhanda
8	High	9	Satjelia
9	High	8	Dayapur
10	High	8	Jamespur
11	High	9	Enpur
12	High	10	Luxbagan
13	High	11	Rajatjublee
14	High	8	Laharipur
15	High	11	Kalitala
16	High	12	Shamshernagar
17	Medium	5	Perghumti
18	Low	3	Tridipnagar
19	Low	2	Hemnagar

The structured questionnaire used was divided into three main sections (Annexure 2). The first section primarily dealt with the demographic details (age, gender, caste, education level, household structure etc.) and visual assessment of the economic condition of the interviewee. The second part dealt with socio-

economic questions pertaining to land holding, livestock owned occupation and annual income. The final section comprised of questions regarding knowledge of tigers, human-tiger interactions, perception towards tiger conservation and suggestions for mitigating conflict. Fishermen, honey collectors and crab collectors were thoroughly interviewed to acquire intricate details of their occupation, methods used, number of members comprising a group, belief in shamans and rituals practiced to avoid conflicts with tigers (Annexure 2. Section 7). The initial questions were related to simple demographic information to ease respondents into the interview session. If the respondent did not understand a given question, it was repeated and elaborated till it became clear that the respondent had understood it, and only then it was noted down. Females were also interviewed (N=115), though not in equal proportion to the number of male respondents. I also inquired about the areas preferred by respondents for fishing and honey collection.

Figure 5.1 Location of villages interviewed around Sundarban Tiger Reserve.



5.4. Data analysis

Responses from the questionnaire survey were analyzed to arrive at economic well being index, primary source of livelihood in the area and attitudes and perception of people towards tigers.

5.4.1. Economic well-being index

To make data comparable among different respondents, it was important to get all the answer categories into a uniform system. Therefore the respondents were first grouped into different categories (Table 5.2-5.5) and each question was then assigned a score. Total score for all the questions was summed up to indicate the well being of the people.

Table 5.2 Scoring of socio-economic variables.

Age Score	Gender Category	Clothing score	Household type score	Roof material score	Electricity score
18- =1, 30-60=2, > 60 years =3	1=Female 0=Male	1=Low 5=High	1=Kutchh 2=Semi-pucca 3=Pucca	1=Thatch 2=Asbestos 3=Tin 4=Concrete	0=No light 1=Solar light

Table 5.3(a) Evaluation score of socio-economic variables.

Distance drinking water	Family staying	Closest urban center	Annual Income (INR)	Purpose of livestock	Public Transport
>60 min =5, 45-60 min =4, 30-45 min =3, 15-30 min =2, <15 min =1	1st gen=1, 2nd gen=2, 3rd gen=3, 4th gen=4	0-30 km=1 30-60 km=2 >60km=3	45,000=1, 45,000-70,000=2, >70,000=3	1=Personal consumption 2=Source of income	1=Bus,walk,cycle 2=Walk 3=Car/vehicle

Table 5.3 (b) Evaluation score of socio-economic variables.

Distance drinking water	Family staying	Closest urban center	Annual Income (INR)	Purpose of livestock	Public Transport
>60 min =5,	1st gen=1, 2nd gen=2, 3rd gen=3, 4th gen=4	0-30 km=1	45,000=1,	1=Personal consumption	1=Bus,walk,cycle
45-60 min =4,		30-60 km=2	45,000-70,000=2,	2=Source of income	2=Walk
30-45 min =3,		>60km=3	>70,000=3		3=Car/vehicle
15-30 min =2,					
<15 min =1					

Table 5.4 Scores of socio-economic variables.

Strength household	Education level	Profession	Resources	Irrigation	Landholding score
Scalar	1=Low(Illiterate) 5=Secondary school completed	1=House wife 2=Boat owner 3=Service 4=Agriculturist 5=Fishermen	1=mobile 2=Radio, mobile 3=T.V., Radio, Mobile	1= Rainwater dependent 2= Irrigation water pump 0=No land for agriculture	1333sq.m=1 >1333-3999=2 3999-5332=3 >5332=4

Table 5.5 Scores for perception and attitude towards tigers.

Responsible for human deaths by tigers	Declaration of tiger reserve whether useful	Role of tigers	Attitude towards tigers
-1=Forest dept. 2=Human negligence 0=Tiger 1=Fate	-1=Not useful 1=Partially beneficial 2=Useful	-1=Destroy 0=Don not know 1=To control prey 2=To control ecological balance	1=Like 0=Dislike

5.4.2. Source of livelihood

The status of respondents were categorized into five major groups- housewives, boat owners, agriculturist and daily wages, service (working in nearby urban areas, business) and fishermen (which included honey collectors and crab collectors).

5.4.3. Attitude and perception of people towards tiger

Respondents' answers to different questions were given scores such as more 'negative attitude' got lower scores while more 'positive attitude' got the higher scores (Table 5.6-5.9).

To check for significant difference between response of respondents I used chi-square analysis in SPSS version 17.0 (SPSS Inc., Chicago, USA) and R (2.15.1). All data analysis was done with SPSS version 17.0 (SPSS Inc., Chicago, USA) and R (2.15.1)**.** A test was considered significant at $P < 0.05$ level and were two tailed (Fisher and Ronald 1925). Responses were either on continuous scale (e.g. land holding, livestock owned) or categorical form (e.g. role of tigers in the wild, responsibility for human deaths by tigers and whether they liked tigers).

Based on forest department records I prepared a map depicting spatial intensity of human deaths by tigers between 2001 and 2012 in Arc GIS 9.3 (ESRI, Redlands, CA, USA). Preferred area maps for fishing and honey collection within different administrative blocks of Sundarban Tiger Reserve were also generated using Arc GIS 9.3 (ESRI, Redlands, CA, USA) based on the questionnaire surveys.

To explore interrelatedness of socio economic variables I used Spearman's rank and rho correlation coefficients (Zar 2010) to check for redundancy in the socio-economic variables and selected only one for further statistical analysis when two or more variables significantly correlated with each other. I performed generalized linear models (GLM) (McCullagh and Nelder 1989) with a binary response to investigate local people's liking towards tigers. I constructed a priori candidate models representing factors behind local people's attitude towards tigers. I used information-theoretic approach to select between candidate models (Kullback and Leibler 1951), selecting the one with the smallest AIC value (Akaike 1974).

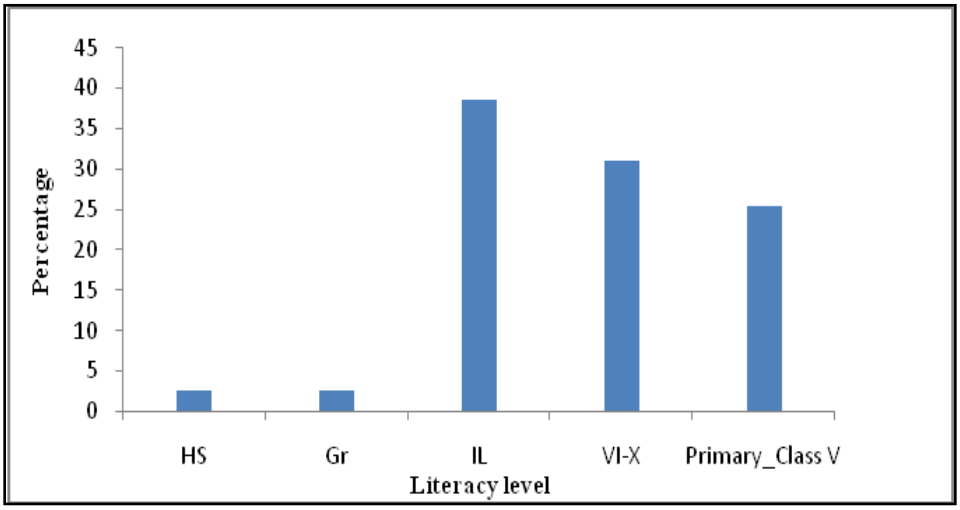
5.5. Results

5.5.1. Socio-economic condition of respondents

A total of 411 respondents were interviewed during the study across 19 villages. Majority of the respondents were middle aged (47 years SD 15.3), with 38% illiterate followed by 31% having completed education till class X, 2% secondary school, 2% graduates and rest 26% studied till class V (Figure 5.2). Sixty-five percent of the respondents were males followed by 35% females. Majority of the respondents (60%) lived in kutcha houses with mud baked walls and thatch, hay, used as roofing material, whereas 32% lived in semi-pucca houses with cemented or concrete sheets as roof covers, rest 7% in pucca household made of bricks and cement (Figure 5.3). Majority of the respondents (68%) had their ancestral home in Bangladesh from where they had moved to the Indian side

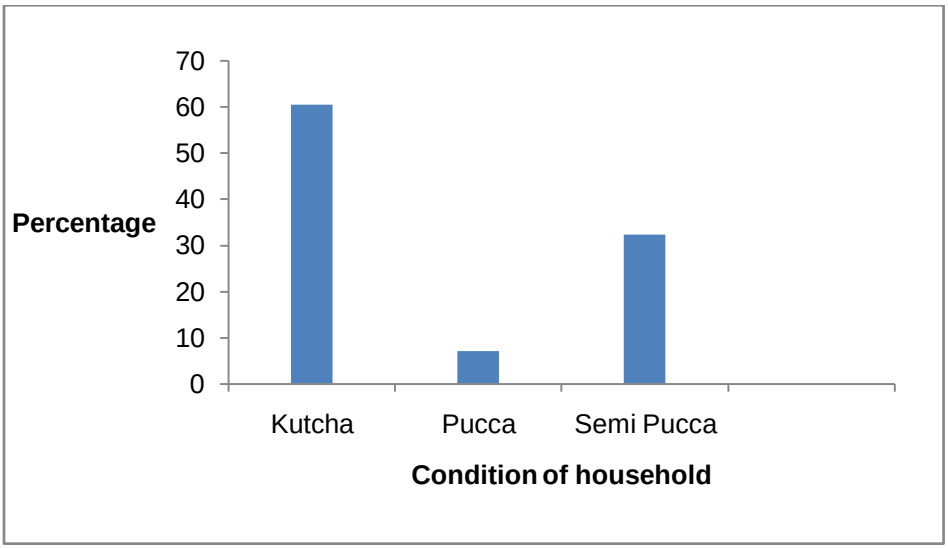
somewhere back in the 1940's and 1970's, followed by 13% from Medinipore, 8% from adjoining North 24 Parganas District and the rest comprised of people from different parts of the country including Chotanagpur Plateau and Orissa (χ^2 = 146.5, df = 4, $p < 0.05$). Sixty two percent of the respondents were third generation residents followed by 16% 2nd generation and 13% 4th generation residents of respective villages (χ^2 = 74, df = 3, $p < 0.05$). Sixty four percent respondents took less than 15 minutes to reach the nearest source of drinking water, 30% took more than 15 minutes, 5% took 30-40 minutes and the rest 1% more than 45 minutes (χ^2 = 100.88, df = 3, $p < 0.05$).

Figure 5.2 Details of literacy level of respondents.



HS = Higher Secondary, GR = Graduate, IL = Illiterate, VI-X = Class VI to X, Primary_ClassV = Primary School to Class V

Figure 5.3 Condition of household of respondents.



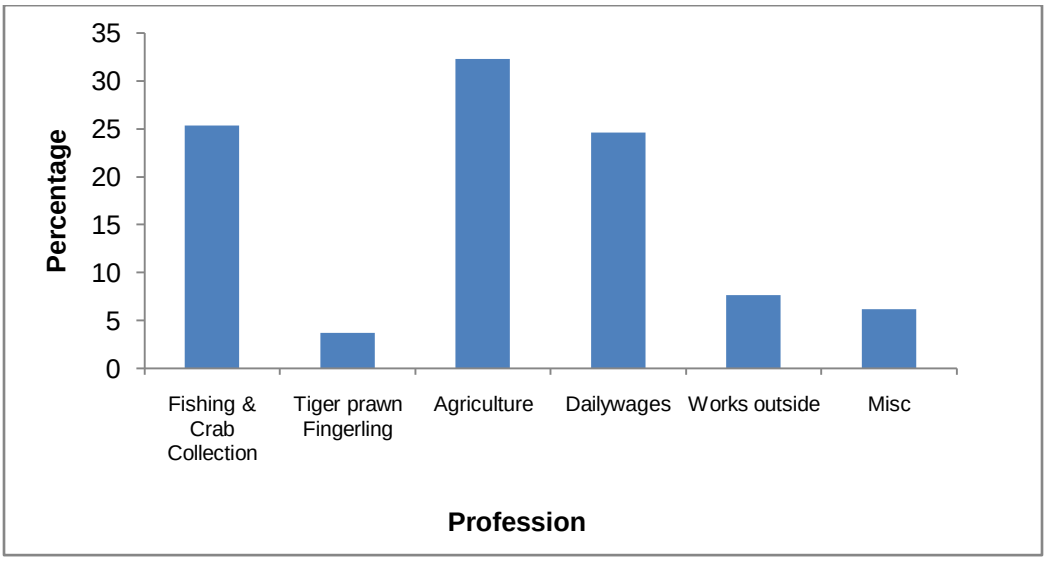
Half of the respondents (52%) stated that the nearest market place for getting necessary accessories was 10 to 20 kilometers away, 30% less than 10 kilometers, 9% in between 20 and 30 kilometers and the rest 9% more than 30 kilometers from respective villages (χ^2 = 50.64, df = 3, $p < 0.05$). Majority 63% used a combination of boat, cycle and country vans as chief mode of transport, followed by 16% who walked, 19% dependent on cycles and the rest 2% by boats (χ^2 = 83.6, df = 3, $p < 0.05$). Sixty-eight percent of the households had solar light facility whereas rest 32% was still coping without electricity.

5.5.2. Profession and land holding of respondents

Respondents interviewed were 57% agriculturists, 28% dependent on extraction of natural resources such as fishermen, crab collectors and 13% involved with miscellaneous service by profession (Figure 5.4). Sixty eight percent of the respondents did not possess land for agriculture and the rest 32% had

agricultural land. Average poultry possessed was by six individuals (SE 2.05) and livestock by eight individuals (SE 4.5) per household. Average landholding of 32% respondents was 2416.6 (SE 155.1) sq.m. The main crop grown was Aman rice (70%), combination of Aman, Rabi rice varieties and green vegetables 8%, Aman, Rabi and chillies 3%, and the rest 18% did not grow any crops on their land (χ^2 = 112.56, df = 3, $p < 0.05$). Overwhelming proportion of 94% were dependent on rainwater for agriculture, 4% on irrigation water and the rest 2% from ponds and channels dug out in their respective villages (χ^2 = 165.68, df = 2, $p < 0.05$). Eighty four percent of the respondents reared livestock for personal consumption and only 16% as source of income.

Figure 5.4 Details of profession of respondents.

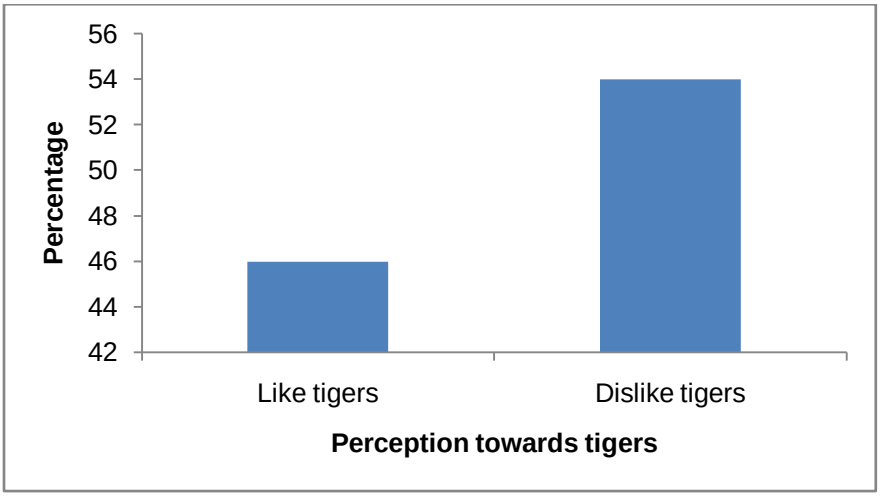


5.5.3. Attitude of respondents towards tiger and human-tiger conflict

There was no significant difference between attitude of respondents with 54% being negative and 46% positive towards tigers (χ^2 = 0.64, df = 1, $p > 0.05$)

(Figure 5.5). Occupation and status wise dislike towards tigers in peripheral villages of Sundarban Tiger Reserve was in the following order; housewives 83% > fishermen 60% > service holders 51% > agriculturists 50% > boat owners 25% ($\chi^2 = 32.39$, df = 4, $p < 0.05$).

Figure 5.5 Perception of respondents by percentage towards tigers in peripheral villages of Sundarban Tiger Reserve.



There was no significant difference observed in opinion concerning negative attitude towards tigers among different age class respondents in the 18 to 30 years age category 43%, in the 30 to 60 years category 55% and in the 60 plus category 58%, ($\chi^2 = 2.42$, df = 2, $p > 0.05$). Gender wise there was significant difference observed between female 65% and male 35% respondents regarding negative attitude towards tigers ($\chi^2 = 9$, df = 1, $p < 0.05$). Fifty six percent of respondents earned more than INR 70,000 annually disliked tigers followed by 52% respondents from the low income status. Majority of respondents 93% felt that human negligence was responsible for human-tiger conflict incidents claiming victims' lives, whereas 3% felt Forest Department were responsible,

followed by 1% who felt tigers were to be blamed and the rest 2% attributed it to the fate of the victim (χ^2 = 251.02, df = 3, $p < 0.05$). Thirty four percent of the respondents stated that the main function of tigers is to play an ecological role in the wild regulating ecosystems, 33% viewed them to be destroyers of all life forms subduing others, 25% opined that they kept prey populations at control, whereas rest 7% were unaware of any role played by the tigers as such (Figure 5.6) (χ^2 = 18.94, df = 3, $p < 0.05$). Sixty percent of the respondents opined that the declaration of Tiger Reserve was not useful for their livelihood followed by 28%, who felt that it was partially beneficial and the rest 12% only a minority stated it to be useful (χ^2 = 35.84, df = 2, $p < 0.05$) (Figure 5.7). Majority of the respondents (90%) stated that tigers considered humans as natural prey in Sundarban with a mere 8% who felt that they killed in self defense (χ^2 = 145.04, df = 2, $p < 0.05$) (Figure 5.8). Forty three percent of the respondents stated that loss and scarcity of natural prey in the wild forced tigers to stray into human habitations whereas 33% said that easy prey in the form of livestock and difficulty in catching native prey were responsible for straying incidents (χ^2 = 119.1, df = 6, $p < 0.05$). Fifty two percent agriculturists, 36% fishermen, 8% service holders and 4% housewives opined that the main role of tigers in the wild is to destroy or subdue other animals (χ^2 = 63.2, df = 3, $p < 0.05$). Gender wise, males 60% and female 40% respondents viewed tigers to be destroyers of all life forms (χ^2 = 4, df = 1, $p < 0.05$).

Figure 5.6 Perception of respondents towards role of tigers.

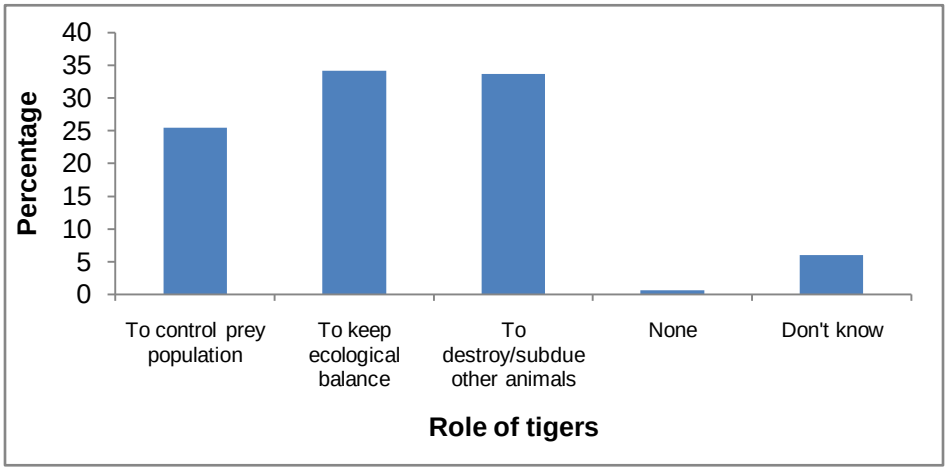


Figure 5.7 Attitude of respondents towards declaration of Tiger Reserve and impact on livelihood.

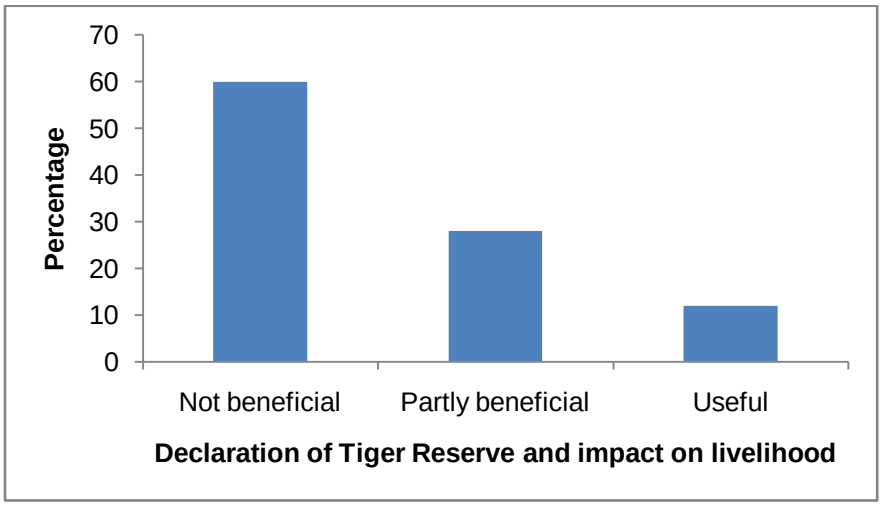
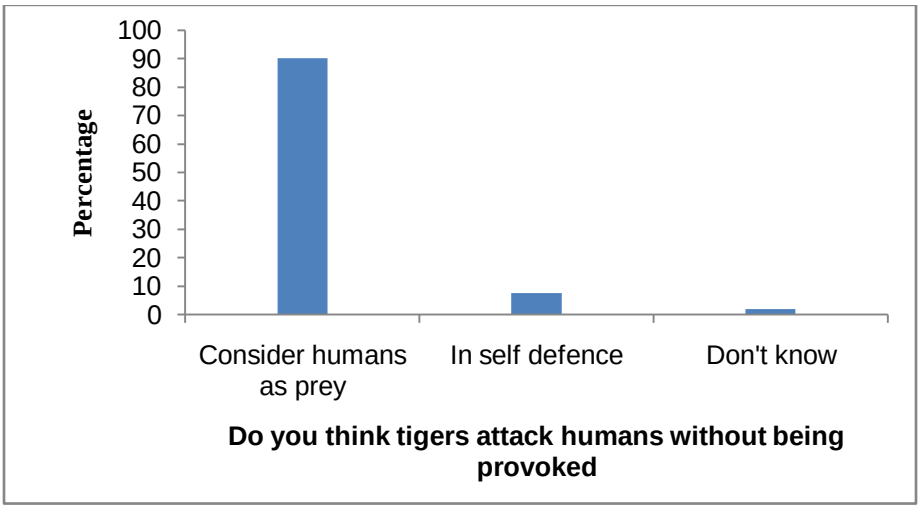


Figure 5.8 Perception of people regarding tigers attacking people without being provoked.

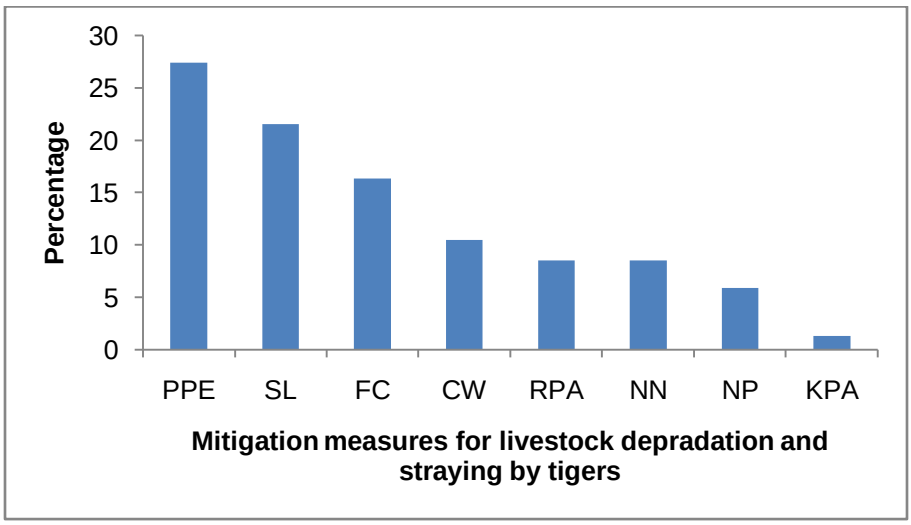


Among the age classes interviewed 68% respondents in the 30 to 60 years age group, 18% in the 60 to 80 years age group and 14% in the 18 to 30 years age group stated that the main role of tigers in the wild were to destroy other animals ($\chi^2 = 54.32$, df = 2, $p < 0.05$). Based on the education status 51% illiterate, 18% having completed secondary school, 18% without secondary school education and 13% having completed primary school viewed tigers to play a destroyer's role in the wild ($\chi^2 = 36.72$, df = 3, $p < 0.05$).

Regarding suggestions for mitigating human-tiger conflict, respondents differed significantly i.e., 27% opined that predator proof enclosures should be provided by the government and state forest department, 22% solar light posts along village river interface, 16% financial compensation to be enhanced for livestock loss and human deaths, injury to tiger attacks, 8% problem animals to be

relocated, 8% nylon nets along forest to be maintained properly, 10% construction of concrete wall along village embankments, 6% introduction of native prey and 3% killing problem animals (Figure 5.9) (χ^2 = 39.36, df = 7, p < 0.05).

Figure 5.9 Respondents suggestions for mitigating livestock depredation and straying of tigers.



PPE= Predator proof enclosure for livestock**, SL=** Solar light along village river interface, **FC=** Financial compensation to be enhanced**, CW=**Concrete wall along village/river interface**, RPA=**Relocating problem animal**, NN=**Nylon net along forest**, NP=** Native prey species to be introduced**, KPA=** Killing problem animal

Table 5.6. Spearman rho correlation plot showing correlation coefficients between respondents' attitudes towards tiger and other socio-economic variables in peripheral villages of Sundarban Tiger Reserve.

	AG	GD	CL	HT	RM	EC	IP	LH	LST	TM	AN	HS	ED	DDW	P	DTR	RT	IC	DF
AG		0.13																	
GD	0.135									-0.199									
CL				0.587	0.487	0.404	0.296	0.133					0.317		-0.214			-0.236	
HT			0.587		0.659	0.289	0.154	0.119	0.122	-0.127			0.208	-0.125	-0.17			-0.168	
RM			0.487	0.659		0.286							.167**	-0.098	-0.146			-0.16	
EC			0.404	0.289	0.286	1	0.22											-0.108	
IP			0.296	0.154	0.16	0.22			0.107										
LH			0.133	0.119					0.133	-0.037	-0.137				-0.154				
LST				0.122			0.107	0.133											0.136
TF		-0.199		-0.127										0.223		-0.099	-0.151		
AN								-0.137				0.113	-0.108	0.098	0.594	-0.105			
HS											0.113				0.128				
ED	-0.033	0.024	0.317	0.208	0.167						-0.108				-0.329	0.104		-0.282	-0.215
DDW				-0.125	-0.098					0.223							-0.115	0.111	0.087
P			-0.214	-0.17	-0.146			-0.154			0.594	0.128	-0.329			-0.109			
DTR										-0.099	-0.105		0.104		-0.109		0.255	-0.117	
RT										0.151				-0.115	-0.015	0.255	1	-0.138	
IC	-0.042	-0.063	-0.236	-0.168	-0.16	-0.108						-0.035	-0.282	0.111	0.092	-0.117	-0.138	1	0.639
DF									0.136				-0.215					0.639	

Only significant correlation coefficients (p < 0.05) have been reported. Variable abbreviations: AG = Age, GD = Gender, CL = Clothing, HT = Household type, RM = Roof Material, EC = Electricity, IP = Items possessed, LH = Land Holding, LST = Livestock, TM = Time since family has settled, AN = Annual Income, HS = Household Strength, ED = Education, DDW = Distance to drinking water source, P = Profession, DTR = Is declaration of tiger reserve beneficial for livelihood, RT = What is the role of tigers in the wild, IC = Intensity of human-tiger conflict in village, DF = Distance of village from forest

5.5.4. Model selection and effect of socio-economic factors on respondents' attitude toward tiger

Table 5.7. A priori model for data predicting the effect of socio-economic factors on respondents' attitude towards tigers in Sundarban Landscape.

Predictor set	Parameters	Wald Chi-Square	df	Overall AIC	Overall AICc	∧AIC
IC + RT + P + DF	4	55.706	3	93.33	94.138	0
IC + RT	2	49.632	2	96.088	96.302	-2.758
IC + RT + DF	3	48.96	3	98.081	98.368	-4.751

Variable abbreviations: IC = Intensity of conflict in peripheral villages (livestock depredation and human-tiger victims), RT = Perceived role of tigers in the wild, P = Profession of respondents, DF = Distance of village from forest

Binary logistic regression in a generalized linear model framework suggested that model containing respondents' profession, perception about role of tigers in the wild, intensity of human-tiger conflict incidents and distance of village from forest to be the best for predicting local people's attitudes towards tigers Table 5.7. The parameter estimates for the best model (IC + RT +P +D) is given in Table 5.7. The influence of individual factor and covariates on the final model outcome is given in Table 5.8. Intensity of conflict in villages and knowledge about role of tigers in the wild were significant factors influencing perception of respondents. Though distance from forest and professions were included in the final model, they were not significant ($p > 0.05$).

Table 5.8. Significance of factors in the best fit model predicting attitude of respondents towards tigers.

Source	Type III		
	Wald Chi-Square	Df	Significance
(Intercept)	.000	1	1.000
Intensity of Conflict	10.426	2	.005
Role of tigers	39.286	3	.000
Profession	4.671	5	.457
Distance from Forest	.123	1	.726

5.6. Socio-economic status and attitude of fishermen

Majority of tiger victims in Sundarban were found to be fishermen, crab collectors and honey collectors, hence a total of 115 people dependent on forest based resources as primary source of livelihood were interviewed. The average age of fishermen interviewed was 50 years (SD 14.23). The average household strength was 5 (SE 0.24)**.** Majority (66%) stayed in kutcha (mud houses) with bare essential, while 33% stayed in semi-pucca households and a mere 1% in pucca houses (χ^2 = 63.38, df = 2, $p < 0.05$). Roof material used in most of the households comprised of thatch and hay (64%), asbestos (3%), concrete (2%) and the rest (31%) tin sheets (χ^2 = 102.8, df = 3, $p < 0.05$). Seventy one percent had their ancestral home in Bangladesh followed by 12% from parts of North 24 Parganas district, 8% from Medinipore, 7% from parts of South 24 Parganas district and 2% percent from other parts of West Bengal (χ^2 = 165.1, df = 4, $p < 0.05$). Literacy level wise 59% were illiterate, 22% having completed primary schooling (till class V), 16% not completing primary school and only 3% with secondary schooling completed (χ^2 = 69.2, df = 3, $p < 0.05$).

Majority of honey collectors (69%) comprised of groups of 6 to 9 persons, 23% with 2 to 5 persons and 8% having > 10 persons ($\chi^2 = 60.62$, df = 2, $p < 0.05$) (Plate 5.1). Fishing groups consisted of 3 persons 57%, 4-6 persons 41% and more than 6 persons 8% ($\chi^2 = 30.38$, df = 2, $p < 0.05$). Seventy three percent favored spring tide phase for fishing and crab collection followed by 27% dependent on neap tide phase for extraction ($\chi^2 = 21.16$, df = 1, $p < 0.05$). As means of self defense 86% used machete, 5% wooden sticks and poles and 8% had no means of self defense ($\chi^2 = 127.82$, df = 2, $p < 0.05$). Majority of fishermen (92%) opined that tigers consider humans as natural prey, only 5% stated that they attacked in self defense while 3% did not have an answer to the question ($\chi^2 = 154.94$, df = 2, $p < 0.05$). Regarding role of tigers in the wild, 62% stated that they destroy and subdue other animals, maintain ecological balance 19%, control prey populations 14% and 5% were unaware of any role played ($\chi^2 = 77.04$, df = 3, $p < 0.05$). Sixty seven percent said that the declaration of Sundarban as Tiger Reserve was not beneficial to their livelihood, 20% felt it was useful, 8% said that only a fraction of the community has benefitted out of it whereas the rest 5% said that Forest Department and the state government did not provide any benefits whatsoever ($\chi^2 = 99.12$, df = 3, $p < 0.05$). Seventy seven percent believed that prayer to Bonbibi (Forest Deity of Sundarban) before venturing to the forest and rituals by shamans, could effectively prevent tiger attacks and the rest 23% felt they were ineffective and presence of mind was crucial to prevent such conflicts (Figure 5.10) ($\chi^2 = 29.16$, df = 1, $p < 0.05$).

Majority 93% said that human negligence was responsible for deaths inflicted by tigers and 7% felt that Forest Department was responsible for human deaths, being the custodians of the forest (Figure 5.11) ($\chi^2 = 73.96$, df = 1, $p < 0.05$). The reason as to why tigers stray into human habitation and depredate on livestock was attributed primarily to loss and scarcity of natural wild prey (67%), followed by easy target in the form of livestock (13%), narrow channel separating villages from forest (12%), confusion with tiger habitat (5%) and encroachment of forest land (3%) ($\chi^2 = 144.99$, df = 4, $p < 0.05$). Since tiger attacks were frequent, people were asked as to whether they are willing to switch profession, for which 84% declined to comment and only 16% responded positive for a changeover ($\chi^2 = 46.24$, df = 1, $p < 0.05$). Regarding making this bold decision of pursuing a profession with high risks involved 39% said that it gave instant cash rewards, 39% cited no other means of secure alternative, 5% spoke about limitations of agriculture and 17% stated that they were best and apt at this compared to other sources of livelihood (Figure 5.12) ($\chi^2 = 34.24$, df = 3, $p < 0.05$).

Figure 5.10 Perception of fishermen/honey collectors towards forest deity and shamans in preventing tiger attacks.

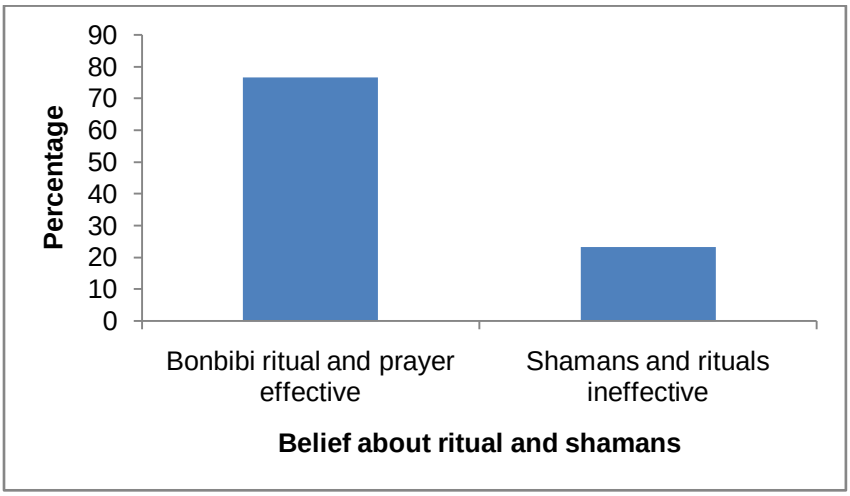


Figure 5.11 Perception of respondents towards human deaths by tigers.

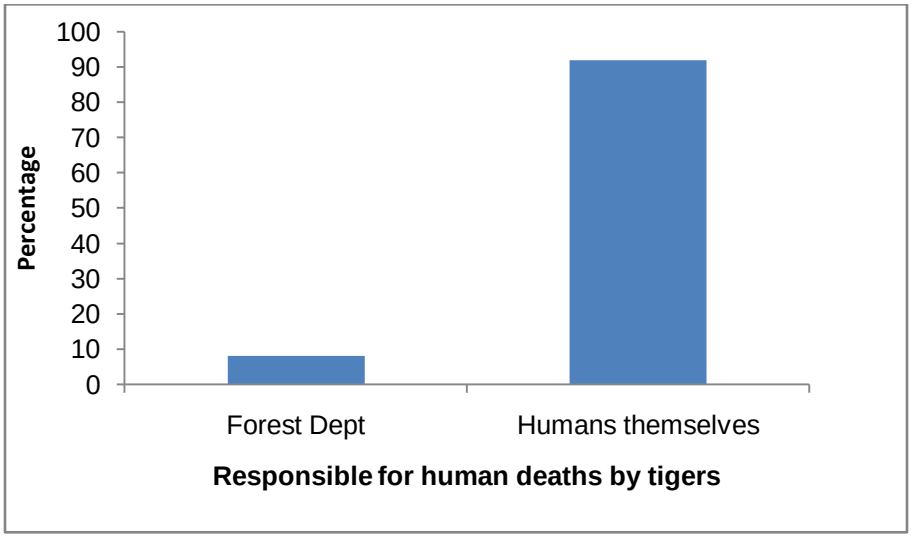
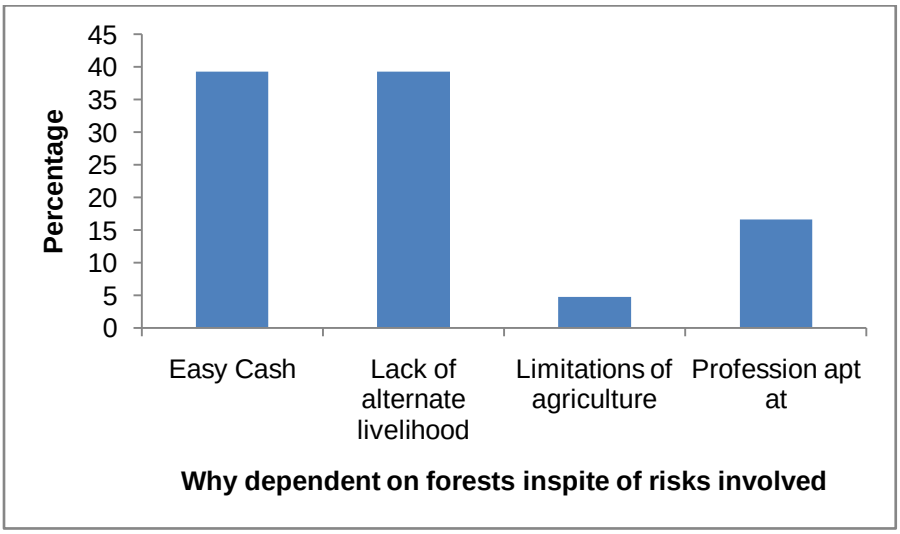


Figure 5.12 Response of fishermen regarding dependence on forests in spite of threats by tigers.



5.7. Annual Income Occupation wise of respondents

The annual income occupation wise as evaluated from socio-economic surveys were in the following order: hotel owner (INR 3,00,000) > Boat owners (INR 2,00,000) > Shopkeeper (INR 80,000) > Fishermen, Crab Collector, Honey Collector (INR 74,282) > Agriculturist (INR 44,377) > Animal Husbandry (INR 36,000) > Tourist Guide (INR 24,000) > Daily wage laborers (INR 15,000-26,000) (NREGA 2013 West Bengal Government wage rate) (Table 5.9) ($\chi^2 = 735886$, df = 7, $p < 0.05$). Lifetime income earned occupation wise was evaluated taking in consideration an earning span of 47 years (18-65 years), 18 being the standard age of commencing to earn a livelihood (derived from questionnaire surveys) and 65 years being the life expectancy independent of juvenile/infant mortality in South and North 24 Parganas District West Bengal.

Table 5.9. Annual and lifetime income occupation wise and how financially it is advantageous to be dependent on forests by the local people.

Major Professions	Annual Income INR	Lifetime Income (18-65) years INR	Surplus/Deficit compared to income at 40 being a fisherman INR	Surplus/Deficit lifetime income being a fisherman INR (18-65) years
Agriculture	44,377	20,85,719	*Deficit-4,51,515	Surplus 14,05,535
Tourist helper	24,000	11,28,000	Surplus 506204	Surplus 23,63,254
Shopkeeper(Tourist Zone)	80,000	37,60,000	Deficit-21,25,796	Deficit -2,68,746
Animal Husbandry	36,000	16,92,000	Deficit-57,796	Surplus 17,99,254
Apiculture	16,000	7,52,000	Surplus 8,82,204	Surplus 27,39,254
Fishing, crab & Honey Collection	74,282	34,91,254		
Boat owner	2,00,000	94,00,000	77,65,796	Deficit 59,08,746
Hotel owner	3,00,000	14,100,000	1,24,65,796	Deficit 1,06,08,746
Daily wage NREGA Unskilled	15,100	7,09,700	Surplus 24,504	Surplus 27,81,554
NREGA Semiskilled	19,500	9,16,500	Surplus 7,17,704	Surplus 25,74,754
NREGA Skilled	26,000	12,22,000	Surplus 4,12,204	Surplus 22,69,254
If dies at 40 yrs due to tiger attack		16,34,204		

5.8. Risk of deaths to tiger attacks compared to other major causes of human deaths

According to Chakrabarty (1992) and Khan (2004), majority of the human casualty by tigers were middle aged men between 35 and 45 years, thus assuming the average age of tiger victims to be 40 years, the income generated was compared to other occupations till that age. I also derived the proportion of people among the overall local community, dependent on harvesting natural resources (fishing and honey collection) as means of livelihood. I also computed the risk of death to tiger attacks based on the number of annual human deaths reported, compared to the entire community dependent on forests. The average age of human victim killed by tiger attack was 40 years in Sundarbans (Forest Department records and present study), thus the income generated till 40 years being a fishermen/crab collector/honey collector was compared to other occupations. Apart from agriculture, shopkeeper, boat owner and hotel owner income from forest based livelihood was significantly more than being daily wage labors, tourist guides and apiculturist. Overall income generated till the age of 65 years being a fisherman fared better as compared to others except shopkeeper, boat owner and hotel owner involved with tourism.

The population of South and North 24 Parganas district comprising Sundarban is 10,00,82,852 (Census of India 2011), with around 20,320 people dependent on forest based resources for their livelihood (Unofficial record, questionnaire surveys, personal observation). The proportion of people dependent on forests out of the entire mass is thus negligibly low i.e. 0.000203. Out of the total number

dependent on forests, an average of 6.7 persons dies annually to tiger attacks. The risk of death from tiger attacks was 0.00033 percent which is considerably low, considering how the local media and popular writings, articles have portrayed it to be over time.

5.9. Socio-economic condition of tiger victims' family members

When these interviews were conducted I came across 15 households having lost a family member to tiger attack in the Sundarban within the last 10 years. Out of the family members interviewed 60% were dependent on forest based livelihood, 20% worked in cities such as Kolkata, Chennai, Andaman etc., 13% were agriculturists and the rest 7% daily wage workers. Fifty three percent of respondents stayed in kutcha household whereas 47% in semi-pucca households. Sixty seven percent of respondents had access to solar light and the rest 37% stayed without any light facility**.** Half of them were illiterate never attending school (53%), 27% having completed primary school and the rest 20% without completing primary schooling.

5.10. Discussion

The presence of large carnivores in human landscapes can have different consequences such as fear evoked by its very presence (Quammen 2003) to fatal attacks on humans (Loe 2004). Though humans and carnivores are not sympatric, yet they exploit common resources across much of their distributional range. Perception on large carnivores specially if sharing resources on a daily basis, staying either near Protected Areas or being dependent on forest based

resources for livelihood will be negative under normal circumstances. This will intensify if the predator is responsible for fatal attacks on con-specifics or leads to economic losses by killing livestock and game. Variation in people's attitudes towards large carnivores seems to be based partly on the extent to which different species conflict with human interests and partly on inherent human prejudices (Kellert 1985). However, attitudes can change considerably over time and assessing the attitudes of people is a complex issue (Dickman 2005) owing to cultural, social, ecological and economic factors.

Tigers have been notorious for attacks on people, livestock as recorded throughout their geographic range since centuries be it Terai landscape of Nepal and India, Russian Far-East and South-east Asia. In the Indian Sundarbans, Chaudhuri and Choudhury (1994) reported that tigers have killed about 1,500 people (75 humans/year) in a 20-year period. These are only the reported cases, an unknown number never get reported. According to Sanyal (1987), an average of 45 people were killed annually during 1975-1982 in the Indian Sundarbans, and according to the Government of West Bengal (2001), a total of 10 people were killed by tigers during 1999-2000. Johnsingh *et al.* (1991) reported that 50% of the human casualties caused by tigers in India is in the Sundarbans. According to Richardson (1992), a total of 50-60 people are killed by tigers each year in the entire Sundarbans of Bangladesh and India, which is probably an underestimate.

Sundarban is one of the poorest and most densely populated regions of South Asia, with an estimated 8 million people (India and Bangladesh combined) directly dependent on its fragile ecosystem (Chowdhury 1999). Majority of the respondents interviewed stayed in kuchha households with bare essentials such as thatch and hay as roof material and mud baked walls susceptible to damage by frequent cyclones and storms. Frequent natural disasters such as cyclonic storms, inrush of tidal waves, ravaging nor-westers and flooding causes recurrent damage to life, crops and property every year in Sundarbans (Chaudhuri 1994). In 2009 this region experienced a severe cyclonic storm, Aila claiming 100 human lives and leaving scores injured with extensive damage to property (Indian Meteorological Department Report 2009). Respondents interviewed in Sundarban had low levels of literacy either being illiterate or just completed basic primary schooling (Figure 5.5). Carter *et al*. (2012) states that education broadens people's perspective on tigers and, perhaps, encourages greater awareness of the benefits of tigers (e.g. ecological importance).

Williams *et al*. (2002) indicated that positive attitudes toward wolves in regions around the world were related to education likely because increased education often brings a greater awareness of wildlife and the environment. Similar relationships between greater education level and positive attitudes expressed toward large carnivores are a prevalent phenomenon (Riley and Decker 2000). The two districts North and South 24 Parganas comprising Sundarban support one of the highest human densities in India (Census 2011). During post Independence period and especially after the Bangladesh war in 1972

Sundarbans has experienced a rapid influx of migrants, land relatively easy to procure and cheap compared to other provinces of present West Bengal State (Das 1981). Thus 68% of the respondents living along the peripheral villages of the tiger reserve had their ancestral place in bordering areas of Bangladesh which makes them recent colonizers of the land hardly dating back to a few decades.

Human-carnivore conflict is believed to be shaped by economic condition of local communities. Financial loss burdened by the local people, be it loss of a family member or depredation of livestock by tigers should be disastrous for the socio-economic status of the affected family. The proportion of people having a stable income was trivial compared to the vast majority, thus respondents of lower income groups were negative about tigers as expected. None of the areas surveyed had electricity, 68% used solar lights as means of survival whereas rest 34% were literally groping in the dark. The major transportation facility available to locals was a combination of boats, country vans and walking making journeys tiring and cumbersome. People having medical emergencies were worst affected and succumbed because of this sluggish transportation. Moreover since the area is crisscrossed by innumerable channels being river islands and cutoff from mainland the state government has struggled to provide smooth hassle free transportation (Bera and Sahay 2010).

Majority (68%) of the respondents did not possess land for agriculture and 32% having land managed to cultivate monsoon dependent crops such as Aman rice.

Since the soil is extremely saline at places only salt tolerant varieties can be grown here, moreover the area does not have fresh water at suitable depth to be extracted and used for irrigation. The entire area of Sundarban faces the problem of salinity, water logging and drainage. In the absence of upland water supply the area is exposed to tidal action making the water highly brackish (Planning Commission Report 1981). Thus rainwater comprised 94% of the agriculture being practiced, with only 4% having access to irrigation water. Since fields were dry without permanent source of water devoid of grass to support livestock, 84% reared them for personal consumption with only 16% thinking it as a commercial income source. Though 54% disliked tigers which were justified considering the intensity of conflict since historic times, as has been with large felids worldwide (Oli *et al*. 1994, Saberwal *et al*. 1994), 46% respondents surprisingly were positive towards tigers.

Although tigers routinely killed people in the Bangladesh Sundarbans, Reza *et al*. (2002) and Khan (2004) reported that 75% of respondents interviewed were not hostile towards tigers and wanted them to be conserved. One possible reason might be tigers being regarded as Dakshin Roy- tiger god in the local folklore and worshipped across the landscape both by the Hindu and Muslim communities (Montgomery 2008). As Montgomery (2008) states in her book Spell of the Tiger "here the tiger is feared but not hated, here it is worshipped but not loved". This belief and religious values might have attributed it to being accepted by the locals preventing retaliatory killings and antagonistic views on conservation. This is prevalent across many areas of Asia where fear and admiration for tiger

historically resulted in a ‘balance of power’ (Bakels 1993) where people and tigers lived and killed in relationships ordered by spirits, myths, and rituals (Bakels 1993, McNeely 1988, Provencher 1986). A wide variety of local traditional beliefs evolved to explain conflict, tigers killed people because someone was wicked, or people killed tigers because the animal itself had sinned. Specialists like the *pawang harimau* (tiger shaman) of Sumatra could speak to tiger and forest spirits (McNeely 1988).

Significant proportion of women interviewed had a negative attitude towards tigers compared to their male counterparts, which might be due to the psychological stress they undergo as widows after their husbands are killed in tiger attacks. In each village there is a separate hamlet for widows, locally called “Bidhoba Palli” meaning community of the widows (Chowdhury 2008). Many of them also take up tiger prawn fingerling collection and occasional crab collection trips inside the protected area where there are severe encounter with tigers and monetary penalty imposed by Forest Department officials. Young people in the age group of 18 to 30 years were positive towards role of tigers in the wild and conservation in general as compared to the middle and old age counterparts in the 30 plus till 80 years category. Older generations had bitter experiences with tiger attacks, government policies and are generally conservative, having endured hardship as compared to the younger group who has had rare human-tiger interactions. Being less educated than the younger generation, old age groups’ awareness about government policies and schemes, about conservation

in general seems considerably lower. A similar pattern was also observed among the Maasai communities in Tarangire-Manyara ecosystem in Tanzania and Greater Amboseli ecosystem in Kenya where elderly people expressed their dislikes for lions more in comparison to the young warriors and perception of the former on livelihood securities has been attributed to such age polarized attitude towards lions (Goldman *et al*. 2010).

Sixty six percent of the respondents felt that the declaration of Sundarban as Tiger Reserve has not been beneficial for their livelihood, primarily being stringent forest and wildlife protection laws enforced by the Forest Department, regulating access and extraction of forest based resources. Though closure of the entire Tiger Reserve for fishing is not a viable option considering limited employment opportunities available, some portion should be open to the local public for fishing and crab collection. This will help generate goodwill and foster public support, though a study on the carrying capacity and sustainable levels of extraction should be taken up a priori before relaxation of the present forest laws.

Due to the low literacy level of locals, respondents opined humans to be natural prey of tigers. This might be attributed to fear provoked by historical levels of conflict passed on through generations inhabiting the land. Among mitigation measures suggested by the local people, putting up solar lights along village river embankments, enhancing financial compensation for loss of livestock and human life to tigers and predator proof enclosures for livestock pens seems viable and

should be taken up by the state in collaboration with regional nongovernmental organizations. Families of fishermen killed are paid a meager compensation of INR 2,00,000 by the Forest Department only if the victim was engaged in fishing and died outside the designated core area of the Tiger Reserve (ACF, DFO Sunderban Tiger Reserve Pers. Communication). Thus most of the incidents inside the PA go uncompensated. As reported by studies (Kumar and Rahmani 1997, Khuukhenduu and Bidbayasakh 2001,Verdade and Campos 2004) paying for wildlife damage can ostensibly stimulate local support for conservation, reduce incentives for retaliatory action and buy time for alternative management practices (Nyhus *et al*. 2005, Wang and MacDonald 2006). Loss of human life and fatal injuries cannot be compensated by money yet they might engender public support and reduce the pain and agony of the family members. Enhancing compensation value thus is justified on grounds of morality when the direct costs incurred on conserving are felt by a small minority (Treves *et al*. 2009). The model predicting respondents' attitude towards tigers was significantly affected by intensity of conflict in that respective village and knowledge about role of tigers in the wild. This seems realistic considering the psychological impact of hearing about human kills in the neighborhood or actually witnessing them.

People have always been concerned about their own health and safety, and they have evolved both positive and negative responses to large carnivores. Self reported fear has thus played a significant role in conservation of many large carnivores, especially in the Scandinivian countries (Røskaft *et al*. 2003). Thus villages experiencing higher livestock depredation, mortality, injury to humans

have shaped perception of respondents' instilling fear and hatred for tigers. Though age, profession and gender were not included in the final model, yet simple binary logistic regression results (Table 5.13) suggests gender wise female and low literacy level (illiteracy and primary schooling) to be significantly affecting perception towards tigers, though more explanatory variables are required to assess the relationship.

Poverty, low levels of literacy, lack of alternate livelihood, meager income, harsh climatic conditions and high levels of conflict intensity combined forms a complex web ultimately shaping negative perception towards tigers in Sundarban (Inskip *et al*. 2013). Fishermen, crab collectors and honey collectors are most vulnerable to tiger attacks (Chowdhury 1994, Sanyal 1987, Khan 2004, Denzau *et al*. 2010) and (present study, Chapter 4) compared to other groups working for subsistence in the Sundarban with majority staying in kutcha households. Sixty percent of respondents disliked tigers which are expected, provided that they are dependent on forests and have regular interactions, some of which might prove fatal at any point of time. Local pastorals experiencing livestock depredation problem are intolerant to snow leopards especially in the Western Himalayas (Bagchi and Mishra 2006). Respondents generally formed groups of 3 to 6 persons while going for fishing trips preferably during spring tide phase, while honey collectors on an average comprised of 6 to 9 persons. The common gear used in the Sundarbans are dragnets (sarengijal, berjaal), shore seines (jaqnga jal, kochal jal), stakenets (charpata and khalpatta), gillnets (galsha), and fixed

bagnets (beoundi jal, bindi jal) (Mukherjee 2007). Tidal fluctuations are at an extreme during spring tide which favors catching certain species of fish and also helps in navigating inside narrow channels for crabs, while during neap tide the water current slows down considerably favoring other alternate techniques of harvesting fish, yet the maximum harvest reaped is during spring tide phase. Though armed with a machete or wooden poles, sticks, majority of the fishermen and honey collectors are followers of the forest deity-Bonbibi and perform rituals and ceremonies before venturing into the forest. Similar beliefs have been reported from Sumatra where holy men communed with tigers in order to speak to dead heroes, Thailand and peninsular Malaysia where tiger is regarded as the avenger of the Supreme Being, Karei punishing those breaking or disobeying tribal taboos (Montgomery 2008).

Majority of the people dependent on forests for livelihood stated that this was profitable and rewarding compared to other employment opportunities. Overall income generated till the age of 65 years being a fisherman fared better as compared to others except shopkeeper, boat owner and hotel owner involved with tourism. Thus in a place with dire poverty levels and limited employment opportunities it makes sense to take the extra risk securing a stable income for the family. The population of South and North 24 Parganas district comprising Sundarban is 10,00,82,852 (Census of India 2011), with around 20,320 people dependent on forest based resources for their livelihood (Unofficial record, questionnaire surveys, personal observation). The proportion of people dependent on forests out of the entire mass is thus negligibly low i.e. 0.0203

percent. Out of the total number dependent on forests, an average of 6.7 persons dies annually due to tiger attacks. The risk of death from tiger attacks are 0.035 percent which is noticeably low, considering how the local media and popular writings, articles have portrayed it to be over time. Sixty percent of the family members of tiger victims' interviewed were dependent on forests which speak of their resilience and courage in spite of death of a dear one. Loss of a human life doesn't really seem to be a deterrent in the struggle for existence, which is probably worth exploring integrating human psychology and fear provoking stimuli in the subconscious mind.

Ultimately conservation of tigers in Sundarban needs a holistic approach not only focusing on the endangered species but also integrating the socio-economic needs of the local inhabitants. Though tigers will survive in the mangrove area set aside as Tiger Reserve yet retaliatory killings will escalate once conflict intensifies. Local support will be crucial for conservation be it mitigating or managing conflict, thus compensation packages should be enhanced and dispatched immediately. To improve agricultural production, salt tolerant varieties should be provided either by government agencies or nongovernmental organizations at subsidy rates to farmers or free of cost to marginal self help groups. Schools and mobile medical emergency units, hospitals should be constructed by the state government to improve basic conditions of life. Solar lights, if possible electricity should be made accessible to all the islands inhabited and transportation system should be improved. Though majority of the Tiger Reserve is inaccessible to the local public for fishing, crab collection, Forest

Department in consultation with concerned non-governmental organizations might think of opening additional areas beyond the present buffer. This fragile ecosystem is facing the brunt of climate change with an annual 28 cm sea level rise to cause decline of 96% tiger habitat (Loucks *et al*. 2010), and urgent steps such as afforestation, constructing concrete embankments and checking illegal encroachment of river islands should be taken up immediately.

Plate 5.1. A group of honey collectors in Sundarban Tiger Reserve.

Plate 5.2. Interviewing a local in one of the peripheral villages of Sundarban.

CHAPTER 6

CONSERVATION IMPLICATIONS

6.1. INTRODUCTION

Human–carnivore conflict is of special concern because of the potentially disastrous consequences for both people and carnivores (Polisar *et al*. 2003, Nyhus and Tilson 2004, Patterson *et al*. 2004, Inskip and Zimmermann 2009) imperiling the future survival of large carnivores (Woodroffe *et al*. 2005). Among carnivores, large felids are prone to conflict (Sillero-Zubiri and Laurenson 2001, Karanth and Gopal 2005). The large habitat requirements and wide-ranging behaviour of these species frequently cause individuals to disperse beyond Protected Areas, increasing their chance of becoming involved in conflict with humans and of being persecuted and killed (Karanth and Gopal 2005, Kolowski and Holekamp 2006, Loveridge *et al*. 2010). Human populations within the tiger's range in Asia have doubled and people increasingly have come into contact with tigers where resource use overlaps (Nyhus and Tilson 2010).

India is a human–tiger conflict hotspot in which an estimated 50% of the global wild tiger population exists in only 11% of the globally available tiger habitat (Johnsingh *et al*. 2010). Prey depletion has surfaced as one of the primary reason for local extinction of tigers in the past 100 years (Karanth and Stith 1999). Tigers readily kill livestock in areas where wild prey are depleted usually due to hunting, habitat degradation and competition with livestock (Miquelle *et al*. 2005, Johnson *et al*. 2006, Wang and MacDonald 2006, Sangay and Vernes

2008). In retaliation local people have poisoned, hunted down tigers to avenge personal and economic losses. Man-eating tigers are believed to have killed 1,000,000 Asians or about 2,500 people annually in the past four centuries (Matthiessen 2000). Man-eating as reported from other parts of the tiger's distribution range is primarily an outcome of old age or injury, making tigers incapable of catching wild prey or defending resource rich areas. This somehow leads them near human habitations in search of soft targets i.e. humans and livestock (Mountfort 1969, Nowell and Jackson 1996).

Sundarban has been publicized for two primary reasons, the first being the largest concentration of tigers believed to exist here and second, for the highest magnitude of human-tiger conflict in the world. According to official records of the Forest department of India and Bangladesh around 250 and 300 tigers reside in the respective countries (GTRP 2012). An average of 36 human lives are lost to tigers each year on the Indian side of Sundarban, with only 28.5% of victims' bodies being recovered (Chakrabarti 1992). Majority of these tiger victims have been fishermen, honey collectors and woodcutters by profession (Chowdhury 1994, Khan 2004, Sanyal 1987, Denzau *et al*. 2010). Apart from man-eating tigers, entire Sundarban region is under intense human pressure with around 3.5 million people living within 20 kilometres of its northern and eastern borders and depending upon the forests for livelihood resources (Chakrabarti 1992).

6.2. Recommendations to reduce human-tiger conflict

There are plenty of historical records, anecdotal evidence and hypothesis proposed by foresters, biologists regarding man-eating tendency of Sundarban tigers. One such hypothesis by Hubert Hendrich based on a three month study was that tiger attacks on humans increased with increasing salinity levels across the Sundarbans. Though such conclusions have been publicized yet they might be flawed due to short duration of the study and lack of rigorous scientific understanding in investigating the problem. The present study investigated spatio-temporal patterns in conflict and looked at activity peaks in movement pattern of tigers. Human-tiger conflict throughout its distribution range has been predominantly reported outside Protected Areas, either near sub-optimal habitats or within peripheral villages. On the contrary, 95% of tiger attacks on humans occurred inside the Protected Area of Sundarban Tiger Reserve, with only a minority 5% recorded from villages. Tigers evade confrontation with humans, by being nocturnal and crepuscular in majority of the landscapes they co-habit, yet in the Sundarbans they are diurnal. Sundarban tigers are probably the least persecuted tiger's in the world and therefore do not fear people. This seems to be the reason for diurnal activity which coincides with the activity of their prey the spotted deer. Majority of the human kills by tigers were recorded in the daytime between 8 AM and 12 PM (Khan, (2004), (Chakrabarti, 1992) and also by the present study. Thus, diurnal movement pattern of tigers in Sundarban seems to be a major factor resulting in fatal attacks on humans.

Majority of fatal attacks on humans almost 78% in the present study and also findings by Khan (2004), corroborated that channels 30 to 50 meters in width were conflict prone and fishing, crab collection within these should be avoided. The telemetry data from collared tigers showed that even banks of wide channels 200 meters to more than a kilometer in width were intensively used by radio-collared tigers suggestive of well guarded territories. Utmost caution should be taken while fishing along these wide channels or venturing inside the woodland during honey collection to reduce chances of aggressive encounters with tigers.

Phoenix, *Ceriops* and *Avicennia* vegetation patches seems to be preferred habitat for tigers in the mangroves and harvesting natural resources should be prohibited within these to reduce conflict and necessary measures to conserve them should be drawn up by the Forest Department. *Phoenix* dominated patches seems to be an ideal habitat for littering cubs, being dense and at a height beyond reach of tidal inundations. Radio-collared tigers routinely commuted between islands in search of mate and prey with channels of width more than 400 meters which probably acted as deterrents and territorial barriers. Tigers here do cross over channels more than a kilometer in width occasionally while dispersing or when displaced by a stronger rival over territorial disputes.

Apart from man-eating tigers, entire Sundarban region is under intense human pressure with around 3.5 million people living within 20 kilometres of its northern and eastern borders and depending upon the forests for livelihood resources (Chakrabarti 1992). Inskip *et al*. (2009) stated that poverty, low levels of literacy, lack of alternate livelihood, meager income, harsh climatic conditions and high

levels of conflict intensity forms a complex web ultimately shaping negative perception towards tigers in Bangladesh Sundarban. Through this study fishermen interviewed were found to be mostly illiterate residing in mud huts, making them vulnerable against frequent natural calamities prevalent across the region. Though majority of the fishermen are proficient in harvesting natural resources, yet their basic knowledge about tigers are somehow shaped by popular myths and local folklore of the region. Sixty percent of them disliked tigers which were expected, provided that they are dependent on forests and have regular interactions with tigers, some of which might prove fatal at any point of time. Majority of tiger attacks were on groups comprising of two to five people, hence people should form an anti-predator strategy, with minimum of 12 to 15 members to increase vigilance and reduce chances of tiger attacks.

Though people dependent on fishing and honey collection earns comparatively more as compared to the other occupation, yet it is a hazardous occupation and alternate employment opportunities such as eco-tourism, home stays, pisciculture and apiculture should be promoted in villages. To treat tiger victims instantaneously and reduce risk of deaths due to lack of timely aid, Mobile Medical Emergency Units should be set up along conflict prone sites especially during April and May. Village tiger response units can be mobilized from the local youth in collaboration with the Forest Department to garner public support and efficiently resolve human-tiger conflicts. Radio-collaring studies should also be taken up to monitor movement and behavior of problem tigers and ward off possible fatal attacks on humans. Awareness programs and campaigns for local

inhabitants should be organized by the Forest Department and local NGO's to prioritize threats and plausible reasons of tiger attacks to reduce intensity of human tiger conflict.

References

Abramov, V.K. 1962. On the biology of the Amur tiger, (*Panthera tigris longipilis)* Fitzinger, 1868. Acta Zoological Society Bohemoslovenicae 26. Pp. 189–202 (in Russian).

Aebischer, N.J., Peter, A.R., Robert, E.K., Robertson, P.A. and Kenward, R.E. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74. Pp. 1313-1325.

Akaike, H. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control 19. Pp. 716-723.

Andersone, Z. and Ozolins, J. 2004. Public perception of large carnivores in Latvia. Ursus 15. Pp. 181-187.

Anderson, D.P., Forester, J.D., Turner, M.G., Frair, J.L., Merrill, E.H., Fortin, D., Mao, J.S. and Boyce, M.S. 2005. Factors influencing female home range sizes in elk (*Cervus elaphus*) in North American landscapes. Landscape Ecology 20. Pp. 257-271.

Andheria, A.P., Karanth, K.U. and Kumar, N.S. 2007. Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. Journal of Zoology 273. Pp. 169-175.

Andre'n, H., et al. 2006. Survival rates and causes of mortality in Eurasian lynx (*Lynx lynx*) in multi-use landscapes. Biological Conservation 131. Pp. 23–32.

Anon 2011. District Population Census 2011, West Bengal literacy sex ratio and density Census of India.
http://www.census2011.co.in/census/district/11-north-twenty-four-parganas.html
http://www.census2011.co.in/census/district/17-south-twenty-four-parganas.html

Allen, P., McCarthy, T., Bayarjargal, A., 2002. Conservation de la panthe`re des neiges (*Uncia uncia*) avec les e´leveurs de Mongolie. In: Chapron, G., Moutou, F. (Eds.), L_e´tude Et La Conservation Des Carnivores. Societe´ Franc¸aise par L_e´tude et la Protection des Mammife`res, Paris. Pp. 47–53.

Altrichter, M., B Oaglio., G. and Perovic, P. 2006. The decline of jaguars (*Panthera onca*) in the Argentine Chaco. Oryx 40. Pp. 302–309.

Ashcraft, M.H. 1994. Human memory and cognition. Second edition, Harper Collins, New York, New York.

Athreya, V., Navya, R., Punjabi, G.A., Linnell, J.D.C., Odden, M., Khetarpal, S., and Karanth, K.U. 2014. Movement and activity pattern of a collared tigress in a human-dominated landscape in central India. Tropical Conservation Science 7. Pp. 75-86.

Athreya, V.R., Thakur, S.S., Chaudhuri, S. and Belsare, A.V. 2007. Leopards in human-dominated areas: a spillover from sustained translocations into nearby forests? Journal of the Bombay Natural History Society 104. Pp. 45-50.

Athreya, V., Odden, M., Linnell, J.D.C. and Karanth, K.U. 2011. Translocation as a tool for mitigating conflicts with leopards in human-dominated landscapes of India. Conservation Biology 25. Pp. 133-141.

Atwood, T.C., Gese, E.M. and Kunkel, K.E. 2009. System spatial partitioning of predation risk in a multiple predator – multiple prey system. Journal of Wildlife Management 73. Pp. 876–884.

Bagchi, S. and Mishra, C. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). Journal of Zoology 268. Pp. 217-224.

Bailey, T.N. 1993. The African leopard: ecology and behavior of a solitary felid. Columbia University Press, New York.

Baker, R.R. 1978. The evolutionary ecology of animal migration. London: Hodder and Stoughton. Pp.1024.

Beedel, J. and Rehman, T. 1999. Using social-psychology models to understand farmers' conservation behavior. Journal of Environmental Management 57. Pp. 169-176.

Balme, G., Hunter, L. and Slotow, R. 2007. Feeding habitat selection by hunting leopards (*Panthera pardus*) in a woodland savanna: prey catchability versus abundance. Journal of Animal Behavior 74. Pp. 589-598.

Banerjee, S, Carlin, B.P. and Gelfand, A.E. 2004. Hierarchical Modeling and Analysis for Spatial Data. Boca Raton: FL: Chapman and Hall/CRC.

Barlow, A.C.D., McDougal, C., Smith, J.L.D., Gurung, B., Bhatta, S.R., Kumal, S., Mahato, B. and Tamang, D.B. 2009. Temporal variation in tiger (*Panthera tigris*) populations and its implications to monitoring. Journal of Mammalogy 90. Pp 472-478.

Barlow, A.C.D. 2009. The Sundarbans Tiger: Adaptation, Population Status, and conflict management. PhD. Thesis. University of Minnesota.

Barlow, A.C.D., Ahmed, M.I.U., Rahman, M.M., Howlader, A., Smith, A.C. and Smith, J.L.D. 2008. Linking monitoring and intervention for improved management of tigers in the Sundarbans of Bangladesh. Biological Conservation 141. Pp. 2032-2040.

Barlow, A.C.D., Greenwood, C.J., Ahmad, I.U. and Smith, J.L.D. 2010. Use of an action-selection framework for human-carnivore conflict in the Bangladesh Sundarban. Conservation Biology 24(5). Pp.1338-1347.

Barlow, A.C.D., Smith, J.L.D., Ahmad, I.U., Hossain, A.N.M., Rahman, M and Howlader, A. 2011. Female tiger (*Panthera tigris*) home range size in the Bangladesh Sundarbans: the value of this mangrove ecosystem for the species' conservation. Fauna and Flora International. Oryx 45. Pp. 125–128.

Bath, A.J. 1987. Attitudes of various interest groups in Wyoming toward wolf reintroduction in Yellowstone National Park. MA Thesis, University of Wyoming, Laramie. Pp. 124.

Beedell, J.P. and Berger, J. 2003. Rapid ecological and behavioral changes in carnivores. The response of black bears (*Ursus americanus*) to altered food. Journal of Zoology 261. Pp. 207-212.

Beier, P. 1991. Cougar attacks on humans in the United States and Canada. Wildlife Society Bulletin 19(4). Pp. 403-412.

Bekoff, M. 2001. Human-carnivore interactions: adopting proactive strategies for complex problems. Pp. 179-195. In: Gittleman, J. L., Funk, S. M., Macdonald,

D.W. and Wayne, R.K. (Eds.). Carnivore conservation. Cambridge University Press, Cambridge, United Kingdom.

Bell, W.J. 1991. Searching behavior: the behavioural ecology of finding resources. Chapman and Hall, CA. Pp. 372.

Bera, G.K. and Sahay, V.S. 2010. In the lagoons of the Gangetic delta. Mittal Publications, New Delhi.

Bera, G.K., Mukhopadhyay, A.K. and Sarkar, A. 2010. Syncretism at Sundarban-anthropological and linguistic dimensions. In: Bera, G.K. and Sahay, V.S. (Eds.). The lagoons of the gangetic delta. Mittal Publications, Delhi.

Berger, J. 1998. Future prey: some consequences of the loss and restoration of large carnivores. Pp. 80-100. In: Caro, T. (Ed.). Behavioral ecology and conservation biology. Oxford University Press, Oxford, United Kingdom.

Bernard, H.R. 1995. Social research methods: quantitative and qualitative approaches. Sage publications, Thousand Oaks, CA, USA. Pp. 784.

Bernier, F. 1670. Historie de la derniere revolution des etats du Grand Mogul (in French). Travel to the Mogul Empire, 1656-1668. Revised English translation (1891), Archibald Constable, London.

Betsch, T., Plessner, H., Schwieren, C. and Gutig, R. 2001. Personality and Social Psychology Bulletin 27. Pp. 242-253.

Beyer, H.L. 2004. Hawth's analysis tools for ArcGIS. Version 3.08.

Bhattacharya, A. 1999. Embankments as large- scale constructions in the Indian Sunderbans and their impacts on the coastal ecosystems.Pp 143-149. In: Bakshi Guha D.N., Sanyal P. and Naskar. K.R. (Eds.). Sunderban Mangal Calcutta: Naya Prokash.

Binelli, A., Sarkar, S.K., Chatterjee, M., Riva, C., Parolini, M., Bhattacharya, B.D., Bhattacharya, A. and Satpathy, K.K. 2007. Concentration of polybrominated diphenyl ethers (PBDEs) in Sundarban mangrove wetland, north eastern part of Bay of Bengal (India). Mar Pollut Bull 54. Pp.1220-1229.

Bingham, B.B. and Noon, B.R. 1997. Mitigation of habitat 'take': application to habitat conservation planning. Conservation Biology 11. Pp. 127-139.

Bixby, K. 1992. Predator conservation, Pp. 199-213. Balancing on the brink of extinction. In: Kohm, K.A. (Ed.), Island Press, Washington DC, USA.

Blanford, W.T. 1891. Fauna of British India: Mammalia. Taylor and Francis, London.

Boitani, L. 1995. Ecological and cultural diversities in the evolution of wolf-human relationships. Ecology and conservation of wolves in a changing world, In: Carbyn, L.N., Fritt, S.H. and Seip, D.R. (Eds.), Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta, Canada.

Boomgaard P. 2001. Frontiers of Fear: Tigers and People in the Malay World, 1600–1950. New Haven, CT: Yale University Press.

Boyce, M.S. 2006. Scale of resource selection functions. Diversity Distrib. 12. Pp. 269–276.

Bragin, A.P. 1986. Population Characteristics and Social-Spatial Patterns of the Tiger (*Panthera tigris*) on the Eastern Macroslope of the Sikhate-Alin Mountain Range, USSR. Pacific Institute of Geography, Vladivostok, Russia.

Brechin, S.R. 2003. Exploring Human-Jaguar Conflicts in Belize, Central America: Six Month Progress Report. Unpublished Report, University of Michigan and University of Illinois, USA.

Brown, J.L. 1969. Territorial behavior and population regulation in birds: A review and reevaluation. Wilson Bulletin 81. Pp. 293–329.

Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24. Pp. 346-353.

Burton, R.G. 1931. A Book of Man-Eaters. London: Hutchinson and Co. Ltd.

Butler, J.R.A. 2000.The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. African Journal of Ecology 38. Pp. 23- 30.

Carter, N.H., Riley, S.J., and Liu, J. 2012. Utility of a psychological framework for carnivore conservation. Oryx 46. Pp. 525–535.

Caughley, H.G. and Sinclair, A.R.E. 1994. Wildlife ecology and management. Blackwell Scientific Publications, Oxford, UK. Pp. 334.

Chakrabarti, K. 1978. Ecology of the Sundarbans tiger with particular reference to range of habitats and adaptability to changes. Cheetal, Vol. 20, no 2, December.

Chakrabarti, K. 1984. Statistical ecology of Sundarbans tiger. Tiger Paper 11. Pp. 29-31.

Chakrabarti, K. 1992. Man-eating tigers. Darbari Prokashan, Calcutta.

Champion, H. and Seth, S. 1968. A revised study of the forest types of India. Government of India Press, New Delhi. Pp. 404.

Chapron, G., Miquelle, D.G., Lambert, A., Goodrich, J.M., Legrandre, S. and Clobert, J. 2008. The impact on tigers of poaching versus prey depletion. Journal of Applied Ecology.

Chaudhuri, A.B. and Chakrabarti, K. 1989. Sundarban Mangrove (Ecology and Wildlife). Jugal Kishore and Co. (Pub. Div.), Dehradun.

Chaudhuri, A.B. and Choudhury, A. 1994. Mangroves of the Sundarbans, Vol. 1: India. IUCN, Bangkok. Pp. 247.

Chowdhury, M.K. and Sanyal, P. 1985. Man-eating behaviour of the tigers of the Sundarbans, West Bengal. Environment and Ecology 2. Pp. 243-248.

Chowdhury, R.A. and Ahmed, I. 1994. History of forest management. Mangroves of the Sundarbans 2. Pp.155–180.

Chowdhury, A.N., Mondal R, Brahma, A. and Biswas, M.K. 2008. Eco-psychiatry and Environmental Conservation: Study from Sundarban Delta, India. Environmental Health Insights 2: Pp. 61–76.

Chundawat, R.S., Gogate, N. and Johnsingh, A.J.T. 1999. Tigers in Panna: Preliminary results from an Indian tropical dry forest. Pp. 123-129. In: Seidensticker, J., Christie, S.and Jackson, P. (Eds.). Riding the tiger. Tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Chundawat, R.S., Gogate, N. and Malik, P.K. 2002. Understanding tiger ecology in the tropical dry forest of Panna Tiger Reserve. Wildlife Institute of India (1996–2002) Technical report. Pp.105.

Chepko-Sade B. D., Halpin, Z.T. and Chepko-Sade B.D. 1987. The effects of dispersal and social structure on effective population size. Pp. 287–321. Mammalian dispersal patterns: the effects of social structure on population genetics. In: Chepko-Sade B.D. and Halpin Z.T. (Eds.). University of Chicago Press, Chicago, Illinois.

Clutton-Brock, T.H. and Harvey, P.H. 1978. Mammals, resources and reproductive strategies. Nature 273. Pp. 191–195.

Coggins, C. 2003.The Tiger and the Pangolin: Nature, Culture, and Conservation in China. Honolulu: University of Hawai'i Press.

Conforti, V. A. and Azevedo, C.C.d. 2003. Local perceptions of jaguars (*Panthera onca*) and pumas (*Puma concolor*) in the Iguacu National Park area, south Brazil. Biological Conservation 111. Pp. 215-221.

Conover, M. 2002. Resolving human-wildlife conflicts: The science of wildlife damage management. CRC Press, Boca Raton, Florida, USA. Pp. 418.

Corbett, J. 1944. Man-eaters of Kumaon. London: Oxford University Press.

Corbett, J. 2005. The Jim Corbett Omnibus. Oxford University Press, New Delhi.

Corlett, R.T. 2007. The impact of hunting on the mammalian fauna of tropical Asian forests. Biotropica 39. Pp. 292–303.

Creel, S. 1998. Social organization and effective population size in carnivores. Pp. 246–265. Behavioral ecology and conservation biology. In: Caro, I. (Ed.). Oxford University Press, Oxford, United Kingdom.

Creel, S., Winnie, Jr. and J.A. 2005. Responses of elk herd size to fine-scale spatial and temporalvariation in the risk of predation by wolves. Animal Behavior 69. Pp. 1181–1189.

Cressie, N. 1993. Statistics for spatial data, Wiley, New York.

Danda, A.A. 2007. Surviving in the Sundarbans: Threats and responses. PhD thesis. University of Twente, Netherlands.

Das, A.K., Mukherji, S. and Chowdhuri, M.K. 1981. A Focus on Sundarban. Calcutta: Editions Indian.

Denzau, N.G. and Denzau, H. 2010. Examining certain aspects of human-tiger conflict in the Sundarbans Forest, Bangladesh Vol. 37: No. 3. Tigerpaper.

de Solla, S.R., Bonduriansky, R. and Brooks, R.J. 1999. Eliminating autocorrelation reduces biological relevance of home range estimates. Journal of Animal Ecology 68. Pp 221-234.

Dey, T.K. 2004. Population ecology of the barking deer (*Muntiacus muntjak*) and spotted deer (*Axis axis*) of Bangladesh. PhD Thesis, Department of Zoology, University of Dhaka.

Dickman, A.J. 2005. An assessment of pastoralist attitudes and wildlife conflict Rungwa in the Rungwa-Ruaha region, Tanzania, with particular reference to large carnivores. MSc dissertation, University of Oxford, Oxford, UK.

Dinda, A. 2010. Economic role and status of tribal women- a study in deltaic Sundarban of west Bengal. In the lagoons of the gangetic delta. In: Bera, G.K. and Sahay, V.S. (Eds.). 2010. Mittal Publications, Delhi.

Dinerstein, E., Loucks, C., Wikramanayake, E., Ginsberg, J., Sanderson, E., Seidensticker, J., Forrest, J., Bryja, G., Heydlauff, A., Klenzendorf, S., Leimgruber, P., Mills, J., O'Brien, T.G., Shrestha., M., Simons, R. and Songer, M. 2007. The fate of wild tigers. BioScience 57. Pp. 508-514.

Dinerstein, E., Wikramanayake, E., Robinson, J., Karanth, K.U., Rabinowitz, A., Olson, D., Mathew, T., Hedao, P., Connor, M., Hemley, G. and Bolze, D. 1997. A framework for identifying high priority areas and actions for the conservation of tigers in the wild, Part I. WWF-US, and Wildlife Conservation Society, Washington, DC.

Dobson, F.S. 1982. Competition for mates and predominant juvenile male dispersal in mammals. Animal Behaviour 30. Pp. 1183–1192.

Dunn, J. E. and Gipson, P.S. 1977. Analysis of radio telemetry data in studies of home range. Biometrics 33. Pp. 85-101.

Ebersole, S.P. 1980. Food density and territory size: An alternative model and test on the reef fish (*Eupomacentrus leucostius*). American Naturalist 115. Pp. 492–509.

Eisenberg, J.F. 1986. Life history strategies of the Felidae: variations on a common theme. Pp. 293–303. Cats of the world: biology, conservation, and

management. In: Miller S.D. and Everett, D.D. (Eds.). National Wildlife Federation, Washington, D.C.

Emlen, S.T. and Oring, L.W. 1977. Ecology, sexual selection and the evolution of mating systems, Science 197. Pp. 215-223.

Fahrig, L. 2007. Non-optimal animal movement in human-altered landscapes. Functional Ecology 21. Pp 1003-1015.

Ferreras, P., Gaona, P., Palomares, F., and Delibes, M. 2001. Restore habitat or reduce mortality? Implications from a population viability analysis of the Iberian lynx. Animal Conservation 4. Pp 265–274.

Fishbein, M. and Ajzen, I. 1975. Belief, attitude, intention and behavior. An introduction to theory and research. Addison-Wesley, Reading, Massachusetts. Pp. 578.

Fishbein, M. and Middlestadt, S. 1995. Noncognitive effects on attitude formation and change: Fact or Artifact? Journal of Consumer Psychology 4. Pp. 181-202.

Fisher and Ronald 1925. Statistical Methods for Research Workers. Edinburgh: Oliver and Boyd. ISBN 0-05-002170-2.

Frank, L.G., Woodroffe, R. and Ogada. M.O. 2005. People and predators in Laikipia District, Kenya. Conservation Biology Series (Cambridge) 9. Pp. 286-304.

Fretwell, S.D. and Lucas, H.L., Jr. 1970. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. Acta Biotheoretica 19. Pp. 16–36.

Gani, M.O. 2002. A study on the loss of Bengal tiger (*Panthera tigris*) in five years (1996-2000) from Bangladesh Sundarbans. Tigerpaper 29(2). Pp. 6-11.

Garga, D.P. 1947. How far a Tiger can swim. Journal of Bombay Natural History Society pp 545-546.

Ghosh, A. 2004. The hungry tide. Ravi Dayal Publisher New Delhi. Pp. 402

Gittleman, J.L. (Ed.). 1996. Carnivore behavior, ecology and evolution. Vol 2. Ithaca: Cornell University Press.

Goodrich, J.M. and Miquelle. D.G. 2005. Translocation of problem Amur tigers (*Panthera tigris altaica)* to alleviate tiger-human conflicts. Oryx 39. Pp. 454-457.

Goodrich, J. M., Kerley, L. L., Smirnov, E.N., Miquelle, D.G., McDonald, L., Quigley, H. B., Hornocker, M.G. and McDonald, T. 2008. Survival rates and causes of mortality of Amur tigers on and near the Sikhote-Alin Biosphere Zapovednik. Journal of Zoology.

Goodrich, J.M., Miquelle, D.G., Smirnov, E.N., Kerley, L.L., Quigley, H.B. and Hornocker, M.G. 2010. Spatial structure of Amur (Siberian) tigers (*Panthera tigris altaica*) on Sikhote–Alin Biosphere Zapovednik, Russia, Journal of Mammalogy 91(3). Pp. 737–748.

Goodrich, J.M., Seryodkin, I.V., Miquelle, D.G., Kerley, L.L., Quigley, H.B. and Hornocker, M.G. 2011. Tooth Breakage in Tigers: cause for conflict? Journal of Zoology.

Goldman, M.J., Roque, De., Joana, P., and Jennifer, P, 2010. Maintaining Complex Relations with Large Cats: Maasai and Lions in Kenya and Tanzania. Human Dimensions of Wildlife 15: 5. Pp. 332-346.

Gorini, L., Linnell, J.D.C., May, R., Panzacchi, M., Boitani, L., Odden, M., Nilsen, E.B. 2012. Habitat heterogeneity and mammalian predator-prey interactions. Journal Mammal Review 42. Pp. 55–77.

Gouldsbury, D.E. 1915. Tiger Slayer by Order. London: G. Bell and Sons.

Goyal, S.P. 2001. Man-eating leopards- status and ecology of leopard in Pauri Garhwal, India. Carnivore Damage Prevention News 3. Pp. 9-10.

Griffith, M. and Van Schaik, C.P. 1993. The impact of human traffic on the abundance and activity periods of Sumatran rainforest wildlife. Conservation Biology 7. Pp. 623-626.

Gurung, B., Smith, J.L.D., McDougal, C., Karki, J.B., and Barlow, A.C.D. 2008. Factors associated with human-killing tigers in Chitwan National Park, Nepal. Biological Conservation 141. Pp. 3069-3078.

Guzzella, L., Vigano, L., Sarkar, S.K., Saha, M., and Bhattacharya, A. 2005. Distribution of HCH., DDT, HCB and PAH in the sediments of coastal environments of West Bengal, northeast part of India. Environ Int, 31. Pp.523-534.

Hansteen, T.L., Andreassen, H.P. and Ims, R.A. 1997. Effects of spatiaotemporal scale on autocorrelation and home range parameters. The Journal of Wildlife Management 61. Pp. 280-290.

Harris, S., Cresswell, W.J., Forde, P.G., Trewhella, W.J., Wollard, T. and Wray, S. 1990. Home–range analysis using radio–tracking data: a review of problems and techniques applied to the study of mammals. Mammal Review 20. Pp. 97–123.

Hayne, D.W. 1949. Calculation of size of home range. Journal of Mammalogy 30. Pp. 1-18.

Hazra, S., Ghosh, T., Das Gupta, R. and Sen, G. 2002. Sea level and associated changes in the Sundarbans. Science and Culture 68. Pp. 309-321.

Hazra, S. 2010. Temporal change detection (2001-2008) of the Sundarban. Unpublished report. WWF-India.

Hemson, G., Johnson, P., South, A., Kenward, R., Ripley, R. and Macdonald, D. 2005. Are kernels the mustard? Data from global positioning systems (GPS) collars suggests problems for kernel home-range analyses with least-square cross-validation. Journal of Animal Ecology 74. Pp. 455-463.

Hendrichs, H. 1975. The status of the tiger (*Panthera tigris)* in the Sundarban mangrove forest (Bay of Bengal). Saugetierk. Mltt. 23. Pp. 161-199.

Hixon, M.A. 1980. Food production and competitor density as the determinants of feeding territory size. American Naturalist 115. Pp. 510–530.

Hodder, K.H. and Kenward, R.E., 1998. Estimating core ranges: a comparison of techniques using the common buzzard (*Buteo buteo*). Journal of Raptor Research 32. Pp. 82–89.

Holmern, T., Nyahongo, J. and Roskaft, E. 2007. Livestock loss caused by predators outside the Serengeti National Park, Tanzania. Biological Conservation 135. Pp. 518–526.

Homer, P.M. and Kahle, L.R. 1988. A structural equation test of the value-attitude behavior hierarchy. Journal of Personality and Social Psychology 54. Pp. 638-646.

Hoogerwerf, A. 1970. Udjung Kulon: the land of the last Javan rhinoceros. E.J. Brill, Leiden.

Hopkins, R.A., Kutlek, M.J. and Shreve, G.L. 1986. Density and home range characteristics of mountain lions in the Diablo Range of California. Pp. 223–235. Cats of the world: biology, conservation, and management. In: Miller, S.D. and Everett, D.D. (Eds.). National Wildlife Federation, Washington, D.C.

Horne, J.S., Garton, E.O. and Rachlow, J.L. 2008. A synoptic model of animal space use: simultaneous estimation of home range, habitat selection, and inter/intra-specific relationships. Ecological Modeling 214. Pp. 338-348.

Hornocker, M.G. 1969. Winter territoriality in mountain lions. Journal of Wildlife Management 33. Pp. 457–464.

Hornocker, M., and T. Bailey. 1986. Natural regulation in three species of felids. Pp. 211–220. Cats of the world: biology, conservation, and management. In: Miller S.D. and Everett, D.D. (Eds.). National Wildlife Federation, Washington, D.C.

Hughes, J.D. 2003. Europe as consumer of exotic biodiversity: Greek and Roman times. Lands Res. Pp. 21-28.

Inskip, C. and Zimmerman, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. Oryx, 43. Pp. 18-34.

Inskip, C., Ridout, M., Fahad, Z., Tully, R., Barlow, A., Greenwood Barlow, C., Islam, M.A., Roberts, T., MacMillan, D., 2013. Human–tiger conflict in context: risks to lives and livelihoods in the Bangladesh Sundarbans. Hum. Ecol. 41. Pp. 169–186.

IUCN 2003 WPC Recommendation V. 20: Preventing and Mitigating Human-WildlifeConflicts.InRecommendations,pp.185186.Http://cmsdata.iucn.org/downloads/recommendationen.pdf [accessed 23 February 2007].

IUCN 2008. The IUCN Red List of Threatened Species.

IUCN 2011. The IUCN Red List of Threatened Species.

Jackson, P. 1985. Man-Eaters! International Wildlife, 15. Pp. 4–11.

Jewell, P.A. 1966. The concept of home-range in mammals. Symposia of Zoological Society of London, 18. Pp. 85-109.

Jhala, Y.V., Gopal, R. and Qureshi, Q. 2008. Status of tigers, co-predators and prey in India. National Tiger Conservation Authority, New Delhi and Wildlife Institute of India. TR08/001.

Jhala, Y.V., Mukherjee, S., Shah, N., Chauhan, K.S., Dave, C. and Zala, Y.P. 2004. Monitoring lions. Pp. 55-71. Monitoring of Gir. In: Jhala, Y.V. (Ed.), Technical report, Wildlife Institute of India, Dehradun, India.

Jhala, Y.V., Qureshi, Q, Gopal, R. and Sinha, P.R. 2010. Status of tigers, co–predators and prey in India. National Tiger Conservation Authority, Govt., of India, New Delhi and Wildlife Institute of India, Dehradun. TR 11/003. Pp. 302.

Jhala, Y.V., Qureshi, Q., Gopal, R. and Sinha, P.R. (Eds.) 2011. Status of the Tigers, Co-predators, and Prey in India, 2010. National Tiger Conservation Authority, Govt. of India, New Delhi, and Wildlife Institute of India, Dehradun. TR 2011/003. Pp-302.

Johnson, A., Vongkhamheng, C., Hedemark, M. and Saithongdam, T. 2006. Effects of human-carnivore conflict on tiger (*Panthera tigris*) and prey populations in Lao PDR. Animal Conservation 9. Pp. 421-430.

Johnsingh, A.J.T., Panwar, H.S. and Rodgers, W.A. 1991. Ecology and conservation of large felids in India. In Wildlife conservation: present trends and perspectives for the 21st century. Proceedings of the International Symposium on Wildlife Conservation in Tsukuba and Yokohama, Japan.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61. Pp. 65-71.

Kaczensky, P. 2003. Is coexistence possible? Public opinion of large carnivores in the Alps and Dinaric Mountains. Living with bears: a large carnivore in a shrinking world. In: Krystufek, B., Flajsman, B., and Griffiths, H.I., (Eds.), Ecological Forum of the Liberal Democracy of Slovenia, Ljubljana, Slovenia. Pp. 59-89.

Karanth, K.U. and Nichols, J.D. 1998. Estimation of tiger densities in India using photographic captures and recapture. Ecology 79. Pp. 2852-2862.

Kaczensky, P., Blazic, M. and Gossow, H. 2004. Public attitudes towards brown bears (*Ursus arctos*) in Slovenia. Biological Conservation 118. Pp. 661-674.

Karanth, K.U. and Nichols, J.D. 2000. Ecological status and conservation of tigers in India. Final technical report to the US fish and wildlife service, Washington DC, and Wildlife Conservation Society, New York. Center for Wildlife Studies, Bangalore, India.

Karanth, K.U. and Sunquist, M.E. 2000. Behavioral correlates of predation by tiger (*Panthera tigris*), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) in Nagarahole, India. Journal of Zoology 250. Pp. 255-265.

Karanth, K.K., Gopalaswamy, A.M., DeFries, R. and Ballal, N. 2012. Assessing patterns of human-wildlife conflicts and compensation around a central Indian protected area. PLoS ONE, 7, e50433.

Karanth, K.U. 1993a. How many tigers? Field censuses in India. Hornbill 1. Pp. 2-9.

Karanth, K.U. 1993b. The relevance of big cat numbers to their conservation. Cat News 19. Pp.11-12.

Karanth, K.U. 1993c. Predator-prey relationships among large mammals of Nagarhole National Park, India. PhD dissertation, Mangalore University, Bangalore.

Karanth, K.U., Nichols, J.D., Kumar, N.S., Link, W. A. and Hines, J. E. 2004. Tigers and their prey: predicting carnivore densities from prey abundance. Proceedings of the National Academy of Sciences, 101. Pp. 4854-4858.

Karanth, K.U. and Madhusudan, M.D. 2002. Making parks work: identifying key factors to implementing parks in the tropics. In: Terborgh JW, van Schaik C, Davenport L, Rao M (Eds.). Mitigating human-wildlife conflicts in southern Asia. Island, Covelo. Pp 250–264.

Karanth, K.U. and Stith, B.M. 1999. Prey depletion as a critical determinant of tiger population viability. Pp 316-332. In: Seidensticker, J., Christie, S., Jackson, P. (Eds.), Riding the Tiger: Tiger Conservation in Human-dominated Landscapes. Cambridge University Press.

Karanth, K.U. and Sunquist, M.E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology 64. Pp. 439–450.

Karanth, K.U., Nichols. J.D., Seidensticker, J., Dinerstein, E., Smith, J.L.D., McDougal, C., Johnsingh, A.J.T., Chundawat, R.S. and Thapar, V. 2003. Science deficiency in conservation practice: the monitoring of tiger populations in India. Animal Conservation 6. Pp. 141-146.

Karanth, K.U. and Gopal, R. 2005. An ecology based policy framework for human-tiger coexistence in India. Pp. 373-387. In: Woodroffe, R., Thirgood, S. and Rabinowitz, A. (Eds.). People and wildlife: conflict or coexistence? Cambridge University Press, UK.

Kellert, S.R. 1985. The public and the timber wolf in Minnesota. Transactions of the North American Wildlife and Natural Resources Conference 56. Pp. 152-161.

Kenward, R.E., Clarke, R.T., Hodder, K.T. and Walls, S.S. 2001. Density and linkage estimators of home range: nearest –neighbour clustering defines multinuclear cores. Ecology, 82. 1905-1920.

Kellert, S.R. 1996. The value of life. Biological diversity and human society. Washington, D.C. Island Press. Pp 280.

Kernohan, B.J., Gitzen, R.A. and Millspaugh, J.J. 2001. Analysis of animal space use and movements. Pp. 125-166. In: Radio tracking and animal populations. Millspaugh, J.J. and Murzluff, J.M. (Eds.). Academic Press. London, UK.

Kerley, L.L., Goodrich, J.M., Miquelle, D.G., Smirnov, Ye.N., Quigley, H.B. and Hornocker. M.G. 2003. Reproductive parameters of wild female Amur tigers. Journal of Mammalogy 84. Pp. 288-298.

Khan, M.M.H. 2004. Ecology and conservation of the Bengal tiger in the Sundarban Mangrove forest of Bangladesh. PhD thesis, University of Cambridge.

Khan, M.M.H. and Chivers, D.J. 2007. Habitat preferences of tigers (*Panthera tigris*) in the Sundarban East Wildlife Sanctuary, Bangladesh, and management recommendations. Oryx 41. Pp. 463-468.

Khan, M.M.H. 2008. Prey selection by tigers (*Panthera tigris*) in the Sundarbans East Wildlife Sanctuary of Bangladesh. Journal of the Bombay Natural History Society 105. Pp. 255–263.

Khan, M.A.R. 1987. The problem tiger of Bangladesh. Pp. 92-96. In: Tilson, R.L. and Seal, U.S. (Eds.). Tigers of the world. Noyes Publications, Park Ride.

Khramtsov V.S. 1995. Behavior of a tiger encountering a human. Russian Journal of Ecology 26. Pp. 228–229.

Khuukhenduu, T. and Bidbayasakh, E. 2001. Wolf depredation in Mongolian park is a fact of life. International Wolf 6. Pp. 10.

Kissling, W., Fernandez, N. and Paruelo, M. 2009. Spatial risk assessment of livestock exposure to pumas in Patagonia, Argentina. Ecography 32. Pp. 807–817.

Kitchener, A.C. 1999. Tiger distribution, phenotypic variation and conservation issues. Pp. 19-39. In: Seidensticker, J., Christie, S. and Jackson, P. (Eds.). Riding the tiger. Tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Kleiman, D.G., and Eisenberg, J.F. 1973. Comparison of canid and felid social systems from an evolutionary perspective. Animal Behaviour 21. Pp. 637–659.

Kolowski, J.M. and Holekamp, K.E., 2006. Spatial, temporal, and physical characteristics of livestock depredation by large carnivores along a Kenyan reserve border. Biological Conservation 128. Pp. 529–541.

Kotwal, P. C. and Gopal, R. 1995. Radio-telemetry and field observations on territoriality of tigers in Kanha National Park. Tiger Paper 22. Pp. 6-11.

Kreeger, T.K. 1996. Handbook of Wildlife Chemical immobilization. International Wildlife Vet. Services Inc. Post Box 37, Larammie, WY, USA.

Kumar, S. and Rahmani, A.R. 1997. Status of Indian grey wolf (*Canis lupus pallipes)* and its conservation in marginal agricultural areas of Solapur district, Maharashtra. Journal of the Bombay Natural History Society 94. Pp. 466–472.

Kullback, S. and Leibler. R.A. 1951. On information and sufficiency. Annals of Mathematical Statistics 22. Pp. 79-86.

Laundre, J.W., Calderas, J.M.M. and Hernandez, L. 2009. Foraging in the landscape of fear, the predator's dilemma: where should I hunt? The Open Ecology 2. Pp. 1-6.

Laver, P.N. and Kelly, M.J. 2008. A critical review of home range studies. The Journal of Wildlife Management 72. Pp. 290-298.

Lenihan, M.L. 1996. Public attitudes about wolves: a review of recent investigations. In: The Yellowstone Wolf—AGuide and Sourcebook. Mill Pond Press, Venice. Pp. 354.

Levin, S.A. 1992. The problem of pattern and scale in ecology: the Robert H. MacArthur Award Lecture. Journal of Ecology 73. Pp. 1943–1967.

Linkie, M., Christie, S. 2007. The value of wild tiger conservation. Oryx 41. Pp. 415–416.

Linkie, M., Dinata, Y., Nofrianto, A. and Leader-Williams, N. 2007. Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. Animal Conservation 10. Pp. 127-135.

Linnell, J.D.C. and Strand, O. 2000. Interference interactions, co-existence and conservation of mammalian carnivores. Diversity and Distributions 6. Pp.169-176.

Linnell, J.D., Odden, C.J., Smith, M.E., Anes, R., and Swenson, J.E. 1999. Large carnivores that kill livestock: do “problem individuals” really exist? Wildlife Society Bulletin 27. Pp. 698-705.

Linenell, J.D.C., Swenson, J.E. and Andersen, R. 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. Animal Conservation 4. Pp. 345-349.

Li, B., Zhang, E. and Liu, Z., 2009. Livestock depredation by Amur tigers in Hunchun Nature Reserve, Jilin, China. Acta Theriologica Sinica 29. Pp. 231–238.

Loarie, S.R., Tambling, C.J. and Asner, G.P. 2013. Lion hunting behaviour and vegetation structure in an African savanna. Animal Behaviour. Pp. 1–8.

Löe, J. and E. Röskaft. 2004. Large Carnivores and Human Safety: a review. AMBIO: A Journal of the Human Environment 33. Pp. 283-288.

Logan, K.A. and Sweanor, L.A. 2001. Desert puma: evolutionary ecology and conservation of an enduring carnivore. Island Press, Washington, D.C.

Lott, D.F. 1991. Intraspecific variation in the social systems of wild GW vertebrates. Cambridge University Press, Cambridge, Massachusetts.

Loucks, C., Meyer, B.S., Hossain, A.A.Md., Barlow, A.C.D. and Chowdhury, M.R. 2010. Sea level rise and tigers: predicted impacts to Bangladesh's Sundarbans mangroves. Climate Change 98. Pp. 291-298.

Loveridge, A.J., Hemson, G., Davidson, Z. and MacDonalad, M. 2010. African lions on the edge: reserve boundaries as ' attractive sinks'. 283-304. Biology and Conservation of wild felids. In: Macdonald, D. and Loveridge, A.J. (Eds.). Oxford University Press, London. UK.

Luo, S.J., Kim, J.H., Johnson, W.E., Walt, J., Martenson, J., Yuhki, N., Miquelle, D.G., Uphyrkina, O., Goodrich, J.M., Quigley, H.B., Tilson, R., Brady, G., Martelli, P., Subramaniam, V., McDougal, C., Hean, S., Huang, S.Q., Pan, W., Karanth, U.K., Sunquist, M., Smith, J.L.D. and. Brien. S.J. 2004. Phylogeography and genetic ancestry of tigers (*Panthera tigris*). PLoS Biology 2:e442.

Macdonald, D.W., Daniels, M.J., Driscoll, C.A., Kitchener, A.C., and Yamaguchi, N. 2004. The Scottish Wildcat: Analyses for Conservation and an Action Plan.Wildlife Conservation Research Unit, Oxford, UK.

MacDonald, D.W. and Sillero-Zubiri, C. 2002. Large carnivores and conflict: lion conservation in context, Lion Conservation Research. Workshop 2: Modeling conflict, Pp. 1-8. In: Loveridge, A.J., and Lynam, T. and MacDonald, D.W. (Eds.), Wildlife Conservation Research Unit, Oxford, UK.

MacDonald, D.W., Ball, F.G. and Hough, N.G. 1980. The evaluation of home range size and configuration using radio tracking data. Pp. 405-425: A handbook on biotelemetry and radio tracking. In: Amlaner, C.J. and Macdonald, D.W. (Eds.), Oxford University Press, UK.

Madden, F. 2004. Creating coexistence between humans and wildlife: global perspectives on local efforts to address human wildlife conflict. Human Dimensions of Wildlife, 9. Pp. 247–257.

Madhusudan, M.D. and Karanth, K.U. 2002. Local hunting and the conservation of large mammals in India. Ambio 31: Pp. 49-54.

Madhusudan, M.D. 2003. Living amidst large wildlife: Livestock and crop depredation by large mammals in J. M. Goodrich © 2010 ISZS, Blackwell Publishing and IOZ/CAS 311the interior villages of Bhadra Tiger Reserve, South India. Environmental Management 31. Pp. 466–475.

Manfredo, M.J., Pierce, C.L., Fulton, D., Pate, J. and Gill. B.R. 1999. Public acceptance of wildlife trapping in Colorado. Wildlife Society Bulletin 27.Pp. 499-508.

Marker, L.L., M.G.L. Mills, and Macdonald. D.W. 2003. Factors influencing perceptions and tolerance toward cheetahs (*Acinonyx jubatus*) on Namibian fannlands. Conservation Biology 17. Pp. 1-9.

Matthiessen, P. 2000. Tigers in the snow. The Harvill Press, London. Pp. 185.

Matyukshin, E. N. 1978. Characteristic features of distribution and ecology of the Amur tiger as a geographical form of a species adapted to an extreme environment. International Tiger Symposium, Leipzig Zoological Garden 1. Pp. 23–32.

Matyushkin, E.N, Zhivotchenko, V.I. andSmirnov, E.N.1980.The Amur tiger in the USSR. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources (IUCN).

Matyushkin, E.N., Pikunov, D.G., Dunishenko, Y. M., Miquelle, D.G., Nikolaev, I.G., Smirnov, E.N., Salkina, G.P., Abramov, V.K., Bazilnikov, B.I. and Yudin, V.G. 1999. Distribution and numbers of Amur tigers in the Russian Far East in the mid- 1990's. Rare mammal species of Russia and neighboring territories (in

Russian). Moscow: Russian Academy of Sciences Theological Society. Pp. 242–271.

Maynard Smith, J. 1976. Evolution and the theory of games. American Scientist 64. Pp. 41–45.

McCullagh, P. and Nelder, J.A. 1989. Generalized Linear Models, 2nd edition. Chapman and Hall, London. Pp. 511.

McDougal, C. 1977. The Face of the Tiger. London: Rivington Books.

McDougal, C. 1987. The Man-eating tiger in geographical and historical perspective. Pp. 435-488. In: Tilson, R.L., Seal, U.S. (Eds.). Tigers of the World: The Biology, Biopolitics, Management and Conservation of an Endangered Species. Noyes Publications, Park Ridge, New Jersey.

McNeely, J.A. and Sochaczewski, P.S. 1988. Soul of the Tiger: Searching for Nature's Answers in Southeast Asia. Honolulu: University of Hawai'i Press.

Mech, L.D. 1995. The challenge and opportunity of recovering wolf populations. Conservation Biology 9. Pp. 270-278.

Meier, M.S, Ramsauer, S., Gabanapelo T. and König, B. 2007. Livestock Predation-Insights From Problem Animal Control Registers in Botswana. The Journal of Wildlife Management Vol. 71, No. 4. Pp. 1267-1274.

Mills, M.G.L. and Hofer, H. 1998. Hyenas: Status survey and conservation action plan.World Conservation Union, Gland, Switzerland and Cambridge, UK. Pp. 154.

Millspaugh, J.J., Nielson, R.M., McDonald, L., Marzluff, J.M., Gitzen, R.A., Rittenhouse, C.D., Hubbard, M.W. and Sheriff, S.L. 2006. Analysis of resource selection using utilization distributions. The Journal of Wildlife Management 70. Pp. 384-395.

Miquelle, D., Nikolaev, I., Goodrich, J., Litvinov, B., Smirnov, E., Suvorov, E. 2005. Searching for the coexistence recipe: a case study of conflicts between people and tigers in the Russian Far East. Pp. 305-322. In: Woodroffe, R., Thirgood, S., Rabinowitz, A. (Eds.), People and Wildlife: Conflict or Coexistence? Cambridge University Press, Cambridge, United Kingdom.

Miquelle, D.G., Smirnov, E.N., Quigley, H.G., Hornocker, M.G., Nikolaev, I.G and Matyushkin. E.N. 1996. Food habits of Amur tigers in Sikhote-Alin Zapovednik and the Russian Far East, and implications for conservation. The Journal of Wildlife Research 1. Pp. 138-147.

Miquelle, D.G., Smirnov, E.N., Merrill, T.W., Myslenkov, A.E., Quigly, H.B., Hornocker, M.G. and Schleyer, B. 1999. Hierarchical spatial analysis of Amur tiger relationships to habitat and prey. Pp. 71-99. In: Seidensticker, J., Christie, S. and Jackson, P. (Eds.). Riding the tiger. Tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Miquelle, D.G., Goodrich, J.M., Kerley, L.L., Pikunov, D.G., Dunishenko, Y.M., Aramiliev, V.V., Smirnov, E.N., Nikolaev, I.G., Salkina, G.P., Zhang, E., Seryodkin, I.V., Carroll, C., Gapanov, V.V., Fomenko, P.V., Kostyria, A.V., Murzin, A.A., Quigley, H.B. and Hornocker, M.G. 2010a. Science-Based Conservation of Amur Tigers In Russian Far East And Northeast China. Pp. 399-419. In: Tilson, R. and Nyhus, P. (Eds.). Tigers of the world: the science, politics, and conservation of *Panthera tigris*, 2nd. Oxford: Elsevier Limited.

Miquelle, D., Nikolaev, I., Goodrich, J., Litvinov, B., Smirnov, E. and Suvorov, E., 2005. Searching for the coexistence recipe: a case study of conflicts between people and tigers in the Russian Far east. Pp. 305-322. In: Woodroffe, R., Thirgood, S., Rabinowitz, A. (Eds.), People and Wildlife: Conflict or Coexistence? Cambridge University Press.

Miquelle, D.G., Pikunov, D.G., Dunishenko, Y.M., Aramilev, V.V., Nikolaev, I.G., Abramov, V.K., Smirnov, E.N., Salkina, G.P., Seryodkin, I.V., Gaponov, V.V.,

Fomenko, P.V., Litvinov, M.N., Kostyria, A.V., Yudin, V.G., Korkishko, V.G. and Murzin, A.A. 2007: 2005 Amur tiger census. - Cat News 46: Pp. 14-16.

Mishra, C.G.H. 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation perspectives. Biological Conservation 24. Pp. 338-343.

Mitra, A. 2000. The northwest coast of the Bay of Bengal and deltaic Sundarban. Pp. 145-160. In: Sheppard, C.R.C. (Ed.). Seas at the millennium: an environmental evaluation: 2. Regional chapters: The Indian Ocean to The Pacific.

Mohr, C.O. and Stumpf, W.A. 1966. Comparison of methods for calculating areas of animal activity. Journal of Wildlife Management 30. Pp. 293-304.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37. Pp. 223-249.

Montgomery, S. 1995. Spell of the tiger: the man-eaters of Sundarbans. Houghton Mifflin Co., New York.

Montgomery, S. 2008. Spell of the tiger: the man-eaters of Sundarban. Chelsea Green Publishing, Vermont.

Moor, J.H. 1837. Notices of the Indian Archipelago, and adjacent countries; being a collection of papers relating to Borneo, Celebes, Bali, Java, Sumatra, Nias, The Philippines islands, Sulus, Siam, Cochin China, Malayan Peninsula and c. Frank Cass and Company Limited, London.

Mountfort, G. 1969. The vanishing jungle. Collins Clear-Type Press, London and Glasgow. Pp. 193-232.

Morris, P.A. 1988. A study of home range and movements in the hedgehog (*Erinaceus europaues*). Journal of Zoology 214. Pp. 433-449.

Mukherjee, S. 2007. Ecological investigations on mangroves of the Sundarban Tiger Reserve in West Bengal (India) with special reference to effective conservation through management practice. University of Kalyani.

Nathan, R., Getz, W.M., Revilla, E., Holyoak, M., Kadmon, R., Saltz, D. and Smouse, P.E. 2008. A movement ecology paradigm for unifying organismal movement research. Proceedings of the Natural Academy of Sciences 105. Pp. 19052-19059.

Naskar, KR, Guha Bakshi and D.N. 1987 Mangrove swamps of the Sundarbans––an ecological perspective. Naya Prokash, Calcutta.

Naughton-Treves, L. 1998. Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. Conservation Biology 12. Pp. 156-168.

Naughton-Treves, L., Grossberg, R. and Treves, A. 2003. Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. Conservation Biology 17.Pp. 1500–1511.

Neu, C.W., Byers, C.R. and Peek, J.M. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 42. Pp. 172-174.

Neumann-Denzu, G. 2006. The tiger as scavenger: Case histories and deduced recommendations. Tiger Paper. Pp. 33.

Nikolaev, I. Yudin, V. 1993. Tiger and man in conflict situations. Bulletin Moskovsky Obschestva Ispytateley Priorody, Otdyel Biologia, 98. Pp. 23–26. In: Matyushkin E, (Ed.). The Amur Tiger in Russia: An Annotated Bibliography. Moscow: World Wildlife Fund; 1998.

Nowell, K. 2009. Tiger farms and pharmacies: the central importance of China's trade policy for tiger conservation. In: Tilson R.L. and Nyhus, P. (Eds.). In Tigers of the World: The Science, Politics and Conservation of *Panthera tigris*, 2nd edn. William Andrew, Norwich, UK.

Nowell, K. and Jackson, P. 1996. Wild cats: status survey and conservation action plan. IUCN, Gland. Pp. 382.

Nowell, K. and Xu, L. 2007. Taming the Tiger Trade: China's Markets for Wild and Captive Tiger Products since the 1993 Domestic Trade Ban. TRAFFIC East Asia, Hong Kong.

Nugraha, R.T. and Sugardjito, J., 2009. Assessment and management options of human– tiger conflicts in Kerinci Seblat National Park, Sumatra, Indonesia. Mammal Study 34. Pp. 141–154.

Nyhus, P., Sumianto, R.T., Ronald, T. 1999. The tiger-human dimension in southeast Sumatra. In: Seidensticker, J., Christie, S., Jackson, P. (Eds.), Riding the Tiger. Tiger Conservation Efforts in Human-Dominated Landscapes. Cambridge University Press, Cambridge, UK. Pp. 144–147.

Nyhus, P.J. and Sumianto, R.T. 2000. Crop raiding elephants and conservation implications at Way kambas National Park, Sumatra, Indonesia. Oryx 34. Pp. 262-274.

Nyhus, P.J. and Tilson, R.L. 2004. Characterizing human-tiger conflict in Sumatra, Indonesia: implications for conservation. Oryx 38(1). Pp. 68-74.

Nyhus, P.J., Osofsky, S.A., Ferraro, P., Madden, F. and Fischer, H. 2005. Bearing the costs of human–wildlife conflict: the challenges of compensation schemes. Pp. 107-121. In: Woodroffe, R., Thirgood, S., Rabinowitz, A. (Eds.), People and Wildlife: Conflict or Coexistence? Cambridge University Press, Cambridge, UK.

Nyhus, P.J. and Tilson, R. 2010. *Panthera tigris* vs *Homo sapiens*: conflict coexistence, or extinction. Pp. 125–141. In: Tilson, R. and P.J. Nyhus (Eds.), Tigers of the World: The Biology, Politics, and Conservation of *Panthera tigris* (Second ed.), Elsevier/Academic Press, San Diego, CA .

Nyahongo, J.W. and Røskaft, E. 2011. "Perception of people towards lions and other wildlife killing humans, around Selous Game Reserve, Tanzania." International Journal of Biodiversity and Conservation 3. Pp. 110-115.

O'Brien, T., Kinnaird, M. and Wibisono, H. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. Animal Conservation 6. Pp. 131–139.

Odden, J., Linnell, J.D.C., Moa, P.F., Herfindal, I., Kvam, T. and Andersen, R. 2002. Lynx depredation on domestic sheep in Norway. Journal of Wildlife Management 66. Pp. 98–105.

Ogada, M.O., Woodroffe, R., Oguge, N.O. and Frank, L.G. 2003. Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology 17. Pp. 1-10.

Ogra, M. 2009. Attitudes toward resolution of human-wildlife conflict among forest-dependent agriculturists near Rajaji National Park, India. Human Ecology 37. Pp. 717-729.

Oli, M.K., Taylor, I.R., Rogers, M.E. 1994. Snow leopard *Panthera uncia* predation of livestock: an assessment of local perceptions in the Annapurna conservation area, Nepal. Biological Conservation 68. Pp. 63–68.

Packer, C., Ikanda, D., Kissui, B. and Hadas, K. 2005. Lion attacks on humans in Tanzania. Nature 436. Pp. 927–928.

Packer, C., Ikanda, D., Kissui, B. and Hadas, K. 2007. The ecology of man-eating lions in Tanzania. Nature and Faune 21. Pp. 10–15.

Packer, C., Kosmala, M., Cooley, H.S., Brink, H, Pintea, L., Garshelis, D., Purchase, G., Strauss, M., Swanson, A., Balme, G., Hunter, L. and Nowell, K. 2009. Sport Hunting, Predator Control and Conservation of Large Carnivores. PLoS ONE 4(6): e5941.

Palmeira, F.B.L., Crawshaw, P.G., Haddad, C.M., Ferraz, K. and Verdade, L.M. 2008. Cattle depredation by puma (*Puma concolor*) and jaguar (*Panthera onca*) in central western Brazil. Biological Conservation 141. Pp. 118-125.

Patterson, B.D., Neiburger, E.J. and Kasiki, S.M. 2003. Tooth breakage and dental disease as causes of carnivore-human conflicts. Journal of Mammalogy 84. Pp. 190–196.

Patterson, B.D., Kasiki, S.M., Selempo, E. and Kays, R.W. 2004. Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National Parks, Kenya. Biological Conservation 119. Pp. 507–516.

Perovic, P.G. and Herran, M. 1998. Distribución del jaguar (*Panthera onca)* en las Provincias de Jujuy y Salta, Noroeste de Argentina. Mastozool. Neotrop. 5(1). Pp. 47-52.

Peters, R. 1978. Communication, cognitive mapping, and strategy in wolves and hominids. Pp. 95-108. Wolf and man: Evolution in parallel. In: Hall, R.L. and Sharp, H.S. (Eds.), New York, Academic Press.

Pierce, B.M., Bleich, C., Wehausen, J.D. and Bowyer, T. 1999. Migratory patterns of mountain lions: implications for social regulation and conservation. Journal of Mammalogy 80. Pp. 986–992.

Polisar, J., Maxit, I., Scognamillo, D. and Farrell, L. 2003. Jaguars, pumas, their prey base and cattle ranching: Ecological interpretation of a management problem. Biological Conservation 109. Pp. 297-310.

Powell, R.A. 1979. Mustelid spacing patterns: Variations on a theme by Mustela. Zeitschrift für Tierpsychologie 50. Pp. 153–165.

Powell, R.A. 1987. Black bear home range overlap in North Carolina and the concept of home range applied to black bears. International Conference on Bear Research and Management 7. Pp. 235-242.

Powell, R. A. 1993a. Why do some forest carnivores exhibit intrasexual territoriality and what are the consequences for management? Proceedings of the International Union of Game Biologists 21. Pp. 268–273.

Powell, R.A. 1994. Structure and spacing of Martes populations. Pp. 101-121. In: Buskirk, S.W. (Eds.). Martens, sables and fishers: Biology and conservation. Syracuse, N.Y. Cornell University Press.

Powell, R.A. 2000. Animal home ranges and territories and home range estimators. Pp. 65-110. In Research techniques in animal ecology: controversies and consequences. In: Boitani, L. and Fuller, T.K. (Eds.), Columbia University, New York.

Powers, D.R. and McKee, T. 1994. The effect of food availability on time and energy expenditure of territorial and non-territorial hummingbirds. Condor 96. Pp. 1064–1075.

Prain, D. 1903. Bengal Plants. Vol 1-2., Calcutta.

Primm, S.A. and Clarke, T. 1996. Making sense of the policy process for carnivore conservation. Conservation Biology 10. Pp. 1036-1045.

Provencher, R. 1986. (Ed.). The Soul of Ambiguity: The Tiger in Southeast Asia. DeKalb: Northern Illinois University; 1986.

Quammen, D. 2003. Monster of God: The Man Eating Predator in the Jungles of the History and the Mind. New York, NY: W.W. Norton and Company.

Quigley, H. and Herrero, S. 2005. Characterization and preventation of attacks on humans. In People and wildlife: conflict or coexistence? Pp. 27-48. In: Woodroffe, R., Thirgod, S. and Rabinowitz, A. (Eds.). Technical Report, Wildlife Institute of India, Dehradun, India, RR -04/002.

Qureshi, Q., Gopal, R., Kyatham, S., Basu, S., Mitra, A. and Jhala, Y.V. 2006. Evaluating tiger habitat at the tehsil level. Project Tiger Directorate, Govt. of India, New Delhi and Wildlife Institute of India, Dehradun. TR No. 06/001.

Rabinowitz, A. 1986. Jaguar: One Man's Struggle to Establish the First Jaguar Preserve. Washington, D.C.: Island Press.

Rahman, Z. 1992. Working plan for the Sundarbans Forest Division. Working Plan Division, Government of the People's Republic of Bangladesh, Volume 1 and 2. Pp. 111.

Rahman, H. A., Barlow, A.C.D., Greenwood, C.J., Islam, M.A., and Ahmed, I.U. 2009. Livestock depredation by tiger on the edge of the Bangladesh Sundarbans. Technical Report. Wildlife Trust of Bangladesh, Dhaka, Bangladesh.

Reza, A.H.M.A., Feeroz, M.M. and Islam, M.A. 2002. Man-tiger interaction in the Bangladesh Sundarbans. Bangladesh Journal of Life Science 14(1 and 2). Pp. 75-82.

Riley, S.J. and Decker, D.J. 2000. Wildlife stakeholder acceptance capacity for cougars in Montana. Wildlife Society Bulletin 28. Pp. 931-939.

Rodgers, A.R. and Kie, J.G. 2010. HRT: Home Range Tools for ArcGIS, version 1.1, 24.4.2011.

Rodgers, W.A. and Panwar, H.S. 1988. Planning a wildlife protected area network in India. II Volume. Project FO: IND/82/003. FAO, Dehradun.

Rogers, L.L. 1977. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Ph.D. thesis. Minneapolis: University of Minnesota.

Rogers, L.L. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. Wildlife Monographs 97. Pp. 1–72.

Rokeach, M. 1973. The Nature of Human Values. New York: Free Press.

Romanach, S.S., Lindsey, P.A. and Woodroffe, R. 2007. Determinants of attitudes towards predators in central Kenya and suggestions for increasing tolerance in livestock dominated landscapes. Oryx 41. Pp. 185-195.

Røskaft, E., Bjerke, T., Kaltenborn, B.P., Linnell, J.D.C. and Anderson, R. 2003. Patterns of self-reported fear towards large carnivores among the Norwegian public. Evolution and Human Behavior 24. Pp. 184-198.

Saberwal, V.K., Gibbs, J.P., Chellam, R., and Johnsingh, A.J.T. 1994. Lion-human conflict in the Gir forest, India. Conservation Biology 8. Pp. 501-507.

Saitoh, T. 1991. The effects and limits of territoriality on population regulation in grey redbacked voles, (*Clethrionomys rufocanus bedfordiae)*. Research on Population Ecology 33. Pp. 367–386.

Samuel, M.D., Pierce, D.J. and Garton, E.O. 1985. Identifying areas of concentrated use within the home range. Journal of Animal Ecology, 54. Pp. 711-719.

Sandell, M. 1989. The mating tactics and spacing patterns of solitary carnivores. Pp. 164–207. Carnivore behavior, ecology, and evolution In: Gittleman, J. L (Ed.). Comstock Publishing Associates, New York.

Sanderson, E., Forrest, J., Loucks, C., Ginsberg, J., Dinerstein, E., Seidensticker, J., Leimgruber, P., Songer, M., Heydlauff, A., O'Brien, T., Bryja, G., Klenzendorf, S. and Wikramanayake, E. 2006. Setting priorities for the conservation and recovery of wild tigers: 2005-2015. The technical assessment. WCS, WWF, Smithsonian, and NFWF-STF, New York - Washington, D.C.

Sangay, T. and Vernes, K. 2008. Human-wildlife conflict in the Kingdom of Bhutan: patterns of livestock predation by large mammalian carnivores. Biological Conservation 141. Pp. 1272-1282.

Sankar, K., Qureshi, Q., Nigam, P., Malik, P.K., Sinha, P.R., Mehrotra, R.N., Gopal, R., Bhattacharjee, S., Mondal, K. and Gupta, S. 2010. Monitoring of reintroduced tigers in Sariska Tiger Reserve, Western India: preliminary findings on home range, prey selection and food habits. Tropical Conservation Science 3. Pp. 301–318.

Sanyal, P. 1987. Managing the man-eaters in the Sundarbans Tiger Reserve of India: a case study. Pp. 427-434. In: Tilson, R.L. and Seal, U.S. (Eds.), Tigers of the world. Noyes Publications, Park Ride.

Salkina, G.P. 1993. Current status of a population of Amur tigers in the south-east Sikhote-Alin. Bulletin Moscovsky Obschectva Prirody Otdyel Biologica 98. Pp. 45–53.

Sarkar, J. 2002. Vulnerability of Sunderban due to recurrent coastal flooding. Paper presented at the National Seminar on Vulnerability of Sunderban Mangrove Ecosystem in the prespective of Global Climate Change. Jadavpur University: Kolkatata, June 14-15.

Sawarkar, V.B. 1986. Animal damage: predation on domestic livestock by large carnivores. Indian Forester, 112. Pp. 858-866.

Seaman, D.E., Millspaugh, J.J., Kernohan, B.J., Brundige, G.C., Raedeke, K.J. and Gitzen, R.A. 1999. Effects of sample size on kernel home range estimates. The Journal of Wildlife Management 63. Pp. 739-747.

Seaman, D.E. and Powell, R.A. 1996. Accuracy of kernel estimators for animal home range analysis. Ecology 77. Pp. 2075-2085.

Schaller, G. 1967. The deer and the tiger. University of Chicago Press, Chicago, USA, Pp 370.

Schaller, G. 1996. Carnivores and conservation biology: In Carnivore behavior, ecology and evolution, Volume 2. Pp. 1-10. In: Gittleman, J.L. (Eds.), Cornell University Press, Ithaca, New York, USA.

Schmitz, O.J. 2005. Behavior of predators and prey and links with population-level processes. Ecology of Predator-Prey Interactions. Oxford University Press Inc, New York. Pp. 256–278.

Schoener, T.W. 1981. An empirically based estimate of home range. Theoretical Population Biology 20. Pp. 281–325.

Schooley, R.L. and Wiens, J.A. 2003. Finding habitat patches and directional connectivity. Oikos, 102. Pp. 559-570.

Schultz, P.W. and Zelezny, L. 1999. Values as predictors of environmental attitudes: Evidence for consistency across cultures. Journal of Environmental Psychology 19. Pp. 255-265.

Seaman, D.E. 1993. Home range and male reproductive optimization in black bears. Ph.D.thesis. Raleigh: North Carolina State University.

Seaman, D.E. and Powell, R.A. 1990. Identifying patterns and intensity of home range use. International Conference on Bear Research and Management, 8. Pp. 243-249.

Seaman, D.E., Millspaugh, J.J., Kernohan, B.J., Brundige, G.C., Raedeke, K.J. and Gitzen, R.A. 1999. Effects of sample size on kernel home range estimates. The Journal of Wildlife Management 63. Pp. 739-747.

Seidensticker, J. 1976. On the ecological separation between tigers and leopards. Biotropica 8. Pp. 225-234.

Seidensticker, J. 1987. Bearing witness: observations on the extinction of (*Panthera tigris balica*) and (*Panthera tigris sondaica*). Pp 1-8. In: Tilson R.L. and Seal U.S. (Eds.). Tigers of the world: biology, biopolitics, management, and conservation of an endangered species. Noyes Publications, Park Ride.

Seidensticker, J.C., Hornocker, M.G., Wiles, W.V. and Messick, J.P. 1973. Mountain lion social organization in the Idaho Primitive Area. Wildlife Monographs 35. Pp. 1–60.

Seidensticker, J., Christie, S. and Jackson, P. (Eds.) 1999. Riding the tiger: tiger conservation in human-dominated landscapes. Zoological Society of London and Cambridge University Press, Cambridge, UK. Pp. 404.

Sen, N. and Naskar, K. 2003. Algal flora of Sundarban Mangal. Daya Publishing House, Delhi.

Senft, R., Coughenour, M., Bailey, D., Rittenhouse, L., Sala, O.E. and Swift, D. 1987. Large herbivore foraging and ecological hiearchies. Journal of BioScience 37. Pp. 789–799.

Seidensticker, J., Dinerstein, E., Goyal, S.P., Gurung, B., Harihar, A., Johnsingh, A.J.T., Manadhar, A., McDougal, C.W., Pandav, B., Shrestha, M., David Smith, J.L., Sunquist, M. and Wikramanayake, E. 2010. Tiger range collapse and recovery at the base of the Himalayas. In: David MacDonald and Loveridge, A.J. (Eds.). The Biology and Conservation of Wild Felids. Oxford University Press, UK>

Sharma R.K. and Jhala Y.V. 2010. Monitoring tiger populations using intensive search in a capture–recapture framework. Population Ecology 53. Pp. 373–381.

Sharma, R.K., Jhala, Y.V. and Qureshi, Q. 2011. Home range size of a tigress in Sundarbans, India: preliminary results. CATNEWS 54. Pp. 13–16.

Siddiqi, N.A. and Choudhury, J.H. 1987. Man-eating behavior of tigers (*Panthera tigris*) of the Sundarbans - twenty-eight years' record analysis. Tigerpaper 14. Pp. 26-32.

Sievers, E, Tsaruk, O. and Zatoka, A. 1995. National parks, snow leopards and poppy plantations (Part II). Cent Asia Monit. 1995; 3. Pp. 17–26.

Sievers, E.W. 1997. Beyond ecoside: Cats and ecology in Cental Asia. Cent Asia Monit. Pp. 5.

Sinha Ray, S.P. 2010. Status of Ground Water Condition in Sundarban area, West Bengal. Commissioned report. WWF-India.

Singh, A., 1993. The Legend of the Man-eater. Ravi Dayal Publisher. Pp. 169.

Sillero-Zubiri, C. and Laurenson, M.K. 2001. Interactions between carnivores and local communities: conflict or co-existence? Pp. 282-312. In: Gittleman, J.L.,

Funk, S.M. Macdonald, D.W. and. Wayne, R.K (Eds.). Carnivore conservation. Cambridge University Press, Cambridge, United Kingdom.

Silverman, B.W. 1986. Density estimation for statistics and data analysis. London, Chapman and Hall. Pp. 175.

Smirnov, E. 1993. Tiger population of the Sikhote-Alinskiy Zapovednik and adjacent territory in the 1980s. Bull. Mosk. Oshestva Ispytateley Prirody. *Otd. biol.* 98(3). Pp. 37-44. In: Matyushkin, E. (Ed.). The Amur Tiger in Russia: An Annotated Bibliography. Moscow: World Wildlife Fund; 1998.

Smirnov, E.N. and Miquelle, D.C. 1999. Population dynamics of the Amur tiger in Sikhote-Alin Zapovednik, Russia. Pp. 61-70. In: Seidensticker, J., Christie, S. and Jackson, P. (Eds.). Riding the tiger. Tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Smith, J.L.D. 1984. Dispersal, communication, and conservation strategies for the tiger (*Panthera tigris*) in Royal Chitawan National Park, Nepal. PhD thesis, University of Minnesota.

Smith, J.L.D. 1993. The role of dispersal in structuring the Chitwan tiger population. Behaviour 124. Pp. 165-195.

Smith, J.L.D. and McDougal, C. 1991. The contribution of variance in lifetime reproduction to effective population size in tigers. Conservation Biology 5. Pp. 484-490.

Smith, J.L.D., McDougal, C.W. and Miquelle, D.1998. Chemical communication in free ranging tigers (*Panthera tigris*). Animal Behaviour 37. Pp. 1-10.

Smith, J.L.D., McDougal, C.W. and Sunquist, M E. 1987. Land tenure system in female tigers. Pp. 97-108. In: Tilson, R.L. and. Seal, U.S. (Eds.). Tigers of the world: the biology, biopolitics, management, and conservation of an endangered species. Noyes Publications, Park Ridge, New Jersey.

Smith, J.L.D., Wemmer, C. and Mishra, H.R. 1987a. A tiger geographic information system: the first step in global conservation strategy. Pp. 464-474. In: Tilson, R.L. and Seal, U.S. (Eds.). Tigers of the world: biology, biopolitics, management and conservation of an endangered species. Noyes Publications, Park Ride.

Smithers, R.H.N. 1983. The Mammals of the Southern African Subregion. University of Pretoria Press, Pretoria, South Africa.

Sokolov, V.Y. et al. 1990. In: Sokolov VY, Syroyechkovskii VY, (Eds.). Zapovedniki Srednei Azii i Kazakstana. Moscow: Mysl. Pp. 304–321.

Stander, P.E., Haden, P.J., Kaqece and Ghau. 1997. The ecology of a sociality in Namibian leopards. Journal of Zoology 242. Pp. 343–364.

Stephens, D.W. and Krebs, J.R. 1986. Foraging theory. Princeton, New Jersey. Princeton University Press. Pp. 262.

Stephens, P.A., Zaumyslava, O.Y., Miquelle, D.G., Myslenkov, A.I., and Hayward, G.D. 2006. Estimating population density from indirect sign: track counts and the Formozov- Malyshev-Pereleshin formula. Animal Conservation 9. Pp. 339–48.

Stoen, O.G. and Wegge, P. 1996. Prey selection and prey removal by tiger (*Panthera tigris*) during the dry season in lowland Nepal. Mammalia 60. Pp. 363-373.

Sunquist, M.E. 1981. The social organization of tigers (*Panthera tigris*) in Royal Chitwan National Park, Nepal. Smithsonian Contribution to Zoology 336. Pp. 1-92.

Sunquist, M., Karanth, K.U. and Sunquist, F. 1999. Ecology, behaviour and resilience of the tiger and its conservation needs. Pp. 5-18. In: Seidensticker, J., Christie, S. and Jackson, P. (Eds.). Riding the tiger. Tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Sunquist, M.E. 2010. Tigers: Ecology and behavior. Pp. 19-33. In: Tilson, R. and Nyhus, P.J. (Eds.). Tigers of the World: The science, politics and conservation of (*Panthera tigris)*, Elsevier, San Diego.

Sunquist, M.E. and Sunquist, F.C. 2002. Wild cats of the world. University of Chicago Press, Chicago and London. Pp. 345-372.

Swihart, R.K. and Slade, N.A. 1985. Testing for independence of observations in animal movements. Ecology 66. Pp. 1176-1184.

Thirgood, S., Redpath, S., Newton, I. and Hudson, P. 2000. Raptors and red grouse: conservation conflicts and management solutions. Conservation Biology 14. Pp. 95-104.

Thirgood, S., Woodroffe, R. and Rabinowitz, A. 2005. The impact of human-wildlife conflict on human lives and livelihood. People and wildlife: conflict or coexistence? In: Woodroffe, R., Thirgood, S. and Rabinowitz, A. (Eds.), Cambridge University Press, Cambridge, UK.

Tilson, R. L. and Seal, U. S. 1987. Tigers of the world. Park Ridge, New Jersey: Noyes Publ.

Tilson, R., Defu, H., Muntifering, J. and Nyhus, P.J. 2004. Dramatic decline of wild South China tigers: Field survey of priority tiger reserves 38. Pp. 40–47.

Treves, A. and Karanth, K.U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology 17. Pp. 1491-1499.

Treves, A. and L. Naughton-Treves. 1999. Risk and opportunity for humans coexisting with large carnivores. Journal of Human Evolution 36. Pp. 275-282.

Treves, A., Jurewicz, R.L., Naughton-Treves, L. and Wilcove, D.S. 2009. The price of tolerance: wolf damage payments after recovery. Biodiversity and Conservation.

Treves, A., Jurewicz, R.R., Naughton-Treves, L., Rose, R.A., Willging, R.C. and Wydeven, A.P. 2002. Wolf depredation on domestic animals in Wisconsin, 1976–2000. Wildlife Society Bulletin 30. Pp. 231–241.

Turchin, P. 1998. Quantitative analysis of movement: measuring and modeling population redistribution in plants and animals. Sinauer Associates, Sunderland, MA. Pp. 396.

Valeix, M., Loveridge, A., Chamaille-Jammes, S., Davidson, Z., Murindagomo, F., Fritz, H. and Macdonald, D.W. 2009. Behavioral adjustments of African

herbivores to predation risk by lions: spatiotemporal variations influence habitat use. Ecology 90. Pp: 23–30.

Vaske, J. J. and Donnelly, M. P. 1999. A value-attitude-behavior model predicting wild land preservation voting intentions. Society and Natural Resources 16. Pp. 523-537.

Verdade, L.M. and Campos, C.B. 2004. How much is a puma worth? Economic compensation as an alternative for the conflict between wildlife conservation and livestock production in Brazil. Biota Neotropica 4.

Verheij, P.M., Foley, K.E. and Engel, K. 2010. Reduced to skin and bones. An analysis of tiger seizures from 11 tiger range countries (2000-2010). TRAFFIC International, Cambridge, UK.

Walter, W.D., Fischer, J.W., Baruch-Mordo, S. and VerCauteren, K.C. 2011. What is the proper method to delineate home range of an animal using today's advanced gps telemetry systems: the initial step. In Modern Telemetry. Intech, Open Access Publishers.

Wang, S.W., Lassoie, J.P. and Curtis, P.D. 2006. Farmer attitudes towards conservation in Jigme Singye Wangchuk National Park, Bhutan. Environmental Conservation 33. Pp. 148-156.

Wang, S.W., MacDonald, D.W. 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. Biological Conservation 129. Pp. 558–565.

Wang, S.W. and Macdonald, D.W. 2009. Feeding habits and niche partitioning in a predator guild composed of tigers, leopards and dholes in a temperate ecosystem in central Bhutan. - Journal of Zoology (London) 277. Pp. 275-283.

Watson, A. and Moss, R. 1970. Dominance, spacing behaviour and aggression in relation to population limitation in vertebrates. Pp. 167-222. In: Watson, A. (Ed.). Animal populations in relation to their food resources, Oxford, U.K.: Blackwell.

Werdelin, L. and Lewis, M.E. 2005. Plio-Pleistocene carnivore of eastern Africa: species richness and turnover patterns. Zoological Journal of Linnean Society 144. Pp.121-144.

White, G.C. and Garrott, R.A. 1990. Analysis of wildlife radio–tracking data. Academic Press, New York. Pp. 383.

Wiens, J.A., Milne, B.T. 1989. Scaling of landscapes in landscape ecology, or, landscape ecology from a beetle's perspective. Landscape Ecology 3. Pp. 87–96.

Wikramanayake, E.D., Dinerstein, E., Robinson, J.G., Karanth, K.U., Rabinowitz, A., Olson, D., Mathew, T., Hedao, P., Conner, M., Hemley, G. and Bolze, D. 1998. An ecology-based method for defining priorities for large mammal conservation: the tiger as case study. Conservation Biology 12. Pp. 865-878.

Wielgus, R.B., Sarrazin, F., Ferriere, R. and Clobert, J. 2001. Estimating effects of adult male mortality on grizzly bear population growth and persistence using matrix models. Biological Conservation 98. Pp. 293–303.

Williams, B.K., Nichols, J.D. and Conroy, M.J. 2002. Analysis and management of animal populations. Academic Press, London UK. Pp. 817.

Woodroffe, R. and Ginsberg, J.R. 1998. Edge effects and the extinction of populations inside the protected areas. Science 280. Pp. 2126-2128.

Woodroffe, R.S. Thirgood, and Rabinowitz, A. 2005. People and wildlife, conflict or coexistence. Cambridge University Press, Cambridge. Pp. 27-48.

Worton, B.J. 1987. A review of models of home range for animal movement. Ecological Modeling 38. Pp. 277-298.

Worton, B.J. 1989. Kernel methods for estimating the utility distribution in home-range studies. Ecology 70. Pp. 164-168.

Yudakov, A.G. Nikolaev, I.G. 1987. Ecology of the Amur Tiger. Winter Observations during 1970–1973 in the Western Section of Central Sikhote-Alin. Moscow: Nauka Press; 1987 (in Russian).

Zar, J.H. 2010. Biostatistical analysis. Fifth edition, Prentice Hall, New Jersey, USA. Pp. 960.

Zarco-Gonzalez, M.M., Monroy-Vilchis, O. and Alaniz, J. 2013. Spatial model of livestock predation by jaguar and puma in Mexico: Conservation planning. Biological Conservation 159. Pp. 80–87.

Zhivotchenko V. 1977. A man-eating tiger in the Primorskiy Kray. (3). Pp. 123-124. In: Matyushkin E, (Ed.). The Amur Tiger in Russia*:* An Annotated Bibliography Moscow: World Wildlife Fund; 1998.

Zimmermann, B., Wabakken, P. and Dotterer, M. 2001. Human-carnivore interactions in Norway. How does the re-appearance of large carnivores affect people's attitudes and levels of fear? Forest Snow and landscape Research 76. Pp. 137-153.

Zimmermann, A., Walpole, M. and Leader-Williams, N. 2005. Cattle ranchers' attitudes to conflicts with jaguar (*Panthera onca)* in the Pantanal of Brazil. Oryx 39. Pp. 406-412.

Appendix I. Details of collaring Protocol

COLLARING PROTOCOL DATA SHEET

Date: _____ Area: _____

GPS Location: _____ N _____ E

Species: _____ Approx. Age: _____yrs Sex: _____

Weight estimated _____, Actual _____Kg

DRUG DETAILS

Drugs used: _____

1) Drug composition:_____

Target site: Shoulder \ Rump Darting time:_____ Hrs

Drug effecting time (visual signs): _____ Hrs

Induction time: _____

Symptom1 Time: _____ Symptom 2 Time _____ Sympt
Time _____ Symptom 4 Time _____

Down time: _____

Extra drug used (Drug & Time):_____

Recumbency period: _____ Hrs _____ Min Revival time: _____ Min

Antidote: _____ Intravenous / Intramuscular

Composition: _____

Time: _____ Hrs Recovery time: _____ Min

BODY MEASUREMENTS

Nose tip to Head: _____ cm Head to Anus: _____ cm

Tail length: _____ cm Neck girth: _____ cm

Shoulder height: _____ cm Hind quarter height: _____cm

Hind foot length: _____ cm Chest girth: _____ cm

Belly: _____ cm

Ear length: Right: _____cm Left:_____ cm

Testes length: ____, ___ cm

Female status: Bred: Yes / No Lactating: Yes / No

If Lactating: No. of teats _____ Measurements: _____

Paws

Right fore:	Length _____ cm	Breadth _____ cm
Left fore:	Length _____ cm	Breadth _____ cm
Right hind:	Length _____ cm	Breadth _____ cm
Left hind:	Length _____ cm	Breadth _____ cm

Upper Jaw

Right Canine length: _____ cm Left Canine length: _____ cm

Right Carnassial:	1st Ht _____ cm	Length _____ cm	Breadth _____ cm
	2nd Ht _____ cm	Length _____ cm	Breadth _____ cm
	3rd Ht _____ cm	Length _____ cm	Breadth _____ cm
Left Carnassial:	1st Ht _____ cm	Length _____ cm	Breadth _____ cm
	2nd Ht _____ cm	Length _____ cm	Breadth _____ cm
	3rd Ht _____ cm	Length _____ cm	Breadth _____ cm

Lower Jaw

Right Canine length: _____ cm Left Canine length: _____ cm

Right Carnassial: 1st Ht _____ cm Length _____ cm Breadth _____ cm

2nd Ht _____ cm Length _____ cm Breadth _____ cm

3rd Ht _____ cm Length _____ cm Breadth _____ cm

Left Carnassial: 1st Ht _____ cm Length _____ cm Breadth _____ cm

2nd Ht _____ cm Length _____ cm Breadth _____ cm

3rd Ht _____ cm Length _____ cm Breadth _____ cm

Status of Canines: _____

Respiration rate: _____ / min Time _____, _____/ min Time _____

Rectal Temperature: _____ ^{0}C, Time_____

Rectal Temperature: _____ ^{0}C, Time_____

Rectal Temperature: _____ ^{0}C, Time_____

Heart Rate: _____/min Time _____

Heart Rate: _____/min Time _____

Heart Rate: _____/min Time _____

Samples collected

Blood: Yes / No Hair: Yes/ No Milk: Yes/ No Skin Yes/No

Parasites Yes/ No

HEALTH CONDITION

Health status: _____

Skin disease (if any): _____

Inoculated: Yes / No, Against: _____

Any ointment applied: _____

Micro Chip # : _____

COLLAR DETAILS

Collar No.: _____ Magnet removed? Frequency listed: _____

Frequency on Receiver: _____

Complications during recumbency (Vomiting, Bradycardia, Respiratory depression, Arrhythmias):

_____

_____

Other Comments:

_____

_____

Appendix II. Questionnaire survey

SOCIO-ECONOMIC, ATTITUDE SURVEY OF HOUSEHOLDS

Socio-Economic Portion GPS: _____

Section 1: Interviewer's assessment (Do a visual assessment of the interviewee)

Name of Interviewee_____

Note: **Do not ask interviewee questions from this section**

1.1Based a visual assessment of the interviewee, answer the following:

(a) Age (appr te): (b) Sex ale/Female

(b) Condition and quality of clothes (rate on a scale of 0-5, where 0 is very poor and 5 is excellent):

Quality and quantity of ornaments, wrist watch, etc. (rate on a scale of 0-5, where 0 is none and 5 is numerous of high quality):

(c) Number of persons in household (genderwise adult and kids) _____

(d) What mode of transportation is being used by the interviewee?

(a) None (b) Cycle (c) Fuel propelled two-wheeler (d) Others (specify).....

1.2 **What is your educational level?**

( ) Illiterate ( ) Primary school incomplete ( ) Primary school complete ( ) Secondary school incomplete ( ) Secondary school complete ( ) Undergraduate course incomplete ( ) Undergraduate course complete

Section 2: Household characteristics

2.1 What type of house do you have?

(a) *pucca* (b) semi-*pucca* (c) *kutcha*

2.2 **What type of roof does your house have?**

(a) Thatch (b) Tinned/cement sheets (c) Mud baked tiles (old/new type) (d) Concrete

2.3 **Do you have electricity connection?**

(a) Yes (b) No

2.4 **What is your source of drinking water?**

(a) Tap (b) Open well (c) Bore hole

(d) Stream/river (e) Lake/pond (f) Others

2.5 **How far do you have to travel to get drinking water?**

(a) Home supply (b) 0-5 minute walk (c) >5-15 minute walk (d) >15 minute walk

2.6 **What source of fuel do you use for cooking purpose?**

(a) LPG gas (b) Kerosene (c) Bio-gas (d) Fuel wood

2.7**How long have you lived in this place?**

(a) First generation (b) Second generation (c) More than two generations

2.8 **How far is the closest urban centre?**

(a) 0-30 kilometres (b) >30-60 kilometres (c) >60 kilometres

2.9**How often you go there?**

(a) Every day (b) Once a week (c)Once a fortnight (d) Once a month

3.0 ii) **What is the local mode of public transportation**

a) Cycle b) Bus c) Boat d) Bike e) Countryvans f) others

3.1 **What is/are your source/s of livelihood?** (List in terms of priority if more than one)

(a) Service (government/private) (b) Agriculture (c) Livestock farming/fishing

(d) Daily wages (e) Hotel/Tourism (e) Others

3.2 **Do you read Newspaper, which one and how often in a week, month**

a) Ananda Bazar b) Aajkal c) Bartaman d) Others

3.3 **Do you have access to**

a) T.V. b) Radio c) Mobiles d) Landphones e) Computer

Section 4: Livestock

4.1 **Do you own livestock?**

(a) Yes (b)No

Purpose of Keeping Livestock

( )Meat ( )Agriculture ( )Milk ( )Personal Consumption ( )Source of Income

4.2 **How much livestock do you own?** (Mention numbers for each)

(a) Sheep (b) Goats (c) Cattle

(d) Buffaloe (e) Poultry (f) Others (specify)..... ..

4.3 **Do you lose livestock to disease/carnivores, if yes, how many per year?(**Financial and number both)

	Disease	Tiger	Year	Economic Loss
Sheep				
Goats				
Cattle				
Others (specify)				

4.4 How far do you have to travel to sell livestock products: milk/wool/meat?

(a) 0-60 kilometres (b) 60-150 kilometres (c) >150 kilometres

Section 5: Agriculture

5.1 **Do you own agricultural land?**

(a) Yes (b)No

If "Yes" to the above, is it irrigated? Yes/No.....

5.2 **What form of irrigation facilities do you use?**

(a) Bore hole (b) Open well (c) Stream/river (d) Pond/lake

(e) Others (specify).....

5.3 **What is the size of your land holding? (bighas/kathas**) ……..

5.4 **How many crops do you get from your land in one year?**

(a) 0 (b) 1 (c) 2 (d)3

Personal Comments

Attitude Portion

Section 6: Perceptions about wildlife

6.1 **Do people in this village consume meat?**

(a) Yes (b) No

If "Yes", how often? .....

6.1.1 **What is the source?**

(a) Domesticated animals _____

(b) Bush meat name species _____

7. **Origin of the family:** (Where did your parents, grandparents, and great-grandparents come from?)

( ) Bihar ( ) Bangladesh ( ) Madhya Pradesh ( ) Other parts of W.Bengal

7.2. **Please, indicate your attitude toward the following: {**Like/ Indifferent/ Dislike/ Do not know}

Tiger_____

Crocodile_____

Nature_____

8. Who is/are responsible for straying of tigers?

9. Who is responsible for human-deaths by tigers?

10. Do u think declaration of the forest area into tiger reserve was useful for your livelihood?

If yes then why? If no then why?

11. What is the role of tigers in the wild?

( ) To control prey population/ to keep the ecological balance

( ) To destroy, subdue or eat other animals

( ) Other:

( ) None

( ) Do not know

Section 7 (**Aimed at fishermen and honey collectors)**

12. Do you think tigers would attack humans without being provoked?

( )Yes ( ) No ( )Don't Know

13. Why are you dependent on forests for your livelihood inspite of the threats involved?

14. What items do you use as selfdefence when inside the forests?

15. Do you practice some form of ritual before venturing into the forest?

16. How effective do you think rituals and shamans in preventing tiger attacks?

17. What are the alternate livelihood options available apart from honey collection and fishing?

18. Why do you think tigers stray into human habitation ?

i) Loss of natural prey ii) Difficulty in capturing prey iii) Easy food i.e. Livestock

iv) Tidal Fluctuations & Natural Calamities v) Natural Aggression vi) Encroachment of tiger habitat vii) By chance viii) Confusion with natural tiger habitat

19. Regarding the predation of livestock killing by tigers what would you suggest for solving the problem?

( ) Using preventive methods in the property (use predator proof-enclosures during night, use electric fences to surround pastures and/or enclosures, keep herds away from the forest, etc.).

( ) Killing the problem animal(s).

( ) Financial compensation for livestock losses by predators.

( ) Relocating the problem animal(s).

( ) Removing/eradicating all tigers from STR.

( ) Restructuring the food chain (reintroduction of native species extinct locally).

( ) Other:

( ) Do not know

20. **Would you be willing to change your husbandry practices in order to minimize predation on your livestock?**

( ) Yes ( ) No

21. **If so, would you pay for the management changes**

( ) Yes ( ) No

Comments:

BVG Trust

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Socio-economic status and perception of fishermen towards resolving human-tiger conflict around Sundarban Tiger Reserve, India

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Abstract

Periodic losses due to large carnivores, be it livestock depredation or death of a family member stimulates fear psychology in the subconscious mind. Thus perceptions of certain species as innately evil or harmful means that even if wildlife damage is entirely mitigated, residual fear and antipathy can lead to continued persecution nonetheless. The socio-economic status and perception of fishermen (n=115) towards tigers along the peripheral villages of Sundarban Tiger Reserve were examined by conducting semi-structured questionnaire surveys between December 2011 and June 2013. Majority of the respondents (66%) resided in kutcha households vulnerable to damage by frequent natural disasters, and 59% of them illiterate and never attended school. Sixty two per cent of the respondents opined that the main role of tigers were to destroy and subdue other life forms, while 67% stated that the declaration of Sundarban Tiger Reserve was not beneficial to their livelihood. Promoting sustainable employment opportunities, organizing educational and awareness programmes about tiger attacks, increasing compensation schemes for tiger victims are important socio-economic measures most likely to reduce human-wildlife conflict.

Key words: attitude, conflict, livelihood, Sundarban and tiger.

INTRODUCTION

Large carnivores are widely acclaimed for inflicting damage on valuable resources especially livestock and occasionally human lives. This has been attributed to the cause of revenge killings and for the negative perception towards their future persistence in human-dominated landscapes (Naughton-Treves, 1998; Naughton Treves et al., 2003; Treves and Karanth, 2003; Inskip and Zimmermann, 2009). Accordingly, understanding and addressing local people's attitudes and behaviour towards human-wildlife conflicts in relation to both social and ecological aspects are vital for successful conservation of many species and are considered as major thrust area of research (Wang and Mac Donald, 2006; Palmeira *et al.*, 2008; Ogra, 2009). People who got encountered with conflict and unable to perceive are unsuccessful in ameliorating the problem obviously developed the attitude of revenge against such wildlife and frequently retaliate the animal (Mills and Hofer, 1998).

Humans have a dynamic relationship with carnivores, few events are sufficient to affect peoples' attitudes and shape their future interactions with particular species. Peoples' perceptions are not only based upon facts and personal experiences, but also upon a myriad of factors such as wider societal experiences, cultural norms, expectations and beliefs (Conover, 2002; Woodroffe *et al.*, 2005). These factors, although play crucial role in human–wildlife conflict, yet are rarely considered.

Tiger-human conflicts have already contributed to the decline and extinction of two sub-species i.e. Bali tiger (*Panthera tigris balica*) and Javan tiger (*Panthera tigris sondaica*) (Hoogerwerf, 1970; Seidensticker, 1987) and there is an urgent need to characterize and develop measures to reduce these conflicts (Nowell and Jackson, 1996; Woodroffe and Ginsberg, 1998; Linnell *et al.*, 1999). Tigers have been infamous for attacks on people, livestock since centuries be it Terai landscape of Nepal and India, Russian Far-East and parts of South-east Asia. Unlike other tiger populations of South-east Asia, tigers of Sundarban are held responsible for a considerable number of human deaths annually, considered to be the highest in the world (Montgomery, 2008). Sundarban tigers of India and Bangladesh form a single population which is isolated from other tiger populations and the only one in a mangrove habitat (Dinerstein *et al.*, 1997).

According to local legends about 100 years ago 4,218 people were eaten by tigers in just six years (Montgomery, 2008) while historical records indicate that 800 human lives were lost in a span of 20 years in the undivided Sundarban (Chakrabarti, 1992). More recent estimates proclaim that on an average 36 lives are lost to tigers every year on the Indian side of Sundarban, and only 28.5% of victims' bodies have been recovered (Chakrabarti, 1992). Majority of these tiger victims have been fishermen, honey collectors and woodcutters by profession as documented by several researchers over a period of time (Chowdhury and Chowdhury, 1994; Chowdhury and Ahmad, 1994; Khan, 2004; Sanyal, 1987; Denzau and Denzau., 2010). The intensity of human lives lost to tigers is further reiterated through the existence of tiger widow villages or 'vaidabapallis' where every woman in the village

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has lost either son, father or husband to tigers (Montgomery, 2008). Thus, local belief is that the "unofficial" figures of those killed by tigers can be far higher than the official figures provided by the administration as all deaths are not reported (Montgomery, 2008). Apart from man-eating tigers entire Sundarban region is under the intense human population with around 3.5 million people living within 20 kilometres of its northern and eastern borders and depending upon the forest resources for livelihood (Chakrabarti, 1992).

Examination of the social aspect of tiger conservation requires investigations on the values and behavioural intentions held by people whose interests may conflict with the presence of tiger. Built on this value are patterns of basic beliefs or value orientation, attitudes, norms, behavioral intensions and behaviours (Rokeach, 1973; Homer and Kahle, 1988; Fulton *et al.,* 1996). For example, measure of tiger's values people hold will be the best predictor for attitudes towards tigers. Therefore, it is critical to understand wildlife value orientation that forms the basic foundation explaining the human behaviour related to wildlife.

Majority of the conflict mitigation studies focus only on the technical aspect of conflict reduction, yet social factors, ethnicity, religious affiliation and cultural beliefs shapes the outcome of conflict. Human-wildlife conflicts are often manifestation of underlying human-human conflicts, be it between authorities and local people or people with diverse cultural backgrounds. In spite of ample evidence for social factors playing crucial role in driving conflicts they are often ignored in the studies on conflicts (Dickman, 2010). Currently, the attitudes of urban people towards the large carnivores are mostly favourable; but the conflicts still exist locally among the economically marginalized rural communities whose livelihoods are directly or indirectly threatened by large carnivores. Ultimately people do learn to coexist with large carnivores. Nevertheless periodic and frequent losses ignite the fear psychosis and hatred towards the large carnivores; that are attributed to the human fear psychology (bio-phobic or bio-philic) and peoples' concern about their own safety and health (Røskaft *et al.,* 2003).

Thus keeping in perspective of the recurrent loss of family members, companions and colleagues due to tiger attacks, the present work was carried out to a) assess the perception of fishermen towards tigers in Sundarban, b) evaluate socio-economic condition of fishermen, and c) investigate the reasons for being dependent on forest based livelihood in spite of it being an occupational hazard.

METHODS

Study Area

Sundarban is the world's largest contiguous mangrove forest created at the confluence of the deltas of Rivers Brahmaputra, Ganga and Meghna. The delta spreads across the countries of India and Bangladesh covering 80,000 km^2 (Chakrabarti, 1992) with 38% (Mitra, 2000) of it in India and the remaining in Bangladesh. It comprises of mudflats, creeks, tidal channels and an archipelago of about 102 islands of which 54 are inhabited by human population (Bera and Sahay, 2010). The Indian part of Sundarban covers about 4,266 km^2 (Sen and Naskar, 2003) in the 24 Parganas district of West Bengal, with parts of the region submerged under water (Fig. 1). It lies in the biogeographic zone 'Coasts' in the province of 'East Coast' as per Rodgers and Panwar's (1988) classification. The Protected Area of Sundarban comprises of 2,585 km^2 with a unique ecosystem of which 1,330 km^2 has been designated as the core zone of the Sundarban National Park. Amongst the larger fauna, tiger *(Panthera tigris tigris),* estuarine crocodile (*Crocodylus porosus*), water monitor (*Varanus salvator*), and three species of terrapin and turtles: northern river terrapin (*Batagur baska*), softshell turtle (*Pelochelys bibroni*) and green sea turtle (*Chelonia mydas*) are native to this region. Among the cetaceans, the Irrawaddy (*Orcaella brevirostris*) and Gangetic dolphins (*Platanista gangetica gangetica*) are rare and endangered. The main prey of tiger in the region comprises of chital (*Axis axis*), wild pig (*Sus scrofa*) and rhesus macaque (*Macaca mulatta*) and lesser adjutant (*Leptoptilos javanicus*) (Khan, 2004).

Socio-economic profile and Colonization History of Sundarban

The Indian Sundarban comprises of 19 community development blocks, with an estimated population of 4.1 million people (Census of India, 2001). Forty four per cent of the population comprises of schedule caste and tribes, with 85% dependent on agriculture. Other major occupations of the region are fishing, pisciculture, wood cutting and honey collection. The literacy level and per capita income are significantly below the state average with majority of the people below the poverty line. The human population density of this region is amongst the highest in the country with 1437.4 persons/ km^2 (Qureshi *et al.,* 2006) making the biodiversity conservation a challenge, although the Tiger Reserve is free of human settlements. Human colonisation of this region happened relatively late due to the inhospitable conditions though some people did occupy the area even in 6th century (Chakrabarti, 1992). By 1878-79, 4856 km^2 of this area was designated a Reserved Forest (Bera and Sahay, 2010; Bera et al., 2010). In 1978, many partition refugees from Bangladesh

escaped from the Dandakaranya government resettlement camp in central India and decided to establish themselves at Marichjhanpi in Sundarban, an area that was until then free of human presence and categorised as a Reserved Forest. This act led to violent clashes between the new settlers and the state government and resulted in mass deaths, brutality and disease in the region (Ghosh, 2004). Most of the areas are inaccessible, with poor communication and transport network. Frequent natural disasters such as cyclones and inrush of tidal waves and flooding results in widespread damage to life and property. In 2009, cyclone Aila caused considerable devastation rendering thousands homeless and leaving hundreds dead across the Sundarban (Choudhury *et al.,* 1999).

Socio-economic interviews

115 fishermen from 19 peripheral villages of Sundarban Tiger Reserve were interviewed (Fig. 2) between December 2011 and June 2013 using closed and open ended structured questionnaires (Bath, 1987; Bernard, 1995) to assess their socio-economic conditions, dependence on forest resources and attitudes toward conserving tigers in the landscape. Apart from fishermen people from other major occupation groups such as agriculture, pisciculture, tourist helpers, boat owners, hotel owners and daily wage labourers were also interviewed to infer about their annual income. Fifteen households who lost at least one of the family members due to tiger attack were also interviewed to understand their socio-economic status.

All the respondents were adults (above 18 years old) and those who willing to participate were interviewed. Interviews were conducted in the local language in an informal way to acquire desired information. The initial questions were related to simple demographic information so as to make ease the respondents to the interview session. Questions were repeated several times to ascertain the genuinity of the information provided by the respondents and the response was recorded only when there was no ambiguity. The questionnaire survey was primarily conducted by the same members of the research team to maintain uniformity and reduce individual bias while scoring of the answers.

A family was treated as the basic unit for the purpose of this study, with only one respondent from a family was interviewed. The respondent was treated as a representative of the family unit. The structured questionnaire used was divided into three main sections. The first section primarily dealt with the demographic details (age, gender, caste, education level, household structure, etc.) and assessment of the economic condition of the respondent was also made (Ranjitsinh and Jhala, 2010). The second part included questions pertaining to socio-economic status including land holding, livestock owned and annual income. The final section comprised questions regarding knowledge of tigers, human-tiger interactions, perception towards tiger conservation and suggestions for mitigating conflict. Information regarding the areas preferred by the respondents for fishing and honey collection was also collected.

Analytical Procedure

Responses from the questionnaire survey were analyzed to evaluate basic statistics regarding socio-economic well being, primary source of livelihood, attitude and perception of local people towards tigers (Ranjitsinh and Jhala, 2010). Percentages for each response were calculated based only on those who answered the respective questions. Significant difference between response of respondents was determined by using chi-square analysis in SPSS version 17.0 (SPSS Inc., Chicago, USA) and (R 2.15.1). Based on the records of the forest department, a map was prepared depicting the spatial intensity of human deaths caused by tigers between 2001 and 2013 in Arc GIS 9.3 (ESRI, Redlands, CA, USA). Maps for fishing intensity and honey collection within different administrative blocks of Sundarban Tiger Reserve were also generated using Arc GIS 9.3 (ESRI, Redlands, CA, USA) based on the questionnaire surveys. The lifetime income from the respective occupation was evaluated taking into consideration of an earning span of 47 years (18-65 years), 18 being the standard age of getting into a profession (derived from questionnaire surveys) and 65 years being the average life expectancy in South and North 24 Parganas District West Bengal. According to Chakrabarty (1992) and Khan (2004) majority of the human deaths caused by tigers were middle aged men between 35 to 45 years and hence the average age of tiger victims was calculated as 40 years. The income generated was also compared to other occupations of the respondents corresponding to that age.

RESULTS

Socio-economic condition of fishermen

The average age of fishermen interviewed was 50 years (SD 14.23). The average number of family members of the respondent was 5 (SE 0.24)**.** Majority (66%) stayed in kutcha houses (mud huts), while 33% stayed in semi-pucca houses (brick walled with hay or clay tiles top) and a mere 1% in pucca houses (X^2= 63.38, df = 2, $p < 0.05$). Roof material used in most of the households comprised of thatch and hay 64%, asbestos 3%, concrete 2% and tin sheets 31% (X^2= 102.8, df = 3, $p < 0.05$). Seventy one per cent had their ancestral home in Bangladesh followed by 12% from parts of North 24 Parganas district, 8% from Medinipore, 7% from parts of South 24 Parganas district and 2% from other parts

of West Bengal (X^2= 165.1, df = 4, p < 0.05). Most of the respondents (59%) were illiterate, 22% having completed primary schooling (till class V), 16% not completed primary school and only 3% with secondary schooling completed (X^2= 69.2, df = 3, p < 0.05).

Group composition of fishermen and honey collectors

Majority (69%) of honey collectors comprised of groups of 6-9 persons, 23% with 2-5 persons and 8% having more than 10 persons (X^2= 60.62, df = 2, p < 0.05). Fishing groups consisted of 3 persons 57%, 4-6 persons 41% and more than 6 persons 8% while going for harvesting fish inside the forest (X^2= 30.38, df = 2, p < 0.05). Seventy three per cent favoured spring tide phase for fishing and crab collection followed by 27% dependent on neap tide phase for extraction (X^2= 21.16, df = 1, p < 0.05). As means of self defense 86% used machete, 5% wooden sticks and poles and 8% used nothing (X^2= 127.82, df = 2, p < 0.05).

Perception and knowledge of fishermen towards tigers

Majority (92%) of fishermen opined that tigers consider humans as natural prey, only 5% stated that they attacked in self defense while 3% did not have an answer to the question (X^2= 154.94, df = 2, p < 0.05). Sixty two per cent of fishermen said that the main role of tigers in the wild is to destroy and subdue other animals, 19% said that they maintained ecological balance, control prey populations 14% and rest 5% were unaware of any role played (X^2= 77.04, df = 3, p < 0.05). Sixty seven per cent of the respondents opined that the declaration of Sundarban as Tiger Reserve was not beneficial to their livelihood, 20% felt it was useful, 8% said that only a fraction of the community has benefitted out of it whereas the rest 5% said that Forest Department and the state government did not provide any benefits whatsoever (X^2= 99.12, df = 3, p < 0.05).

Seventy seven per cent believed that prayer to Bonbibi (Forest Deity of Sundarban) before venturing in to the forest and rituals by shamans, could effectively prevent tiger attacks and the rest 23% felt that they were ineffective and presence of mind was crucial to prevent such conflicts (X^2 = 29.16, df = 1, p < 0.05). Majority (93%) were of the view that human negligence was responsible for deaths inflicted by tigers and 7% felt that Forest Department, being the custodians of the forest, was responsible for human deaths due to many reasons (X^2= 73.96, df = 1, p < 0.05). The reason as to why tigers stray into human habitation and depredate on livestock was attributed primarily to loss and scarcity of natural wild prey 67%, followed by easy target in the form of livestock 13%, narrow channel separating villages from forest 12%, confusion with tiger habitat 5% and encroachment of forest land 3% (X^2= 144.99, df = 4, p < 0.05).

Annual income of local communities

Since tiger attacks were frequent on people of particular occupations (honey collectors and fishermen), such category of respondents were asked as to whether they were willing to switch their profession. Majority (84%) declined to comment and only 16% responded positively for a changeover (X^2= 46.24, df = 1, p < 0.05). When inquired about their profession which involves high risks, 39% said that it gave instant cash rewards, 39% cited no other alternative means to secure income, 5% spoke about limitations of agriculture and rest 17% stated that they were best and apt at this compared to other sources of livelihood (X^2= 34.24, df = 3, p < 0.05) (Fig 3).

Occupation wise annual income as evaluated from socio-economic surveys was in the following order: hotel owner (INR 3,00,000) > Boat owners (INR 2,00,000) > Shopkeeper (INR 80,000) > Fishermen, Crab Collector, Honey Collector (INR 74,282) > Agriculturist (INR 44,377) > Animal Husbandry (INR 36,000) > Tourist Guide (INR 24,000) > Daily wage laborers (INR 15,000-26,000) (NREGA 2013 West Bengal Government wage rate; 1 INR H" 60 US$) ($X^2$= 735886, df = 7, p < 0.05). Apart from agriculture, shopkeeper, boat owner and hotel owner, income from forest based livelihood was significantly more than the daily wage labourers, tourist guides and apiculturists. A comparative analysis of the overall income generated till the age of 65 years revealed that a fisherman earned better than others except shopkeepers, boat owner and hotel owners who get income through tourism (Table 1).

Socio-economic condition of tiger victim's family

Out of the family members interviewed 60% were dependent on forest based livelihood, 20% worked in cities such as Kolkata, Chennai, and Andaman, 13% were agriculturists and the rest 7% daily wage workers. Fifty three respondents stayed in kutcha household whereas 47% in semi-pucca households. Sixty seven per cent of the respondents had access to solar light and the rest 37% stayed without any light facility. Half of them 53% were illiterate, 27% completed primary school and the rest 20% did not complete primary schooling.

Spatial distribution of the intensity of fishing and honey collection across Sundarban Tiger Reserve

Based on the map derived from Arc GIS (Fig 4 and 5) fishing and honey collection intensity were the highest along the north-western part of the tiger reserve. Honey collection was also common in the eastern part of the tiger reserve. Moderate level of fishing was done along the northern and central portion of the reserve. North-western part of the reserve being close to peripheral villages seemed easily accessible by majority of

Figure 1. Map of Sundarban Tiger Reserve,West Bengal India

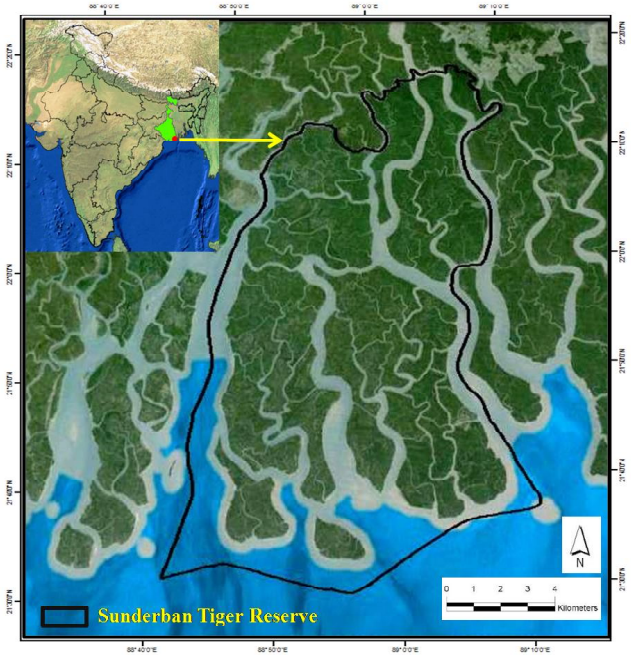

Figure 2. Map of Sundarban Tiger Reserve, India with locations of interviews conducted along peripheral

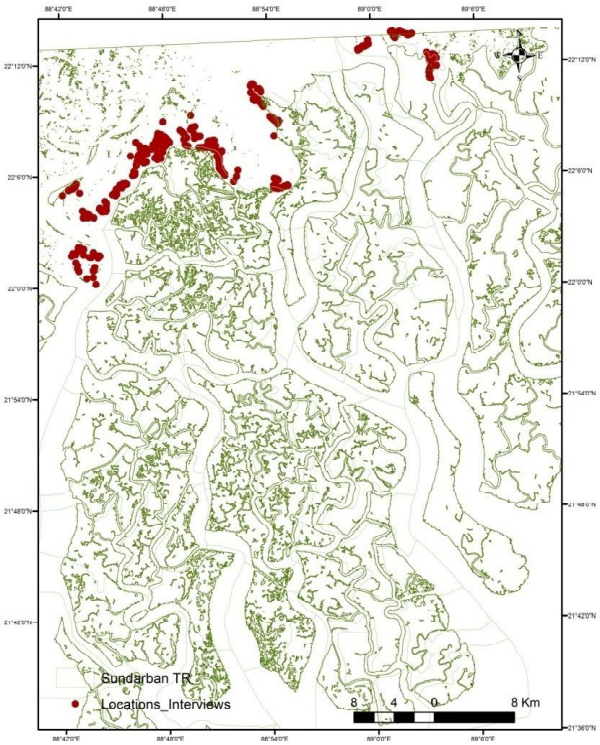

Figure 3. Response of fishermen regarding dependence on forests in spite of threats by tigers (X^2= 34.24, df = 3, p < 0.05)

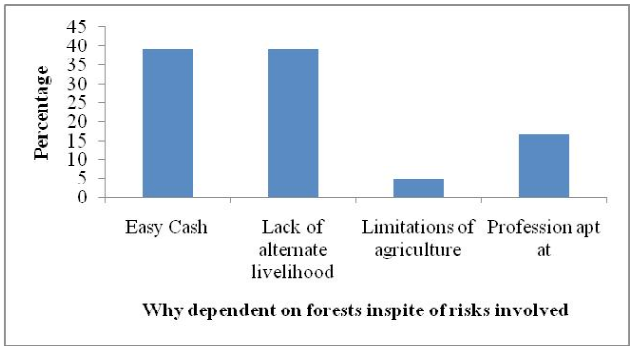

Figure 4. Fishing intensity across the administrative blocks of Sundarban Tiger Reserve

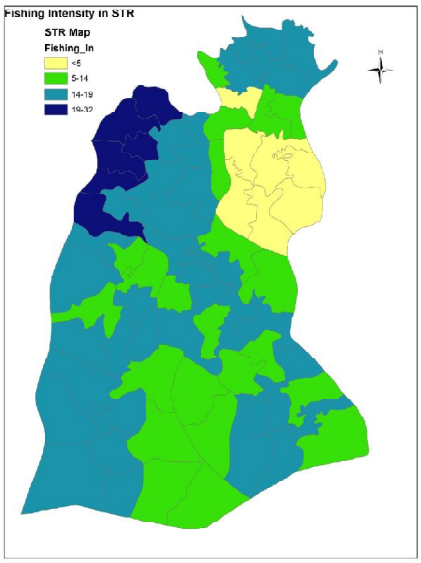

Figure 5. Honey collection intensity across the administrative blocks of Sundarban Tiger Reserve

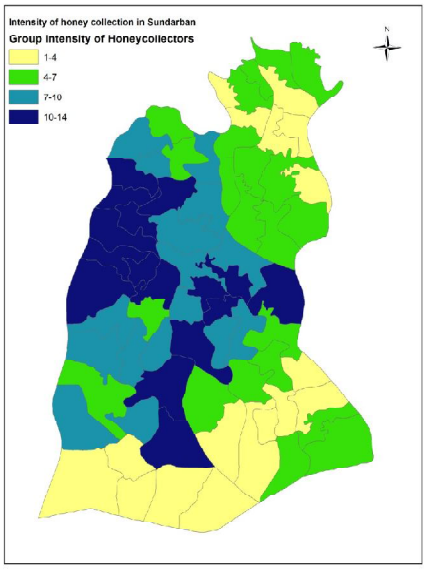

Table 1. A comparison of annual and lifetime occupation wise income to show as to how financially it is advantageous to be dependent on forests in spite of the risks involved

Major Professions	Annual Income INR	Lifetime Income (18-65) years INR	Surplus/Deficit compared to income at 40 being a fisherman INR	Surplus/Deficit lifetime income being a fisherman INR(18-65) years
Agriculture	44,377	20,85,719	Deficit-4,51,515	Surplus 14,05,535
Tourist helper	24,000	11,28,000	Surplus 506204	Surplus 23,63,254
Shopkeeper (Tourist Zone)	80,000	37,60,000	Deficit-21,25,796	Deficit -2,68,746
Animal Husbandry	36,000	16,92,000	Deficit-57,796	Surplus 17,99,254
Apiculture	16,000	7,52,000	Surplus 8,82,204	Surplus 27,39,254
Fishing, crab & Honey Collection	74,282	34,91,254		
Boat owner	2,00,000	94,00,000	Deficit	
Hotel owner	3,00,000	14,100,000	Deficit	
Daily wage NREGA Unskilled	15,100	7,09,700	Surplus 24,504	Surplus 27,81,554
NREGA Semiskilled	19,500	9,16,500	Surplus 7,17,704	Surplus 25,74,754
NREGA Skilled	26,000	12,22,000	Surplus 4,12,204	Surplus 22,69,254
If dies at 40 yrs due to tiger attack		16,34,204		

fishermen and honey collectors. Eastern part being near the international boundary of Bangladesh and relatively far flung from human habitation recorded low intensity of fishing. Rest of the northern and central part recorded moderate level of honey collection. Apparently maps based on fishing and honey collection depicted certain hotspots along the northwestern part close to human habitation.

DISCUSSION

Inskip and Zimmermann (2009) stated that poverty, low levels of literacy, lack of alternate livelihood, meager income, harsh climatic conditions and high levels of conflict intensity form a complex web which ultimately shaping negative perception towards tigers in Bangladesh Sundarban. Fishermen interviewed were mostly illiterate residing in mud huts, making them vulnerable against frequent natural calamities prevalent across the region. Though majority of the fishermen are proficient in harvesting natural resources with excellent natural history skills, their basic knowledge about tigers is somehow shaped by popular myths and local folklore of the region. Sixty per cent of them disliked tigers. This is because of the fact that they are dependent on forests and have regular interactions with tigers, which sometimes prove fatal at any point of time. Local pastorals experiencing livestock depredation problem were equally intolerant to snow leopards especially in the Western Himalayas (Bagchi and Mishra, 2006). Though armed with a machete or wooden poles, sticks, majority of the fishermen and honey collectors are followers of the forest deity-Bonbibi and performed rituals and ceremonies before venturing into the forest. Similar beliefs have been reported from Sumatra where holy men communed with tigers in order to speak to dead heroes, In Thailand and peninsular Malaysia tiger is regarded as the avenger of the Supreme Being- Karei, and those who are breaking or disobeying tribal taboos are punished. In a place with dire poverty levels and limited employment opportunities it makes sense to take the extra risk of securing a stable income for the family. Families of fishermen killed are paid a meager compensation of INR 2,00,000 by the Forest Department only if the victim died outside the designated core area of the Tiger Reserve (ACF, DFO Sunderban Tiger Reserve Pers. communication). Thus most of the incidents inside the PA go uncompensated. As it has been reported that (Kumar and Rahmani, 1997; Khuukhenduu and Bidbayasakh, 2001; Verdade and Campos, 2004) paying for wildlife damage can ostensibly stimulate local support for conservation, reduce incentives for retaliatory action and buy time for alternative management practices (Nyhus *et al.*,

2005; Wang and MacDonald, 2006). Sixty per cent of the family members of tiger victims' interviewed were dependent on forests which testify their resilience and courage, and expose the lack of alternate employment opportunities. Loss of a human life doesn't really seem to be a deterrent in the struggle for existence, which is probably worth exploring considering the economic benefits and the occupational hazards.

CONCLUSION

An isolated tiger population of Sundarban faces threats of local extinction prominently due to human-tiger conflict. Hence garnering local support becomes essential for conservation through mitigation or management of conflict. Loss of human life and fatal injuries inflicted by tiger attacks cannot be compensated by money yet they might engender public support and reduce the pain and agony of the family members. Enhancing the quantum value of compensation is justified on the grounds of morality, when the direct costs incurred on conservation are felt by a small minority (Treves *et al*., 2009). Northwestern part of the tiger reserve being frequented by people, might surface as a hotspot of conflict and restraint on harvesting natural resources should be imposed by the forest department to reduce the risk of tiger attacks on humans. Though majority of the Tiger Reserve is inaccessible for fishing, crab collection, forest department might consider opening of additional areas outside the risk zone to enhance employment generation opportunities. Ultimately conservation of tigers in Sundarban needs a holistic approach not only focusing on the endangered species but also integrating the socio-economic needs of the local inhabitants. Considering limitations of livelihoods, promoting eco-tourism might provide a gradual shift from present forest based sustenance. Though marginal local communities like fishermen have learned to co-exist with tigers in spite of recurrent economical or personal losses, the future depends on finding permanent solutions to mitigate human-tiger conflict.

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REFERENCES

Bagchi, S. and Mishra, C. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *J. Zool.,* 268: 217-224.

Bath, A. J. 1987. *Attitudes of various interest groups in Wyoming toward wolf reintroduction in Yellowstone National Park.* MA Thesis, University of Wyoming, Laramie. 124.

Bera, G. K. and Sahay, V. S. 2010. *In the lagoons of the Gangetic delta.* Mittal Publications, New Delhi.

Bera, G. K., Mukhopadhyay, A. K. and Sarkar, A. 2010. Syncretism at Sundarban- anthropological and linguistic dimensions. In : *The lagoons of the gangetic delta.* Bera, G.K. and Sahay, V.S. (Eds.), Mittal Publications, Delhi.

Bernard, H. R. 1995. *Social research methods: quantitative and qualitative approaches.* Sage publications, Thousand Oaks, CA, USA. 784.

Census of India. 2001. Provisional population totals, West Bengal, Table 4. Census Commission of India. Accessed on 2007-08-24.

Chowdhury, A. N., Chowdhury, S. and Chakraborty, A. 1999. Eco-stress, quality of life and mental health in Sundarban delta of India. *International Medical Journal.,* 6: 59–63.

Chakrabarti, K. 1992. Man-eating tigers. Darbari Prokashan.

Chaudhuri, A. B. and Choudhury, A. 1994. *Mangroves of the Sundarban,* Vol. 1: India. IUCN, Bangkok. 247.

Chowdhury, R. A. and I. Ahmed. 1994. History of forest management. *Mangroves of the Sundarbans* 2: 155–180.

Conover, M. 2002. *Resolving human-wildlife conflicts: The science of wildlife damage management.* CRC Press, Boca Raton, Florida, USA. 418.

Denzau, N. G. and Denzau, H. 2010. Examining certain aspects of human-tiger conflict in the Sundarban Forest, Bangladesh. *J. Tigerpaper* 37: No. 3.

Dickman, A. J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation,* 13: 458-466.

Dinerstein, E. Wikramanayake, E. D., Robinson, J. G., Karanth, K. U., Rabinowitz, A., Olson, D., Mathew, T., Hedao, P., and Connor, M. 1997. *A framework for identifying high priority areas and actions for the conservation of tigers in the wild.* World Wildlife Fund-US and Wildlife Conservation Society. Published in Association with the National Fish and Wildlife Foundation's Save the Tiger Fund, USA.

Fulton, D. C., Manfredo, M. J. and Lipscomb, J. 1996. Wildlife value orientations: A conceptual and measurement approach. *J. Human Dimensions of Wildlife,* 1: 24-47.

Ghosh, A. 2004. *The hungry tide.* Ravi Dayal Publisher New Delhi. 402.

Hoogerwerf, A. 1970. *Udjung Kulon: the land of the last Javan rhinoceros.* E.J. Brill, Leiden.

Homer, P. M. and Kahle, L. R. 1988. A structural equation test of the value-attitude behavior hierarchy. *J.Personality and Soc. Psychology,* 54: 638-646.

Inskip, C. and Zimmermann, A. 2009. Human-Felid Conflict: A Review of Patterns and Priorities Worldwide. *Oryx* 43: 18–34.

Khan, M. M. H., 2004. *Ecology and conservation of the Bengal tiger in the Sundarban Mangrove forest of Bangladesh.* PhD thesis, University of Cambridge.

Khuukhenduu, T. and Bidbayasakh, E. 2001. Wolf depredation in Mongolian park is a fact of life. *International Wolf* 6: 10.

Kumar, S. and Rahmani, A. R. 1997. Status of Indian grey wolf (*Canis lupus pallipes)* and its conservation in marginal agricultural areas of Solapur district, Maharashtra. *J. Bombay Nat.Hist. Soc.,* 94: 466–472.

Linnell, J. D., Odden, C. J., Smith, M. E., Anes, R. and Swenson, J. E. 1999. Large carnivores that kill livestock: do "problem individuals" really exist? *J. Wildl. Soc. Bull.,* 27: 698-705.

Mills, M. G. L. and Hofer, H. 1998. *Hyenas: status survey and conservation action plan*. World Conservation Union, Gland, Switzerland and Cambridge, UK. 154.

Mitra, A. 2000. The northwest coast of the Bay of Bengal and deltaic Sundarbans, In: Sheppard, C.R.C. (Eds.), *Seas at the millennium: an environmental evaluation: 2. Regional chapters: The Indian Ocean to The Pacific.* 145-160.

Montgomery, S. 2008. *Spell of the tiger: the man-eaters of Sundarban.* Chelsea Green Publishing,Vemont.

Naughton-Treves, L. 1998. Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. *Conservation Biology.,* 12: 156-168.

Naughton-Treves, L., Grossberg, R. and Treves, A. 2003. Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. *J. Conservation Biology.,* 17: 1500–1511.

Nowell, K. and Jackson, P. 1996. *Wild Cats. Status and conservation Action plan* IUCN/SSC Cat Specialist Group, Gland, Switzerland.

Nyhus, P. J., Osofsky, S. A., Ferraro, P., Madden, F. and Fischer, H. 2005. Bearing the costs of human–wildlife conflict: the challenges of compensation schemes. In: Woodroffe, R., Thirgood, S., Rabinowitz, A. (Eds.), *People and Wildlife: Conflict or Coexistence?* Cambridge University Press, Cambridge, UK. 107–121.

Ogra, M. 2009. Attitudes toward resolution of human-wildlife conflict among forest-dependent agriculturists near Rajaji National Park, *India. Human Ecology.,* 37: 717-729.

Palmeira, F. B. L., Crawshaw, P. G., Haddad, C. M., Ferraz, K. and Verdade, L. M. 2008. Cattle depredation by puma (*Puma concolor*) and jaguar (*Panthera onca*) in central western Brazil. *Biological Conservation.,* 141: 118-125.

Qureshi, Q., Gopal, R., Kyatham, S., Basu, S., Mitra, A. and Jhala, Y. V. 2006. *Evaluating tiger habitat at the tehsil level.* Project Tiger Directorate, Govt. of India, New Delhi and Wildlife Institute of India, Dehradun. TR No. 06/001.

Ranjitsinh, M. K. and Jhala, Y. V. 2010. *Assessing the potential for reintroducing the cheetah in india.* Wildlife Trust of India, Noida and Wildlife Institute of India, Dehra Dun. TR2010/001. 161.

Rodgers, W. A. and Panwar, H. S. 1988. *Planning a Wildlife Protected Area Network in India.* A report prepared for the Ministry of Environment and Forests and Wildlife, Government of India, volumes 1 and 2.

Rokeach, M. 1973. *The Nature of Human Values.* New York: Free Press.

Røskaft, E., Bjerke, T., Kaltenborn, B. P., Linnell, J. D. C. and Anderson, R. 2003. Patterns of self-reported fear towards large carnivores among the Norwegian public. *Evolution and Human Behavior.,* 24: 184-198.

Sanyal, P., 1987. Managing the man-eaters in the Sundarban Tiger Reserve of India: a case study. In : Tilson, R.L., and Seal, U.S., (Eds.), *Tigers of the world.* Noyes Publications, Park Ride. 427-434.

Seidensticker, J. 1987. Bearing witness: observations on the extinction of (*Panthera tigris balica*) and (*Panthera tigrissondaica*) In : R.L. Tilson and U.S. Seal (Eds.), *Tigers of the world: biology, biopolitics, management, and conservation of an endangered species.* Noyes Publications, Park Ride. 1-8.

Sen, N. and Naskar, K. 2003. *Algal flora of SundarbanMangal.* Daya Publishing House, Delhi.

Treves, A. and Karanth, K. U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. *J. Conservation Biology,* 17: 1491–1499.

Treves, A., Jurewicz, R. L., Naughton-Treves, L., Wilcove, D. S. 2009. The price of tolerance: wolf damage payments after recovery. *J. Biodiversity and Conservation.* doi: 10.1007/s10531-009-9695-2.

Verdade, L. M., Campos, C. B., 2004. How much is a puma worth? Economic compensation as an alternative for the conflict between wildlife conservation and livestock production in Brazil. *Biota Neotropica 4 (2).* <*http://www.biotaneotropica.org.br/v4n2/en/toc*>*(accessed 09.04.2010).*

Wang, S. W. and MacDonald, D. W. 2006. Livestock predation by carnivores in JigmeSingyeWangchuk National Park, Bhutan. *J. Bio. Conservation.,* 129: 558-565.

Woodroffe, R. and Ginsberg, J. R. 1998. Edge effects and the extinction of populations inside the protected areas. *J. Science.,* 280: 2126-2128.

Woodroffe, R., S. Thirgood, and A. Rabinowitz. 2005. *People and wildlife, conflict or coexistence.* Cambridge University Press, Cambridge.