ECOLOGY AND CONSERVATION OF THE BENGAL TIGER IN THE SUNDARBANS MANGROVE FOREST OF BANGLADESH

by

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This dissertation is dedicated to

IUCN – The World Conservation Union

and

WWF – World Wide Fund For Nature

for their significant contributions in biodiversity conservation throughout the world,

and in the memory of the late

Ruediger Maelzig

A German nature-lover who sadly died in a car accident while still young.

His parents decided to donate the money of his life insurance to support conservation.

This money partially supported my fieldwork.

'… the one-horned rhinoceros (Javan rhinoceros) has become rare and is only found within the southern portion of the reserved forests. Buffaloes are also fast disappearing and at present are only found in the waste lands of the Backergunge portion of the Sundarbans (eastern Sundarbans). Tigers and crocodiles, however, are still as numerous as ever.'

– Bengal District Gazetteer (1908)

(PS. Rhinoceros and buffaloes are now extinct in the Sundarbans, and tigers and crocodiles are now threatened.)

'Studying a tiger is always thrilling, but if not carried out with sufficient care and knowledge it can be dangerous.'

– Sankhala (1978a)

'In the Sundarbans, tigers, deer, forest, and men are linked inseparably and so must be their management.'

– Seidensticker and Hai (1983)

'The tiger is a symbol of the natural heritage of our planet. None of us want it to end up as a bag of bones, or its home as furniture for our homes.'

– Thapar (1999)

'… these two areas (Sundarbans mangrove forest of Bangladesh and India and the Russian Far East) have the largest surviving single populations of tigers.'

– WWF (1999)

'Here (in the Sundarbans) tigers are exceptionally difficult to observe and study – so difficult that a recent writer made four trips, wrote a good book, and made a National Geographic *film about Sundarbans tigers without ever setting eyes on even one.'*

– Matthiessen (2000)

'Wild tigers are the warning lamps that indicate how healthy natural landscapes continue to remain in the face of our onslaught; their survival is as useful to us as the oil-pressure lamp on the dashboard of a car or the battery live indicator on a laptop computer.'

– Karanth (2001)

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PREFACE

The work described in this dissertation was conducted from the Wildlife Research Group, Department of Anatomy, University of Cambridge, under the supervision of Dr David J. Chivers. This is the result of my own research, except where explicitly stated otherwise. No part of this dissertation has been submitted to this or any other educational institution for any degree or diploma.

Mohammad Monirul Hasan Khan
Cambridge, May 2004

SUMMARY

The ecology and conservation of the Bengal tiger (*Panthera tigris tigris*) was studied in the Sundarbans mangrove forest of Bangladesh for 18 months (September 2001-February 2003). The objective was to provide baseline information on: a) prey population structure and density, b) prey selection by tigers, c) relative habitat use by tigers, d) breeding and litter size of tigers, and e) tiger-human interactions, which is a key requirement for effective conservation of this globally-threatened animal. The main methods used in the field were line-transect sampling, scat analysis and kill study, sign surveying, and interviewing.

The spotted deer (*Cervus axis*) was the dominant prey species, both in terms of individual density and biomass density. Based on the prey density, the tiger density was inferred at 4.3 tigers/100 km^2 (excluding cubs) in the high density area. The spotted deer and rhesus macaque (*Macaca mulatta*) were identified as the most social prey species. Other prey species, such as wild boar (*Sus scrofa*), lesser adjutant (*Leptoptilos javanicus*), red junglefowl (*Gallus gallus*) and ring lizard (*Varanus salvator*) were mainly solitary.

The spotted deer was the most frequent prey in scats and kills (78%) and it forms 80.1% of the prey biomass consumed by tigers. Other than the spotted deer, tigers also preyed on wild boar, rhesus macaque, lesser adjutant and some other smaller prey species. Soil and sungrass were found in scats (as non-food items). In general, the trend of prey selection appeared to follow prey size and abundance. Most spotted deer kills were adult animals.

Tigers may have habitat preference for feeding, resting, defaecation and interaction, but not for movement, scratch-scent-urinal and ‘others’ (hunting, drinking, etc.). They were found to use soft-barked trees for scratching more often than other types.

Tigers may breed throughout the year, but the peak is in winter (October-March). For possible litter size, one was the commonest (60.7%), but the mean litter size was 1.4, which is lower than in other tiger ranges.

During this fieldwork, humans killed 7 tigers and tigers killed 41 humans. Based on interviewing local people it was found that most of tigers killed were middle-aged (68%) males (73%). Sixty-eight percent tigers were killed mainly in the villages around the Sundarbans. The main reasons for tiger-killing by people were attacks on humans

and cattle (76%), but poaching was also a significant reason (19%). Most of the tiger attacks were on middle-aged (73%) fishermen and ‘Bawalis’ (woodcutters, leaf collectors, etc.), but the pattern mainly followed availability. Tiger-human conflict was highest in winter. The majority of the local people interviewed (53%) relied only on spiritual measures to protect themselves from the tiger. Forty-two percent of the interviewees believed on the medicinal use of tiger parts. Interestingly, despite all of the fatal encounters, 75% of the interviewees wanted the tiger to remain in the Sundarbans, so that the area could be protected from illegal loggers and poachers. A total of 2.8% of the animal protein consumed by local people surveyed came from tiger prey; prey protein was more expensive than non-prey protein.

The main threats to tigers persisting in the Sundarbans are illegal human consumption of tiger prey combined with direct poaching of tigers. Over time this may have detrimental effects on the persistence of tigers in the Sundarbans, unless steps are taken to control these activities.

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CHAPTER 1 INTRODUCTION

1.1 GENERAL

The Bengal tiger [*Panthera tigris tigris* (Linnaeus 1758)] is the National Animal of both Bangladesh and India. It is an intimate part of the history and culture of this region. In some archaeological sites, as in Razaram Roy's Temple in Madaripur, Bangladesh, some terracotta plaques have been discovered which depict the tiger and its prey. Perhaps these were treated as sacred animals in Razaram Roy's reign. The tiger is admired, feared and respected by humans for its beauty, grace, strength, ruthlessness and other natural and supernatural attributes (Tamang 1993).

The tiger is the largest of the cats (WWF 2001, Sunquist and Sunquist 2002) and is one of the world's most magnificent animals. Of eight sub-species of the tiger [Bengal tiger (*P. t. tigris*), Caspian tiger (*P. t. virgata*), Amur tiger (*P. t. altaica*), Javan tiger (*P. t. sondaica*), South China tiger (*P. t. amoyensis*), Bali tiger (*P. t. balica*), Sumatran tiger (*P. t. sumatrae*), and Indo-Chinese tiger (*P. t. corbetti*)], the Bengal tiger mainly occurs in India, Bangladesh, Nepal and Bhutan. Of these eight sub-species, three have become extinct since 1950s (Caspian, Javan and Bali tigers), two are virtually extinct (South China and Indo-Chinese tigers), and from the 100,000-150,000 tigers that might have existed 150 years ago, we are left with 5,000-7,000 animals today (Thapar 1996, WWF 1999). At present, more tigers exist in captivity than in the wild (Nowell and Jackson 1996, Karanth 2001).

There are eight species of wild cats found in Bangladesh (Table 1.1; see Khan 2004a, 2004b, in Appendices I and II, for more information), of which five are globally threatened (IUCN 2003) and six nationally (in Bangladesh) threatened (IUCN-Bangladesh 2000). According to IUCN Criteria, the Bengal tiger has been categorised as globally Endangered (IUCN 2003) and nationally Critically Endangered (IUCN-Bangladesh 2000).

The Sundarbans of Bangladesh and India harbours one of the two biggest unfragmented tiger populations on earth comparing only to the tiger population in the Russian Far East (WWF 1999; Khan 2002, see Appendix III for the whole article). This mangrove habitat is unfragmented and naturally inaccessible to people, which offers excellent potential for long-term conservation of the tiger. Hence, the Sundarbans has been identified as a high-priority area for tiger conservation (Dinerstein *et al.* 1997, Wikramanayake *et al.* 1999). Tidal mangrove forest is a rare habitat for the tiger (UNDP and FAO 1998). Seidensticker (1986) mentioned that the Sundarbans is large, so a large population (effective population size, Ne, >100; Allendorf 1986) of tigers has been and can continue to be maintained for the next 50, 100 or even 200 years from now.

The tiger is the pride of the fauna of the Sundarbans. Since the tiger is at the top of the ecological pyramid of the mangrove ecosystem, it is also considered as the Flagship or Umbrella Species to conserve the unique biodiversity of the Sundarbans.

Fifty years ago tigers were found in all the forested areas of Bangladesh, but today the only stable population is in the Sundarbans. Large carnivore species occur at naturally low densities, which makes them particularly susceptible to extirpation and extinction (Lande 1988, Caughley 1994). The tiger is legally protected under the 3rd Schedule of Bangladesh Wildlife Act 1974 and, as such, it should not be killed or captured. The use and export of the tiger or its parts is banned under the provisions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Bangladesh acceded to CITES in 1982. The habitat of the tiger is legally protected under Forest Act 1927. Practical conservation of Sundarbans tigers, however, still remains undeveloped.

The prey of the tiger in the Sundarbans mainly comprises deer and boars, and also includes monkeys, monitor lizards, birds, crabs and fish (De 1990). Three factors are essential for the tiger: 1) the proximity of large animals upon which it can prey, 2) ample shade for sleeping, and 3) water to quench its thirst (Prater 1971).

It appears that, despite excessive human pressure on the natural resources, intense tiger-human conflict, and natural disasters, the tiger population of the Sundarbans is not declining (Tamang 1993). This is the result of the natural inaccessibility of the forest, and the existence of man-eating tigers. In other words, man-eating tigers serve as a barrier to natural resource exploitation by humans.

Table 1.1 Status of wild cats (Order: Carnivora, Family: Felidae) in Bangladesh

Sl. no.	Scientific name	English name	Local name	Global status	Local status	Distribution in Bangladesh
1	*Felis chaus* Guldenstaedt 1776	Jungle cat, swamp cat	Ban biral, wab	-	Endangered	Widely distributed
2	*Catopuma temmincki* (Vigors and Horsfield 1827)	Asiatic golden cat, Temminck's cat, Asian golden cat, golden cat	Sona bagh, sonali biral	Vulnerable	Critically Endangered	South-east and south
3	*Neofelis nebulosa* (Griffith 1821)	Clouded leopard	Gechho bagh, lam chita	Vulnerable	Critically Endangered	South-east and north-east
4	*Panthera pardus* (Linnaeus 1758)	Leopard, panther	Chita bagh	-	Critically Endangered	South-east and north-east
5	*Panthera tigris* (Linnaeus 1758)	Tiger, Bengal tiger, royal Bengal tiger	Bagh	Endangered	Critically Endangered	South-west
6	*Pardofelis marmorata* (Martin 1837)	Marbled cat	-	Vulnerable	Data Deficient	South-east
7	*Prionailurus bengalensis* (Kerr 1792)	Leopard cat	Chita biral	-	Data Deficient	Widely distributed
8	*Prionailurus viverrinus* (Bennett 1833)	Fishing cat	Mechho biral, mechho bagh	Vulnerable	Endangered	Widely distributed

N.B. The global status is according to IUCN (2003) and the local status (i.e. the status in Bangladesh) is according to IUCN Bangladesh (2000).

1.2 TIGER IN THE HUMAN CULTURES

As the largest predator, the tiger has been revered as a cultural icon throughout much of its former and present range (Weber and Rabinowitz 1996). The association and interactions between the tiger and the human is almost as old as the human civilisation in Asia. The oldest man-made representation of a tiger was discovered on the rocks by the Amur river in Siberia, which dates back to 4,000-3,500 BC (Thapar 1992). A 5000-year-old seal from the Indus valley civilisation in South Asia depicts a man sitting on a tree addressing a tiger waiting for him below (Karanth 2001). Thapar (1996) mentioned that, for the people who lived in the forest, the tiger was the most important and most powerful representation of nature. The tiger seemed to symbolise the force that could provide life, defeat evil and act as an ‘elder brother’ to humans, defending crops and driving out evil spirit. It was the protector, the guardian, the intermediary between heaven and earth. It was the symbol of fertility and regeneration.

It is believed that the Tigris river of the Caspian region derived its name from the tiger. Thapar (1992) tells the story as: “A princess waits on the bank of a river, desperate to cross to the other side. The water of the river rages in front of her. Suddenly, a tiger appears by her side. She climbs on his back and they set forth to cross the waters. The tiger is a powerful swimmer and carries the princess safely to the other side. The princess gives birth to a baby on the far bank. The river is called Tigris and weaves a long course through the land, symbolising the ‘fertile connection’ between man and the tiger in the legends of the area.”

Throughout tropical Asia and north to the Sea of Okhotsk, men were credited with the ability to turn into tigers, and spirit tigers were believed to roam the forests (Jackson 1999). In the mountains of Tibet, the people used tiger-skin rugs to ward off snakes, scorpions, insects and other creatures (Thapar 1996). Many Chinese still believe that their land is blessed by the Blue Dragon and White Tiger. They also venerated the tiger as the benevolent messenger of the mountain spirit San Shin (Thapar 1992). In China, a variety of objects bearing the image of the tiger have survived from the sixth and seventh centuries. There the tiger was considered as the guardian of the dead as well as the living. Every twelfth year is dedicated to the tiger in Chinese calendar. The impressions of tigers are made in different ways, and children wear tiger caps and tiger slippers to celebrate the Year of the Tiger. In Korea, the tiger became the symbol of the Mountain Spirit, and the White Tiger the Guardian of the West. Malaysia has two tigers supporting the National Crest (Jackson 1999). In Indonesia, the Muslims believe that Allah (God) empowered the tiger to protect the faithful and to mete out punishment to anyone who dares transgress the laws of Islam (Matthiessen 2000). There, in the communities living in and around the forests, the tiger is known as ‘Nenek’, which means something like ‘Grandfather’ or ‘Old Man of the Forest’. In Sumatra, it is commonly believed that the tiger does not bother man unless man bothers him. In one part of the island, people offer buffalo for the tiger so that the tiger protects the pepper plantations and rice fields (Thapar 1992).

The tiger is deeply rooted in the history, culture, beliefs and myths of the Indian sub-continent. One seal of the Indus valley civilisation, which dates back to 2,500 BC, shows the naked figure of a woman, upside down with her legs apart and two tigers standing to one side. It implies the close connection of the tiger with fertility and birth and that man and tiger evolved together from the same ‘earth mother’ (Thapar 1992).

Later on, when the Aryans spread the Hindu religion, the tiger was absorbed into Hinduism and became a potent image as the tiger ridden by the great female deity, Durga, while one of the most important of the Gods, Siva, sits on a tiger skin. When Buddhism evolved from Hinduism and spread through Asia, the tiger came as spiritual and cultural images, which adorn splendid murals in temples in Bhutan, China, Thailand and Tibet (Jackson 1999). In the 18th century, the tiger was worshipped by the well-known Muslim ruler Tippu Sultan and his people in southern India. Tippu Sultan was known as ‘The Tiger of Mysore’. His banner carried the words ‘The Tiger is God’, and his throne was decorated to resemble a tiger. His soldiers had tiger-striped uniforms, and tiger images and stripes on their weapons (Jackson 1999).

The Warli tribes of Central India believe the tiger to be a God – the Vaghadeva (Thapar 1992). Many other forest communities worship the tiger as the lord of the jungle. In Madhya Pradesh, India, the tiger is worshipped as Bagh Deo. In Karnataka coast, India, the tiger is worshipped as Pili Bhoota; people perform the tiger dance or ‘Huli Vesha’ during Dasara celebrated by Hindus (Karanth 2001). In one northern part of Bengal the Tiger God was worshipped by the people of both Hindu and Muslim communities. Scroll paintings depicted the Muslim holy man astride a tiger, carrying a string of prayer beads and a staff and attacking all that was evil (Thapar 1992). Despite the fact that tigers kill many people in the Sundarbans, the tiger is respected by people and they seek protection with offerings to the folk deities before entering the forest (see Chapter 7 and Khan 2004c in Appendix IV for details).

The tiger is widely used as a potent brand image for anything from beer to gasoline, breakfast cereals to varnish paint (Karanth 2001). Many military units across the world have tigers as their mascots (Karanth 2001). Bangladesh has the image of the tiger on banknotes and the national cricket team has a band of tiger stripes on the jersey. Because the tiger is a symbol of power, Hong Kong, Malaysia, Singapore, South Korea and Thailand have been dubbed ‘Asian tigers’ because of their rapid economic advance (Jackson 1999).

1.3 STUDY SPECIES: TIGER *Panthera tigris*

1.3.1 Origin

About 65 million years ago, there was a dramatic change in mammalian evolution following the extinction of the dinosaurs, which opened up a world of opportunities for the shrew-like early mammals. In dank tropical forests and swamps, the mammals diversified and filled the niches left vacant, some becoming large herbivores, others ‘omnivores’, others predators (Macdonald 1992). The early carnivores, known as miacids, lived at the time between 60 and 55 million years ago. All modern members of the Order Carnivora (about 236 species) are the descendants of the miacids. About 55 million years ago these early arboreal carnivores split into two branches, the cats (Feloidea) and the dogs (Canoidea). The cat-branch dominated in the Old World and the dog-branch in the New World. The first true cat was *Pseudaelurus*, which evolved by 20 million years ago. They were medium-sized ambushers of small vertebrates. Among all the families of the carnivores only the members of the family Felidae (i.e. true cats) are specialised hunters and they are purely carnivorous. They are characterised by having high-domed skulls and short snouts, which provide anchorage for muscles that power a lethal bite. The cats have the sharpest carnassial teeth among all the carnivores (Macdonald 1992). They also have acute hearing, specialised paws and camouflaged coat colour to make their hunt successful.

The larger cats, like the sabre-toothed cats, were originated from the medium-sized ancestors and they were common at the end of the Miocene, between five and six million years ago, when the world’s climate changed in ways that revolutionised the lives of most carnivore families. During that climatic change, a new lineage of swifter and more agile cats rose, which are known as pantherines. All today’s larger members of the cat family, including the tiger, are their descendants (Macdonald 1992).

Evidence for the evolution of the tiger comes from the fossil remains, as well as from the modern molecular phylogenies. The genus *Panthera* probably evolved within the last five million years or so (Hemmer 1976, Collier and O’Brien 1985, Wayne *et al.* 1989, Kitchener 1999).

Molecular phylogenies confirm the close relationship among the members of the genus *Panthera* and show that the tiger diverged more than two million years ago and before the divergence of the lion, leopard and jaguar (Collier and O'Brien 1985, Wayne *et al.* 1989, Wentzel *et al.* 1999).

It is almost certain that the tiger originated in eastern Asia (Hemmer 1981, 1987; Herrington 1987; Mazak 1981, 1996; Kitchener 1999). The oldest fossil remains of the tiger have been discovered from northern China and Java (Hemmer 1971, 1976, 1987). Originally described as *Felis palaeosinensis* (Zdansky 1924), the fossil of a small tiger from Henan, northern China, is thought to date from the end of the Pliocene and the beginning of the Pleistocene and so may be up to two million years old (Hemmer 1967, 1987). Perhaps this was the ancestor of two or more *Panthera* cats of today, including the modern tiger (Kitchener 1999). Abundant tiger fossils have been discovered from China, Sumatra and Java, which are dated from the middle to late Pleistocene, but tiger fossils only appeared in the Indian sub-continent, the Altai, northern Russia and elsewhere in the late Pleistocene (Brandt 1871, Lydekker 1886, Tscherski 1892, Dubois 1908, Zdansky 1924, Brongersma 1935, Loukashkin 1937, Hooijer 1947; Hemmer 1971, 1976, 1987).

According to Hemmer (1987) and Mazak (1996), the tiger originated in east Asia, from where two major dispersals took place about two million years ago. To the north-west, tigers migrated through woodlands and along the river systems into south-west Asia. To the south and south-west, tigers moved through continental south-east Asia, some crossing to the Indonesian islands, and others finally reaching India (Nowell and Jackson 1996). The South China tiger may be regarded as the relict population of the 'stem' tiger, living in the probable area of origin. Its skull morphology is the most primitive among all the living tiger sub-species (Herrington 1987). The radiation of tigers was driven by two primary factors: changes in climate and vegetation, which in turn led to the radiation of large ungulate prey species across Asia (Karanth 2001).

The late arrival of the tiger in the Indian sub-continent is apparently supported by its absence in Sri Lanka, which was cut off by rising sea levels at the beginning of the Holocene (Kitchener 1999). Tigers had colonised this area either coming through north-east Asia via central Asia (Hemmer 1987, Mazak 1981), or through north-west India (Heptner and Sludskii 1992).

Since the soil formation of the Sundarbans is of recent origin (Hussain and Acharya 1994), it is presumed that the tiger colonised there in the relatively recent past. The tiger might have been forced to colonise in the Sundarbans in the face of the rapid decline of the evergreen and deciduous forests of the Indian sub-continent.

1.3.2 Taxonomy

Linnaeus (1758) laid the foundation of the felid classification, as he did for most other groups of organisms. He first coined the generic name *Felis*, but the family name Felidae was given by Fischer (1817). Later on, Jardine (1834) made a significant contribution to the taxonomic relationships between the species in the family Felidae.

Severtzov (1857-1858) was the first person to begin the modern age of felid classification. His classification was based on felid evolution and biogeography. It includes 5 genera and 27 sub-genera. Most of the names used by Severtzov, whether newly coined by him or adopted from earlier authors, are still in use for felid taxa. In Severtzov's classification we see the seeds of a modern concept of Panthera in his genera *Panthera* and *Tigris* (Werdelin 1996).

The classification of the family Felidae, as well as the genus *Panthera*, by Wozencraft (1993) is the most recent evaluation, which has been adopted by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the World Conservation Monitoring Centre (WCMC), and the IUCN/SSC Cat Specialist Group. Wozencraft (1993) put four species under the genus *Panthera.* These are *P. tigris* (tiger), *P. leo* (lion), *P. pardus* (leopard) and *P. onca* (jaguar).

The species *Panthera tigris* has again been divided into eight distinctive sub-species, which apparently vary in body size, characteristics of the skull, and colour and markings of the pelage (Mazak 1981, 1996; Herrington 1987, Nowell and Jackson 1996). The definition of a sub-species is recently given as a label for a local geographical variant to represent a morphologically- and genetically-distinct sub-population, which has evolved in isolation, but which may subsequently hybridise with neighbouring populations to a limited extent (Corbet 1970, 1997; Mayr and Ashlock 1991, O'Brien and Mayr 1991). The advent of molecular techniques has shown that there is often a real discrepancy between traditionally-recognised sub-species and genetically-distinct populations (Kitchener 1999).

Other than Linnaeus' (1758) type description of *P. t. tigris*, which is not supported by a specimen, the first accepted tiger sub-species dates to 1815, when the Caspian tiger (*P. t. virgata*) was described (Illiger 1815). Later on, Temminck (1844) described the Amur tiger (*P. t. altaica*) and the Javan tiger (*P. t. sondaica*). Thus, four of the today's accepted tiger sub-species were described by the middle of the nineteenth century, three others (*P. t. amoyensis*, *P. t. balica* and *P. t. sumatrae*) in the early twentieth century (Hilzheimer 1905, Schwarz 1912, Pocock 1929) and the last one (*P. t. corbetti*) was described in the 1960s (Mazak 1968). Herrington (1987) noted, however, that there is considerable overlap of *P. t. tigris* and *P. t. corbetti*, and some overlap of *P. t. corbetti* and *P. t. sumatrae.*

At present there are about 160 distinct and fragmented populations of tigers, which have been designated as Tiger Conservation Units (TCUs) by Dinerstein *et al.* (1997). There are three main sources of variation that can be observed in tigers: body size, stripe patterns and colour of the pelage, and skull characteristics (Kitchener 1999). Authors often point out the wide variation in coat colour and markings within the populations (e.g. Pocock 1929, Brongersma 1935, Weigel 1961, Mazak 1967, Schroeter 1981, Heptner and Sludskii 1992). According to Hooijer (1947), most variation in tigers is clinal.

1.3.3 Distribution

1.3.3.1 Global Distribution

At present, the tiger is found only in southern, south-eastern and eastern parts of Asia. The geographic distribution of the tiger once extended across Asia from eastern Turkey to the Sea of Okhotsk, but its range has been greatly reduced in recent times. Now tigers survive only in scattered populations from India to Vietnam, and in Sumatra, China, and the Russian Far East (Figure 1.1) (Nowell and Jackson 1996).

According to Nowell and Jackson (1996), the distributions of the eight sub-species are as follows –

1. Bengal tiger (*P. t. tigris*): Indian sub-continent.
2. Caspian tiger (*P. t. virgata*): formerly in Turkey through central and west Asia (extinct).

3. Amur tiger (*P. t. altaica*): Amur river region of Russia and China, and North Korea.
4. Javan tiger (*P. t. sondaica*): formerly in Java, Indonesia (extinct).
5. South China tiger (*P. t. amoyensis*): South-central China.
6. Bali tiger (*P. t. balica*): formerly in Bali, Indonesia (extinct).
7. Sumatran tiger (*P. t. sumatrae*): Sumatra, Indonesia.
8. Indo-Chinese tiger (*P. t. corbetti*): continental South-east Asia.

In all range states, the latest tiger sightings have been confirmed in 158 protected areas, except North Korea (Table 1.2). These protected areas range in size from Xiaolingzhi at 21 km^2 in China to Kerinci Seblat in Indonesia at 14,846 km^2. Many of these protected areas are isolated forest patches, where the tiger has little chance for long-term survival (WWF 1999).

Table 1.2 Number of protected areas in different tiger range states where the presence of tigers have been recorded (Source: WWF 1999)

Country	**No. protected areas where tigers present**
Bangladesh	3 (all in the Sundarbans)
Bhutan	4
China	21
India	66
Indonesia	7
Laos (proposed PAs)	16
Malaysia	13
Myanmar	1
Nepal	4
Russia	4
Thailand	14
Vietnam	11
Total	**158**

1.3.3.2 Distribution in Bangladesh

The Bengal tiger was once found in all the forests and even in some village groves of Bangladesh. According to Mitra (1957), tigers were present in 11 of the 17 civil districts of the eastern Bengal (now Bangladesh) until 1930s. At that time the tiger was treated as a pest and the Government used to pay rewards for killing them (Prater 1940). Tigers were hunted from the deciduous forests of central and north-western Bangladesh, and from the mixed-evergreen forests of the north-east and south-east even during the 1950s-1960s (Husain 1981, Ahmed 1981; Khan 1986a, 1987; Mawla 1996, Khan and Islam 1999, Bangladesh Forest Department 2000a, Khan 2004a). The last tiger hunted or sighted in the deciduous forests of the Madhupur Tract in the central Bangladesh was in 1963 (Madhupur in 1963 and Sandhanpur in 1952) and Greater Rangpur (north-west) in 1962 (Banglabandha in 1962, Madhyapara in 1960 and Boda in 1950); in the mixed-evergreen forests of Greater Chittagong and Chittagong Hill Tracts (south-east) in 1984 (Kassalong in 1984, Mainimukh in 1979, Ramgarh in 1960 and Najirhat in 1950) and in Greater Sylhet (north-east) in 1985 (Patharia hill in 1985 and Srimangal in 1962); in the Sundarbans mangrove forest (south-west) tigers had a wider distribution (Khan 2004a) (Figure 1.2). At present, the only stable population of the tiger is found in the Sundarbans, but there are vagrant tigers in mixed-evergreen forests in Sangu-Matamuhuri valley and Kassalong-Sajek valley (south-east) (Figure 1.2). According to MacKinnon and MacKinnon (1986), tigers may still occur in Teknaf, located in the extreme south-eastern tip of the country bordering Myanmar (Burma).

It was found that the density of the tiger in the Sundarbans varies from north to south, following the density of its prey. Based on the relative abundance of pugmarks, the highest density of the tiger was recorded in the southern Sundarbans characterised by having the mosaic of forests and grasslands (Khan 2004a, 2004c). The grassland pockets are ideal habitats for the prey, and thus provide higher carrying capacity for the tiger.

Wikramanayake *et al.* (1999) classified the Sundarbans and Sangu-Matamuhuri valley as Level I Tiger Conservation Unit (TCU), i.e. these habitats offer the highest probability of persistence of tiger population over the long term. Moreover, Kassalong-Sajek valley has been classified as Level III TCU, i.e. this habitat offers low probability of persistence of tiger population over the long term due to its small size, isolation from other habitat blocks containing tigers, and fragmentation within its representative major habitat type.

(**Figure 1.1** Global distribution of the tiger in ca. 1800 and ca. 2000 → import from Maps and Illustrations folder.)

(**Figure 1.2** Tiger distribution in Bangladesh in ca. 1950 and ca. 2000 → import from Maps and Illustrations folder.)

1.3.4 Population Density

1.3.4.1 Global Population Density

Counting tigers is difficult because they normally live secretively in the dense forests. Pugmarks (footprints), scratches on trees, calls, and occasional sightings are often the only indication of their presence (WWF 1999). Different estimates in different parts of the tiger ranges indicate that the world population of living tigers is 5,000-7,000, of which two-thirds are Bengal tigers in the Indian sub-continent (WWF 1999) (Table 1.3).

Tiger ranges vary in accordance with prey densities. While females need ranges suitable for raising cubs, males seek access to females and have larger ranges (Nowell and Jackson 1996). Thus, in areas rich in prey throughout the year, such as Nepal's Royal Chitwan National Park (NP) and India's Kanha NP, female ranges of 10-39 km^2 and male ranges of 30-105 km^2 have been recorded (Sunquist 1981), while in the Russian Far East, where prey is unevenly distributed and moves seasonally, ranges are as large as 100-400 km^2 for females and 800-1,000 km^2 for males (Matjuschkin *et al.* 1980). Bragin (1986) estimated tiger density at 1.3-8.6/1,000 km^2 in the Sikhote-Alin mountains of eastern Russia, while Karanth and Nichols' (1998) estimate shows that the densities of tigers more than one year old ranged from 4.1 ± 1.3 to 16.8 ± 3.0 tigers/100 km^2 in Indian habitats. The density of tigers in different areas is given in Table 1.4.

The home of the Bengal tiger is the Indian sub-continent (India, Bangladesh, Nepal and Bhutan), but they are also found in China (Tibet) and western Myanmar. India's 2,500-3,750 tigers are found in 66 protected areas, of which 23 are specifically tiger reserves forming part of the Project Tiger network, but the population has been scattered into well over one hundred isolated units, which, in many cases too inbred to maintain a vital population, are dying out ever more rapidly (Matthiessen 2000). The Sundarbans mangrove forest of Bangladesh and India and the Russian Far East are the two areas in the world having the largest surviving single populations of the tiger (WWF 1999).

Table 1.3 Status of the tiger in 1999 (Source: WWF 1999)

Tiger sub-species	Population		References
	Minimum	Maximum	
Bengal (Indian) tiger *P. t. tigris* (Linnaeus 1758)	**3,176**	**4,556**	**-**
Bangladesh	362	362	Jalil 1998
*Bhutan	67 (adults)	81 (adults)	McDougal and Tshering 1998
China	30	35	Wei 1998
India	2,500	3,750	V. Thapar 1994 (pers. comm. by P. Jackson), Project Tiger 1993
Myanmar, western	124	231	Uga and Thang 1998
*Nepal	93 (adults)	97 (adults)	Govt. of the Kingdom of Nepal 1997
Caspian (Turan/Hyrcanian) tiger *P. t. virgata* (Illiger 1815)	**Extinct 1970s**	**-**	**-**
Formerly Afghanistan, Iran, Chinese and Russian Turkestan, Turkey			
Amur (Siberian/Ussuri/ Manchurian/North-east China) tiger *P. t. altaica* (Temminck 1844)	**360**	**406**	**-**
China	30	35	Wei 1998
Korea (North)	<10	<10	P. U-Il 1994 (in litt.)
*Russia	330 (adults)	371 (adults)	Matyushkin *et al.* 1996
Javan tiger *P. t. sondaica* (Temminck 1844)	**Extinct 1980s**	**-**	**-**
Formerly Java, Indonesia			
South China (Amoy) tiger *P. t. amoyensis* (Hilzheimer 1905)	**20**	**30**	Wei 1998
China			
Bali tiger *P. t. balica* (Schwarz 1912)	**Extinct 1940s**	**-**	**-**
Formerly Bali, Indonesia			
Sumatran tiger *P. t. sumatrae* Pocock 1929	**400**	**500**	Wartaputra *et al.* 1994
Sumatra, Indonesia			
Indo-Chinese tiger *P. t. corbetti* Mazak 1968	**1,227**	**1,785**	**-**
Cambodia	150	300	Samith *et al.* 1995
China	30	40	Wei 1998
Laos	Present	-	-
Malaysia	491	510	Abdul 1998
Myanmar, eastern	106	234	Uga and Thang 1998
Thailand	250	501	Rabinowitz 1993, Govt. of the Kingdom of Thailand 1999
Vietnam	200	200	Bao *et al.* 1995
Totals	**5,183**	**7,277**	**-**
Rounded totals	**5,000**	**7,000**	**-**

***Figures for Bhutan, Nepal and Russia are for adult tigers counted. Tiger specialists consider such figures more realistic because many cubs are unlikely to survive to maturity.**

Table 1.4 Population density of tigers in different areas

Habitat	Tiger density (no. tigers/ 100 km^2)	Method	Reference
Kanha, India	6.8	Radio-tracking	Schaller 1967
Kanha, India	15.6	Camera-trapping	Karanth and Nichols 1998
Nagarhole, India	13.3-14.7	Camera-trapping	Karanth 1995
Nagarhole, India	15.3	Camera-trapping	Karanth and Nichols 1998
Nagarhole, India	11.9	Camera-trapping	Karanth and Nichols 2000
Kaziranga, India	22.4	Camera-trapping	Karanth and Nichols 1998
Kaziranga, India	16.8	Camera-trapping	Karanth and Nichols 2000
Kanha, India	11.7	Camera-trapping	Karanth and Nichols 2000
Bandipur, India	12.0	Camera-trapping	Karanth and Nichols 2000
Bhadra, India	3.4	Camera-trapping	Karanth and Nichols 2000
Pench, India	4.9	Camera-trapping	Karanth and Nichols 2000
Ranthambhore, India	8.2	Camera-trapping	Karanth and Nichols 2000
Sundarbans, India	0.8	Camera-trapping	Karanth and Nichols 2000
Chitwan, Nepal	5.8	Radio-tracking	Sunquist 1981
Chitwan, Nepal	2.7-7.1	Radio-tracking	Smith *et al.* (1999a)
Sundarbans, Bangladesh	10 (arbitrary)	Information of tiger sightings by forest officials and local people	Hendrichs 1975
Sundarbans East, Bangladesh	4.3	Based on the carrying capacity calculated from prey density	This study
Tiger habitats in Thailand	1 (arbitrary)	Sign survey	Rabinowitz 1993
Huai Kha Kheang, Thailand	0.5-1.4	Based on GIS of potential tiger habitats	Smith *et al.* 1999b
Way Kambas, Indonesia	4.3	Camera-trapping	Franklin *et al.* 1999
Kerinci Seblat, Indonesia	21.1	Camera-trapping	M. Linkie pers. comm. 2000
Sikhote-Alin, Russia	1.3-8.6	Track count on the snow	Bragin 1986
Sikhote-Alin, Russia	0.3-0.6	Track count on the snow	Smirnov and Miquelle 1999

The tiger population estimates for India are derived from the demonstrably failure-prone and invalidated (Karanth 1987, 1988, 1993a, 1993b) 'pugmark census' method (Panwar 1979, Das and Sanyal 1995, Singh 1999) or its variants (Gore *et al.* 1993). Consequently, the resulting tiger population estimates do not appear to be meaningful in the light of what is known about the tiger ecology (Schaller 1967, Sunquist 1981, Smith *et al.* 1987a, Karanth 1993b). Although methodically better, the snow-track counts used by the Russian scientists also have problems that may result in undercounts

(E.N. Smirnov and D.J. Miquelle unpubl. ms.). In Nepal's Royal Chitwan NP, counts of long-term resident tigers are made by experienced naturalists from individual identification of tracks, based primarily on injury-related differences (McDougal 1977). Smallwood and Fitzhugh (1995), as well as Grigione *et al.* (1999), however, claimed that it is possible to identify individual pumas (*Puma concolor*) by the tracks.

Regarding reliable tiger density estimation, Smith *et al.* (1987b) was the first, synthesising prior information on tiger densities derived from radio-telemetry in Chitwan, Nepal, with assessments of habitat quality and prey abundance, using a GIS approach. Karanth (1995) pioneered the application of capture-recapture models for estimating tiger numbers in India from camera-trap data. This method is considered as more reliable than pugmark census. He placed the camera-traps along regular travel routes of tigers and obtained photographic 'captures' of individual tigers during the sampling occasions. He analysed capture history data in the conceptual framework of capture-recapture theory, using probabilistic models. Griffiths (1993) derived rough home-range size estimates for some tigers in Gunung Leuser NP, Indonesia, from camera-trap photos. Rabinowitz (1993) assessed tiger populations in Thailand by combining subjective categorisations of habitat quality with arbitrarily assumed tiger densities. Most other tiger estimates (e.g. Seal *et al.* 1987, Jackson 1993) are based largely on unsubstantiated guesswork (Karanth 1995).

1.3.4.2 Population Density in Bangladesh

Even a few hundred years ago, the forests of former Bengal (which is now Bangladesh and part of north-east India) were teeming with tigers. One George U. Yule of the Bengal Civil Service killed 400 tigers in 25 years in Bengal, after which, although he continued to shoot, he did not think it worthwhile to continue recording them. Since the Government used to pay a bounty for tiger killing, the 'Pariah' people of the hill tribes of Bengal took up tiger killing as a profession (Sankhala 1978a).

The tiger is nationally categorised as a Critically Endangered species (IUCN-Bangladesh 2000). There is no work on the home range size of the tiger in Bangladesh, but Hendrichs (1975) felt that tigers were fairly evenly distributed throughout the Sundarbans at a density of about 1/10 km^2, but subsequent studies (e.g. Sarker 1982) have suggested that there may be a density gradient, numbers being highest (1/12.6

km^2) in the south and lowest in the north. Some scattered surveys have taken place on the tiger population in the Bangladesh Sundarbans (Hendrichs 1975; Bangladesh Forest Department and Department of Zoology, University of Dhaka, 1982; Bangladesh Forest Department 1992, 2004; Tamang 1993). Most of these estimates, or 'guesstimates', of the tiger population so far made in the Bangladesh Sundarbans are based on sample counts of pugmarks and interviewing. Since these methods are questionable, these estimates do not reflect the actual number of tigers. Seidensticker (1987a) pointed out that there has never been any census with reasonable confidence limits to tell us how many tigers actually live in the Sundarbans. Nevertheless, using Sunquist's (1981) crude density estimate of one adult tiger/40 km^2 in Nepal's Royal Chitwan NP, Seidensticker (1987a) believes that there is indeed room for about 250 adults to live in the entire Sundarbans of Bangladesh and India. According to the estimates conducted a few years ago, there are 362 tigers in the Bangladesh Sundarbans (Tamang 1993, Jalil 1998) and 263 in the Indian Sundarbans (Government of West Bengal 2001). These are the two figures officially used in Bangladesh and India. Based on the most recent pugmark census, simultaneously done in both parts of the Sundarbans, the rough estimates are 500 tigers for the Bangladesh Sundarbans (Bangladesh Forest Department 2004) and 250-300 for the Indian Sundarbans (Forest Department of West Bengal 2004). This broke all the previous records of over-estimate.

1.3.5 Morphology

The tiger has dark reddish-ochre to pale yellow body colour with vertically-arranged black stripes, more pronounced towards the rump and thighs; underparts whitish. Young are born with stripes. Yellow tail has a series of black rings, ending in a black tip. Back side of the ears black with a clearly visible white spot. Pupil of the eyes is rounded. Claws retractile. Head-body length 140-280 cm and the tail length 60-110 cm; height at the shoulder 95-110 cm. Male weigh 180-280 kg and female 115-185 kg (IUCN-Bangladesh 2000). The heaviest Bengal tiger on record was a male that weighed 258.2 kg.

There are three main sources of variation that can be observed in tigers: body size, stripe patterns and colour of the pelage, and skull characters (Kitchener 1999). It is known that the largest tigers occur in the Russian Far East and the smallest are in the Sunda Islands (Hooijer 1947, Mazak 1996, Kitchener 1999). Kitchener's (1999) analysis shows that size and sexual dimorphism increases with latitude as indicated by the skull and tooth measurements.

The background colour of the tiger's pelage varies from a dark reddish-ochre to a pale yellow (Pocock 1929, Brongersma 1935; Mazak 1981, 1996). This seems to be related to the habitat and/or humidity (i.e. Gloger's Rule; Ortolani and Caro 1996). The tiger in South-east Asia is darker than the Amur tiger (Pocock 1929, Mazak 1967). No two tigers have the same markings (Sunquist and Sunquist 1989). The stripe patterns differ between individual tigers and from one side of the body to the other in the same individual. The stripes vary in number as well as in width (Nowell and Jackson 1996). Males have a prominent ruff, which is especially marked in the Sumatran tiger (Nowell and Jackson 1996). In the wild, even in semi-open habitats, the striped coat seems to break up the body outline, and the cat almost fades from view (Sunquist and Sunquist 2002).

There is evidence that white tigers have existed in the wild, at least in South Asia. There are a number of old records of shooting white tigers in different parts of India, Nepal and Myanmar (Pollock and Thom 1900, Sankhala 1978a). A white male tiger cub, caught in central India in 1951, was the last record. This white tiger, named Mohan, became the progenitor of most of the white tigers now in captivity. White tigers have brown stripes on an off-white background and ice-blue eyes (Maruska *et al.* 1987, Nowell and Jackson 1996). These are not albinos, but resulted from a mutation that occurred about a hundred years ago (Thorton *et al.* 1967, Thorton 1978, Roychoudhury 1978, Roychoudhury and Sankhala 1979).

Black tigers have also been reported occasionally (Pocock 1929, Burton 1933, Perry 1964, Guggisberg 1975, Mazak 1981). Pocock (1929) lists three records of black tigers, all of which are reported from the same general area of Myanmar, north-eastern India and Bangladesh, within 600 km of each other. A tiger skin was recovered from the illegal traders in Delhi, India, in October 1992, with deep black on the top of the head and back extending down the flanks to end in stripes (Nowell and Jackson 1996), but this was not a true melanism, which is found in leopards, jaguars, and many other cat species; it may be an expression of the agouti gene, which causes the merging of stripes (L. Lyons in litt. 1993).

The fur of the Amur tiger (as well as the extinct Caspian tiger) differs sharply in winter and summer. Paler, or more ochraceous, long, dense hairs are grown in winter (Heptner and Sludskii 1972).

1.3.6 Biology

Tigers normally mate year-round, but most frequently from the end of November to early April (Mazak 1981). The breeding peak varies in different regions. The oestrus cycle is 15-61 days (Sadlier 1966; Sankhala 1967, 1978a; Smith 1978, Sunquist 1981). The average duration of oestrus is 5-7 days (Sunquist 1981, Sunquist and Sunquist 2002). Tigers copulate frequently (Sunquist and Sunquist 2002). A tigress' pregnancy lasts for about 103 days (Sankhala 1978a, Sunquist and Sunquist 1991, Kitchener 1991). Short before the birth, the tigress selects a secluded place to have her young. The birth den may be in a rock crevice or cave, an impenetrable thicket, or a shallow depression in dense grass (Sunquist and Sunquist 2002). The cubs are born blind and helpless, weighing 0.7-1.6 kg (Veselovsky 1967).

Mean litter size of the tiger is 3.0 (Smith and McDougal 1991), but observations of females with cubs indicate that 2-3 is the commonest (Sankhala 1978a). In Chitwan, Nepal, Smith and McDougal (1991) found first-year cub mortality to be 34% (n = 144 cubs), of which 73% was whole litter loss due to causes including infanticide, fire and floods. Overall, infanticide was found to be the commonest cause of cub death. It happens when the resident male (father of the cubs) is evicted by a new male who takes over all the females in its territory (few breeding females live inside one breeding male's territory) and kills the cubs in order to bring the female into oestrus.

Sunquist and Sunquist (2002) mentioned that tigresses are extremely cautious and secretive when they have young cubs, and will often move them to a new den if disturbed or threatened. Cubs do not begin to eat solid food until they are 6-8 weeks old, but they continue to suckle until 5-6 months. Cubs begin to follow their mother when they are about two months old, but do not join her in hunting. At four months of age the cub is about the size of a dog, and spends the time mainly playing. They grow rapidly, and males grow faster than females. Young tigers learn hunting by imitation and practice under the guidance of the mother. Both male and female tigers become independent from the mother when they are 18-28 months old (Smith 1984, Kerley *et al.* 2003). Young males disperse farther than females (on average 33 km and 9.7 km, respectively) (Smith 1984, 1993). This stage is very important, especially for males, when they might get into serious fights with other tigers and get killed.

The male becomes sexually mature at 3-4 years, whereas the female becomes sexually mature at about 3 years (Sankhala 1967, Smith 1984, Smith and McDougal 1991, Christie and Walter 2000, Sunquist and Sunquist 2002, Kerley *et al.* 2003). The female to male ratio of adult tigers may be as much as 2:1 to 4:1 depending upon habitat and food situation (Tamang 1993). Tigresses have a high reproductive potential, and normally give birth to a new litter every two years (Smith and McDougal 1991). The inter-birth interval is shorter when the tigress loses cubs, or after raising a single cub (Smith and McDougal 1991, Kerley *et al.* 2003). Smith and McDougal (1991) did extensive long-term monitoring of the tiger population in Chitwan, Nepal, and presented pioneering data on the lifetime reproduction of tigers. They found the average reproductive life span of tigers in Chitwan to be 6.1 years for females, and just 2.8 years for males. For females, the mean number of offspring surviving to dispersal was 4.5, and the average number of offspring eventually incorporated into the breeding population was just 2.0. For males, on the other hand, an average of 5.8 of their offspring survived to dispersal, and 2.0 were incorporated into the breeding population.

Although captive tigers have lived up to 26 years (Jones 1977), the maximum life expectancy for wild tigers may be around 20 years (Schaller 1967, Sankhala 1978a). The oldest known tigress in the wild was in Nepal and was killed when she was at least 15.5 years old (McDougal 1991).

1.3.7 Ecology and Behaviour

The ecology of the tiger varies in different sub-species, as well as in different habitats. The tiger is found in a variety of habitats: from tropical evergreen and deciduous forests of southern Asia to the coniferous, scrub oak, and birch woodlands of the Russian Far East. It also thrives in the mangrove swamps of the Sundarbans, dry thorn forests of north-western India, and the tall grass jungles at the foot of the Himalayas

(Nowell and Jackson 1996). Prater (1971) reported the tracks of tiger in the winter snow at 3,000 m altitude in the Himalayas. In recent years, however, the tiger has been reported to about 4,000 m altitude in the mountains of Bhutan and south-eastern Tibet (Matthiessen 2000). The extinct Caspian tiger frequented seasonally-flooded riverine land consisting of trees, shrubs, and dense stands of tall reeds and grasses up to six metres in height. When hunting in these reed thickets, tigers sometimes reared up on their hind legs or leaped upward in order to see their surroundings (Heptner and Sludskii 1972). The basic habitat requirements of the tiger are: 1) some form of dense vegetation cover, 2) sufficient large ungulate prey, and 3) access to water (Sunquist and Sunquist 1989, Nowell and Jackson 1996).

Tigers are adapted to a wide range of environments (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993) through a social organisation that permits considerable behavioural plasticity (Sunquist 1981, Smith *et al.* 1987a, Smith 1993). Today, wild tigers inhabit less than 5% of the 1.5 million km^2 of forest habitat available (Karanth 2001), because the lack of prey base and anthropogenic disturbances do not permit existence of wild tigers in most of the forested areas. Based on their studies of the prey selection in Nagarhole, India, Karanth and Sunquist (1995) suggested that the ecological densities of tigers and other sympatric predators may be governed primarily by how their prey community is structured, in terms of abundance of different size classes. According to their predictions, where tigers and leopards occur sympatrically, if both large and medium-sized prey are abundant, tigers would select large prey enabling the coexistence of leopards at high densities. Where large prey are scarce, tigers would switch to medium-sized prey and reduce leopard densities through competition, as hypothesised for Chitwan, Nepal (Seidensticker *et al.* 1990). On the other hand, if both large and medium-sized prey are scarce, leopards would be relatively more abundant because of their ability to survive on smaller prey, as recorded in Huai Kha Khaeng, Thailand (Rabinowitz 1989). A number of studies on the prey and prey selection by tigers have established the fact that tigers normally prefer large ungulates, but availability also plays an important role (Schaller 1967, Johnsingh 1983, Seidensticker 1986, Seidensticker and McDougal 1993, Karanth and Sunquist 1995, Miquelle *et al.* 1999, Tamang 1993, this study).

Tigers are usually solitary and territorial animals, except for females with cubs, but they are not anti-social (Nowell and Jackson 1996, Sunquist and Sunquist 2002). Males associate with females for breeding and have been observed with females and cubs when feeding or resting (Schaller 1967, McDougal 1977, Sankhala 1978a, Sunquist 1981; Thapar 1986, 1989). Bragin (1986) quoted reports of tigers socialising and travelling in groups. Wright (1989) reported that a mature male in Kanha, India, was greeted by a female and cubs and by a sub-adult male, thought to be from a previous litter, and they moved away together.

In many parts of their range tigers have become totally nocturnal in response to human activities, but where they are undisturbed, they can be found at any time of the day or night (Thapar 1992, Sunquist and Sunquist 2002). Tigers are probably most active between 1900-2400 h and 0300-0600 h in the Sundarbans (M.M.H. Khan pers. obs.); they prefer to avoid people and generally give them a wide berth. Even when provoked or approached, they will normally give a warning growl and allow the intruder to back off (Corbett 1957, Sunquist and Sunquist 2002). The tiger depends far more on hearing than on scent or sight, especially in closed forests where visibility is poor (Sankhala 1978a).

The tiger makes a stealthy approach using every available tree, rock, or bush as cover to get as close as possible to its target before it launches its attack (Sunquist and Sunquist 2002). Based on the food abundance tigers travel 7-32 km/night (Schaller 1967, Sunquist 1981). According to Sankhala (1978a), however, the tiger is a wanderer and apparently wanders with no definite plan in mind. They prey mainly on various species of deer and boar throughout their range, but Karanth and Sunquist (1992) state that in India's Nagarhole NP, gaurs (*Bos frontalis*) are the main prey, including bulls weighing up to 1,000 kg. It has been reported that tigers will also attack young elephants (*Elephas maximus*) and rhinos (*Rhinoceros unicornis*), and take smaller species like monkeys, birds, reptiles and fish (Nowell and Jackson 1996). According to Heptner and Sludskii (1972), tigers sometimes kill and eat leopards and their own kind, as well as other carnivores, including bears, weighing up to 170 kg, which they have attacked in their winter dens. Tigers kill animals from a broad range of age classes, not just the old or the very young (Sunquist and Sunquist 2002). Moreover, they readily eat carrion (Schaller 1967).

According to Nowell and Jackson (1996), tigers usually attack large prey with a stalk from the rear, ending with a rush and, sometimes, a spring to bring down the prey. When seizing and killing the prey, the tiger's main target is the neck, either nape or throat. The part seized depends on several factors, such as the size of the prey; the size of the tiger; whether the attack is from front, rear or side; and the reactive movements of the prey. Attack and killing methods of tigers are described elsewhere (Brander 1923, Champion 1927, Burton 1933, Corbett 1957, Schaller 1967, McDougal 1977, Thapar 1986, Karanth 1993c, Sankhala 1993, Seidensticker and McDougal 1993). Schaller (1967) noted that adult tigers appeared to be very cautious, and attacked the prey only when the danger of injury was minimal. He also reported that a tiger characteristically grasps the throat after felling its prey, holding on until the animal dies from suffocation. The throat hold protects the tiger from horns, antlers, and hooves and prevents the prey from regaining its feet. Sankhala (1993) reported that tigers prefer to bite the back of the neck, as close as possible to the skull, killing the victim by fracturing the vertebrae and compressing the spinal cord, but larger animals are generally killed with a throat bite. Karanth (1993c) examined 181 tiger kills and found that most large prey, such as sambar (*Cervus unicolor*) and gaur, were killed by throat bites. The prey is then usually dragged into cover (Sunquist and Sunquist 2002). They can drag or even lift kills, but never load on their back as some local people in the Sundarbans believe. Sankhala (1978a) mentioned the dragging of a buffalo calf for a distance of 300 m, but in the Sundarbans human kills are sometimes dragged as far as 8 km (this study). Pocock (1939) cited an example in Myanmar (Burma) of a tiger dragging the carcass of a gaur that 13 men could not move. Tigers normally do not hunt in the water, but in India's Ranthambore Tiger Reserve, V. Thapar (unpubl. data) observed tigers charging into the lakes to kill sambar, where both animals were momentarily submerged. He also observed crocodiles killed and eaten by tigers there.

Communal hunting has been observed in tigers. Pocock (1939) mentioned that couples and family groups hunted together. Thapar (1986) reported that a group of two males and three females, possibly a family, behaved like lions, taking up positions round a lake where deer congregated and driving a target animal from one to the other. Corbett (1954) mentioned the villagers' reports of two tigers, attacking in concert, killing a large tusker elephant.

Although lions and leopards also kill humans, tigers have the greatest reputation as man-eaters (Nowell and Jackson 1996). The Champawat tiger is said to have killed 434 people in Nepal and India before it was shot (Corbett 1954). Many deaths, however, arise from accidental confrontations, in which the tiger makes a defensive attack (Nowell and Jackson 1996). Corbett (1957) believed that only injured or old tigers turn into man-eaters and the changeover from animal to human flesh is, in most cases, accidental.

With greatly-reduced numbers of tigers in recent times, the attacks on people have been relatively rare, except in the Sundarbans mangrove forest in Bangladesh and India, where most victims were fishermen, wood-cutters, and honey gatherers entering the reserve (Nowell and Jackson 1996). Jackson (1991) reported that the Sundarbans tigers have taken people out of boats. The management measures, however, including the use of human face-masks on the back of the head to deter tigers (which usually attack from the rear), are thought to be reducing the toll (Rishi 1988, P. Sanyal unpubl. data 1990).

Tigers take their prey into cover before beginning to eat. A tiger normally eats 18-40 kg of meat at a time (Baikov 1925, Locke 1954, Schaller 1967) beginning from the rump. Tigers need about 3,000 kg of meat on average (or about 50 ungulates) every year (Schaller 1967, Sunquist 1981, Tamang 1982, Sunquist *et al.* 1999). Karanth (1993c) reported that, if undisturbed, a tiger returns to its kill for 3-6 days to feed until little remains. Large prey is taken about once a week (Nowell and Jackson 1996). Sunquist (1981) estimated frequency of killing by females without cubs at once every 8-8.5 days in Chitwan, Nepal. Although highly skilled hunters, tigers are often unsuccessful (Nowell and Jackson 1996). They do not normally pursue the prey after a failing attack, but Rice (1986) once observed a tiger pursue a wounded sambar for more than two kilometres for over two hours in southern India. Schaller (1967) observed 12 complete stalks, of which only one was successful, and he suggested that probably only one attack in 20 attacks succeeded. Only one in 10 attacks is successful in Ranthambhore, India (V. Thapar unpubl. data, Nowell and Jackson 1996). Tigers crop about 10% of the available prey biomass, suggesting that about 500 ungulates are required to sustain one tiger in the wild (Karanth 2001). Tiger predation does not generally appear to limit prey numbers over the long term (Sunquist and Sunquist 2002).

Unlike many other cat species, tigers readily enter water. During hot seasons they like to lie half-submerged in the lakes and ponds. In the Ganges-Brahmaputra mangrove delta region of the Sundarbans, they constantly swim creeks and across broad rivers (Nowell and Jackson 1996). In the Indian Sundarbans, tigers are known to swim a distance of over 10 km (Chaudhuri and Choudhury 1994). In the Sundarbans East WS, Bangladesh, I have recorded a tiger swim across a 3-km-wide estuary and another crossed a 0.5-km-wide river. According to Karanth (2001), tigers are capable of crossing water bodies as wide as 8 km.

The social system of the tiger is maintained through a combination of visual signals, scent marks, and voice. While some signals and advertisements (pheromones, male-female calls, etc.) to bring tigers together, others serve to maintain spatial separation (Sunquist and Sunquist 2002). However, it is controversial whether the tiger itself has any odour (Sankhala 1978a). In the Sundarbans, I had close encounters with tigers, but could not get any odour, except once, an odour between rotten meat and cooked 'basmati' rice, but it was probably from the rotten kill that the tiger had with it (see Appendix V). The smell might remain with the tiger for a while, even after leaving the kill. Loud calls or roars of the tiger are used for communication, which can carry as far as 5 km through the silence of the night. Such long-distance calls are used both by female tigers in oestrus and males searching for them (Karanth 2001).

Tigers rarely climb trees, although they can and will, especially if provoked (Sunquist and Sunquist 2002). In the Bangladesh Sundarbans during the floods of 1969 many tigers reportedly escaped the high water by climbing into trees (Mountfort 1973). Tiger jumps as far as 8-10 m have been recorded, but leaps covering half that distance are more typical (Guggisberg 1975, Mazak 1981). Based on pugmarks, I have recorded the longest leap of 2.1 m in the Sundarbans.

1.3.8 Threats

The tiger has been used as a charismatic flagship species in the efforts to protect overall biodiversity in several Asian countries (Karanth 1995). Despite this, the threats to its survival appear to have increased in recent years due to widespread over-hunting of its prey (Karanth 1991, Rabinowitz 1991), poaching of tigers for commercial reasons (Jackson 1993, Rabinowitz 1993), and from habitat destruction (Seidensticker 1986), combined with slackening protection efforts for socio-political reasons (Ghosh 1993). Habitat loss, as well as habitat degradation and fragmentation, is the main cause of the decline of the large cats, including the tiger, with illegal killing playing an increasingly damaging role as tigers have become more vulnerable (WWF 1999). Habitat loss remains a grave danger for the tiger, particularly in South and South-east Asia, while illegal killing is considered as the immediate threat, which hastens extinction (WWF 1999). According to Nyhus and Tilson (2004), however, the four main reasons for the tiger's decline are: 1) reduced, degraded and fragmented habitat, 2) diminished prey populations, 3) killing of animals for the illegal trade in tiger parts (Dinerstein *et al.* 1997, Seidensticker 1997, Hemley and Mills 1999, Karanth and Stith 1999), and 4) persecution by humans in response to real or perceived livestock predation and attacks on people (McDougal 1987, Nowell and Jackson 1996, Tilson *et al.* 2000). Throughout the global range, tiger population sizes are estimated to vary from less than 20 to less than 200 breeding animals (Jackson 1993), which makes the populations vulnerable to stochastic genetic, demographic, and ecological events (Shaffer 1981, Frankel and Solue 1981). In Bangladesh, indiscriminate hunting of the tiger and its prey together with habitat loss caused the extirpation of the tiger from the deciduous and mixed-evergreen forests, but in the Sundarbans the main threat to the tiger is the poaching of its prey (M.M.H. Khan unpubl. data). The major threats facing by the tiger throughout its global range, as pointed out by WWF (1999), are as follows –

1.3.8.1 Illegal Hunting and Poaching

Poaching of tigers for the oriental medicine trade is widely perceived as the chief causal factor driving the current decline of tigers (WWF 1999). In 1997, a comprehensive assessment of potential tiger habitat ranked over 85% as subject to moderate-to-high poaching pressure (Dinerstein *et al.* 1997). Kenny *et al.* (1995) used a model of a tiger population in Nepal to argue that, in the long term, tigers are at high risk of extinction from poaching, but there is empirical evidence that hunting mortalities among big cats may not depress their densities, if hunters remove less than 10-25% of the total population annually (Lindzey *et al.* 1992, Lindzey *et al.* 1994). Martin and de Meulenaer (1988) argue that hunting can drive big cat populations into rapid extinction, only if it exceeds threshold levels set by habitat quality and reproductive potential of the species. The magnificent striped skin of the tiger has been in great demand for wall hangings, coats, etc. from long ago. Blower (1985) mentioned that he saw tiger skins in several different tourist shops in Dhaka, Bangladesh; all of which have said to come from the Sundarbans, and the price was about US $ 1,200 for each.

The bounty causes its death in many parts of its range through illegal hunting. By the middle of the 20th century, many wild creatures in China, including the tiger, had been declared pests. Hunters were encouraged to kill tigers and were paid a bounty for each one. For the forest communities a price had been put on the head of their God (Thapar 1996). Previously tigers were hunted mainly for the skin, but in the late 1980s, bones and other parts became the principal target to meet the demand for medicinal use not only in eastern Asia (primarily China, Taiwan, and South Korea), but also in South-east Asia (WWF 1999). Historically, in India, tiger fat has been used as a home remedy for leprosy and rheumatism (Vijan and Gurunathan 1994). Seizure of illegally-killed tigers is now common in India, with perhaps 200-400 being killed annually to supply the traditional Asian medicine trade (Karanth and Madhusudan 1997).

In Chinese medicine, every part of the tiger's body played a role in the treatment of human illness (Thapar 1996). In 1991 Chinese authorities have disclosed that exports of tiger bone medicines included 15,079 cartons of tablets, 5,250 kg of liquid medicines, and 31,500 bottles of wine, but the best data come from South Korea where the imports were legal up to 1993. Between 1975 and 1992, over six tonnes of tiger bones were imported which represents the equivalent of 550-1,000 tigers (using dried bone weights of 10-12 kg per tiger) (WWF 1999). The prices over the 18-year period averaged US $ 127/kg of bones. Most of the exports of tiger parts were from Indonesia. Other listed suppliers (export/re-export) were China, Japan, Thailand, Malaysia, India, Singapore, and Taiwan (WWF 1999). Although the tiger skins are easily identifiable, few people can distinguish tiger bones from those of domestic animals. In most tiger habitats, there are too few guards, if any, to stop poaching.

To a small proportion of the humans living in and around the forests, killing tigers for their body parts yields a substantially greater income than live tigers roaming free (Damania *et al.* 2003). Nowell (2000) suggested that the retail value of an adult male tiger varies from US $ 15,000 to 20,000.

The impact of poaching is not restricted only to the actual animal killed. If it is a female with cubs, the cubs will die. If it is a male, there will be an intensive struggle among other males to take over the territory, during which cubs get killed and breeding is disrupted for a long period (WWF 1999). Plowden's (1997) findings show that, where no documentation of international tiger poaching to meet an international demand for tiger bones was recorded in Indonesia, the domestic demand for tiger bones, teeth and claws is still a potential threat to the future survival of the Sumatran sub-species. In Bangladesh, there is a good demand of tiger skins, but the demand for other parts is restricted only to the villages around the Sundarbans.

1.3.8.2 Prey Depletion

According to Karanth and Stith (1999), prey depletion is a critical determinant of tiger population viability. Even in areas of low-level poaching, tigers can survive provided their prey base is maintained at adequate levels (Karanth and Stith 1999). Although habitat shrinkage has been a historically well known factor responsible for tiger population declines (Schaller 1967, Mountfort 1981, Panwar 1987, Thapar 1992), but recent assessments (Wikramanayake *et al.* 1999) based on forest-cover maps show that extensive stretches of potentially suitable tiger habitats still exist in most range countries. In the Indian sub-continent alone, the potential tiger habitat is estimated to exceed 300,000 km^2 (Karanth and Stith 1999). Moreover, tigers are adapted to occur in a diverse range of tropical and temperate habitats (Sunquist 1981, Seidensticker and McDougal 1993). Across its global range, about 1,500,000 km^2 of habitat is potentially suitable for tigers, but they occupy a tiny fraction of the potential habitat available (Karanth 2001).

Earlier studies (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993) described qualitatively a positive correlation between tiger and prey densities. Recent studies (Karanth and Sunquist 1995, Miquelle *et al.* 1996, Karanth and Nichols 1998, Karanth *et al.* 2004) suggest that abundance of tigers and other similar predators are largely mediated by densities of different-sized ungulate prey. Ramakrishnan *et al.* (1999) worked on tiger decline caused by the reduction of large ungulate prey in southern India. Their findings supported that the reduction of grazing land causes the decline of the large ungulates, which finally leads to the decline of the tiger population.

Ample evidence endorses that over-hunting by humans has depressed the densities of ungulate prey over the tiger's range (Karanth 1991, Rabinowitz 1993, WCS 1995, Miquelle *et al.* 1996). When the effect of prey depletion is simulated, the carrying capacity for breeding females is depressed, cub survival is reduced and the tiger population size declines rapidly (Karanth and Stith 1999). Based on the above empirical evidence, Karanth and Stith (1999) proposed that prey depletion is a major factor for driving the current decline of wild tiger populations. Salter (1984) reported that the spotted deer is heavily poached in the Bangladesh Sundarbans for its meat, hide and antlers, which is a major threat to the existence of tigers in the Sundarbans.

1.3.8.3 Habitat Loss, Degradation and Fragmentation

The growth of the population increases the pressure on the land, as well as on the natural resources, which leads to the loss of habitats for large animals. In the tiger's range, some 2.9 billion people or 59% of the world's population live, causing a deforestation rate of 47,000 km^2/year (Thapar 1996). For a forest-dwelling animal like the tiger, the loss of natural forests is a major cause of their decline. Even 30 years ago Bangladesh had around 20% of the total land covered by natural forests, which has reduced to around 5% by this time. The rate of forest loss is very high in Bangladesh. The mangroves of the Sundarbans, the last remaining shelter of the tiger in Bangladesh, have been in a state of progressive deterioration since the 1970s (Saenger *et al.* 1983), but there has been no visible encroachment in the last 20 years (M.M.H. Khan unpubl. data). The current global range of the tiger extends through one of the world's most densely populated areas where the population-increasing rate is much higher than the average global rate. According to the World Resources Institute, the human numbers are rising at an average of 2% per annum, i.e. doubling in 37 years, in the tiger range countries except Thailand and China (WWF 1999). During the 25 years since Project Tiger began in 1973, the human population of India has increased by over 300 million, and livestock by over 100 million. In the past 30 years, Vietnam's population has doubled, making it one of the world's most densely-populated countries. It is second to another tiger range state, Bangladesh, in terms of farming population per hectare of cultivated land (WWF 1999). Tiger and other big cats have little future outside the protected areas because of the danger they present to the livestock and humans. Local people often poison or shot the tiger that stray out of reserves and attack livestock and people (WWF 1999). However, many of the protected areas are too small to support viable population of large mammals over the long term, and isolated populations in such refuges have a high probability of local extinction (Hanski 1994, Noss *et al.* 1996; Wikramanayake *et al.* 1998, 2004)

1.3.8.4 Weak Law Enforcement

Under extreme international pressure, mainly from the USA and CITES, China (1993), Taiwan (1994), and South Korea (1994) banned the trade in tiger bones, and their use in traditional medicines, but undercover investigators obtained tiger products in various places in China after the imposition of the ban. Despite the announced bans, evidence has been collected that tiger-based medicines are still widely available, and the illegal trade is likely to continue for a long time. A major problem for law enforcement authorities is to prove that the medicines actually contain tiger or other forbidden animal product (WWF 1999). In several countries, including the UK, USA and the Netherlands, it has now become an offence just to claim that the medicines or other products contain tiger or rhino parts. This can be followed by other countries (WWF 1999). The tiger is a protected species in Bangladesh under the 3^{rd} Schedule of Bangladesh Wildlife Act 1974, and as such it should not be killed or captured. As a signatory to CITES (signed in 1982), the export, import and use of tiger products are banned, since it is in the Appendix I of the CITES, but none of these regulations is properly enforced.

1.3.8.5 Inbreeding and Genetic Threat

Wildlife populations that are isolated or have a probability of exchanging fewer than one individual per generation are vulnerable to inbreeding depression (Mills and Allendorf 1996). Now most tiger populations consist of fewer than 100 individuals, but only about 40% of them constitute the breeding population. In such a situation inbreeding is inevitable and father-daughter and mother-son matings have been recorded. The balance of the sexes may be distorted, thus increasing the impact of inbreeding. The loss of variability and genetic deterioration ultimately leads to lower cub production and survival (WWF 1999). Several workers involved in captive breeding (Seal *et al.* 1994, Wiese *et al.* 1994) have hypothesised that potential genetic problems arising from population insularisation may pose serious threats to tigers. Unfortunately, there is no, or very few, genetic data for wild tigers, but the quasi-extinction probabilities generated by using field-derived vital rates for normal tiger populations suggest that even small, insular populations (e.g. with six breeding tigresses) have a low probability of extinction (Karanth and Stith 1999). This capacity for population persistence is basically a function of the high reproductive potential of the tiger, which is a pattern typical of large felids (Martin and de Meulenaer 1988, Lindzey *et al.* 1992, Laing and Lindzey 1993, Lindzey *et al.* 1994). The authors cautioned that their model does not include several other factors that could affect tiger population dynamics.

1.3.8.6 Natural Disasters

Small and isolated tiger populations are vulnerable to natural disasters like forest fires, floods, hurricanes, and epidemic diseases. The forest-fires of north-eastern China in 1987 may have led to the deaths of many Siberian tigers. Monsoon floods and hurricanes regularly kill some tigers in the Indian sub-continent (WWF 1999). The tiger population in the Sundarbans is particularly vulnerable to coastal cyclones. After the most catastrophic cyclone in 1988, a total of eight tiger deaths was recorded in the Bangladesh Sundarbans (Bangladesh Forest Department 2000b). It is presumed that there were many more unrecorded deaths deep in the Sundarbans.

1.3.9 Conservation

1.3.9.1 Global Conservation Efforts

Saving the tiger is a challenge for mankind (Johnsingh 1997). The tiger is a legally protected species all over its global range, but still there are threats from poaching, prey depletion, habitat loss, etc. According to Seidensticker and Hai (1978), the three principles of tiger management are: 1) protection, 2) habitat continuity, and 3) habitat quality. As Schaller (1995) pointed out, we know how to protect tigers, but don’t know how to manage them; of the twin evils of loss of prey species and poaching, the former is more serious, since most carnivore populations can withstand a certain amount of loss. The recent advances in the field research techniques, e.g. telemetry and camera-trapping, are playing important roles in gathering scientific knowledge on the tiger, which is a crucial requirement for successful conservation of the tiger in the wild. The concept of tiger metapopulation management (Wikramanayake *et al.* 2004) is promoting throughout the fragmented tiger landscapes.

The tiger is one of the priority species for World Wide Fund For Nature (WWF). In order to strengthen tiger conservation activities in India, WWF developed the Tiger Conservation Programme (TCP) in 1997. The TCP is concentrating on high-priority Tiger Conservation Units identified in the WWF Tiger Conservation Strategy. The Tiger Conservation Units cover not only reserves, but also surrounding areas of suitable habitats for tigers. Help is being given to strengthen the management of the reserves in cooperation with the central government and the state governments, which have responsibility for the reserves (WWF 1999). WWF also provides financial and technical support in most of other tiger range countries.

The World Conservation Union (IUCN) supports tiger conservation in some countries. IUCN regularly monitors the status of wild tigers and other threatened species. IUCN has listed the tiger as an Endangered species (IUCN 2003) in the Red List of Threatened Species to aware people for its conservation. The IUCN/SSC Cat Specialist Group, which consists of some 200 wildlife biologists and wildlife managers from 50 countries (WWF 1999), gives all possible support to tiger conservation all over its range. The Group published a Cat Action Plan in 1996, which reviews the status and conservation requirements for tigers and other species of wild cats, and publishes a biannual newsletter.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), to which 130 governments are now Party, banned international commerce in the tiger and its derivatives, but the effectiveness of the ban rests on the actions of the governments, who must have supporting legislation enforced by trained personnel. It depends not only on the range countries, but of other countries which trade with them (WWF 1999).

In order to make CITES work, WWF and IUCN jointly formed the wildlife trade monitoring programme known as TRAFFIC in 1976. Its mission is to ensure that trade in wild plants and animals are not a threat to the conservation of nature. TRAFFIC works closely with the tiger range and consuming states to broker an unprecedented agreement to halt the trade. This agreement was unanimously adopted by all CITES members at the 9th CITES Conference of the Parties in Florida (WWF 1999). In India, TRAFFIC investigations in 1995 led to numerous seizures of tiger bones and skins, the arrest of an important smuggling gang, and the uncovering of illicit trade routes between India, Nepal, Bhutan and East Asia. In 1993, TRAFFIC-India masterminded an operation that resulted in the seizure of nearly 500 kg of tiger bones in New Delhi. This biggest-ever haul of tiger bones and skins shook the world and convinced the conservation community that the tiger was on the path to extinction (WWF 1999). TRAFFIC (South-east Asia) was opened in Malaysia in 1992 for field investigations and general trade monitoring throughout South-east Asia. Vietnam, Myanmar and Cambodia have acceded to the treaty pressurised by TRAFFIC. In 1995, TRAFFIC (South-east Asia) carried out a study of tiger trade in Malaysia, Singapore, and Thailand (WWF 1999).

Established in 1994, the Global Tiger Forum (GTF) is a Regional Agreement of tiger range countries and few other bodies in order to strengthen tiger conservation in all over its range. The Forum aims to eliminate illegal trade in tiger parts, increase the area of protected tiger habitat and promote training, awareness building and scientific research. The GTF pressurised and supported the tiger range countries to prepare the National Tiger Action Plan. Bangladesh hosted the first General Assembly of the GTF in January 2000.

Considering the need to address urgent and unforeseen threats to tiger populations in the wild, e.g. at the time of natural disaster, the WWF/IUCN Tiger Emergency Fund (TEF) was set up in 1998 during WWF's 'Year for the Tiger', to provide funds quickly to support necessary action. A three-person committee, composed of representatives of WWF International's Species Conservation Unit, its Asia/Pacific Programme, and the IUCN/SSC Cat Specialist Group, is committed to decide on applications within five working days and provide funds of up to US $ 10,000 as quickly as possible (WWF 1999). Since its inception, the TEF has supported some 50 projects in Bangladesh, India, Indonesia, Russia and Vietnam (WWF 2001).

Save the Tiger Fund and Rhinoceros and Tiger Conservation Fund give strong financial support in many tiger conservation projects all over the range. The former is controlled by the National Fish and Wildlife Foundation, USA, in partnership with ExxonMobil Corporation, and the latter by the US Fish and Wildlife Service. Save the Tiger Fund was launched pledging US $ 5,000,000 over a five-year period.

All of these actions have helped keep tiger conservation a high-priority issue among the government officials, but there have been too few actions ‘on-the-ground’ (Rabinowitz 1999).

1.3.9.2 Conservation Efforts in Bangladesh

The tiger is legally protected under the 3rd Schedule of Bangladesh Wildlife Act 1974 and, as such, it should not be killed or captured, but in the extreme situation of threats to human lives, man-eaters are officially notified by the Chief Conservator of Forests (CCF) for trapping or killing. It should be noted that prior to the promulgation of Bangladesh Wildlife Act 1974, there was no legal restriction on killing of tigers in the country. The use and export of the tiger or its parts is banned under the provisions of the CITES. Although Bangladesh acceded to CITES in 1982, there is no specific legislation in the country to implement this (Mainka 1997). The habitat of the tiger is legally protected under Forest Act 1927. Moreover, three wildlife sanctuaries (Sundarbans East: 312 km^2, Sundarbans South: 370 km^2, and Sundarbans West: 715 km^2) in the Sundarbans were declared under the provisions of Bangladesh Wildlife Act 1974. The total area covered by these three wildlife sanctuaries of the southern Sundarbans was declared a World Heritage Site by UNESCO in December 1997.

To date, practical tiger conservation in Bangladesh remains at a preliminary level. Bangladesh Forest Department has so far prepared at least three big projects for tiger conservation in the Sundarbans, but none could be implemented due to lack of funds (Akonda *et al.* 2000). Besides, forestry projects of the government in the Sundarbans do not focus proper emphasis on tiger conservation.

In 1999, WWF and IUCN-Bangladesh jointly launched a project entitled ‘Tiger Conservation in the Sundarbans Through Improved Trans-border Co-operation Between Bangladesh and India’. Under this project the forestry officials of both Bangladesh and Indian Sundarbans visited each other’s working areas and exchanged knowledge and experience. Moreover, a small project entitled ‘Ecology of the Bengal tiger in the Sundarbans, Bangladesh’ was implemented in 1999 by IUCN-Bangladesh with teachers and students from Jahangirnagar University and University of Dhaka. The Forest Department prepared the draft of the national Tiger Action Plan in January 2000. Two projects, i.e. 'Forest Resource Management Project (FRMP)' and 'Sundarbans Biodiversity Conservation Project (SBCP)', have been implemented by the Forest Department, which partially covered tiger conservation. In January 2001, the Forest Department, with University of Minnesota and Wildlife Conservation Society, initiated a project entitled 'A Study of the Status, Behaviour and Ecology of the Tiger in the Sunderbans of Bangladesh'. Although the project had funding from Save The Tiger Fund, virtually nothing has yet been implemented in the field.

In an effort to control domestic trade in wildlife, in particular items generated towards tourists, an education campaign was initiated by the Forest Department in April 1995 including posters, stickers and billboards advocating wildlife conservation (Brooks *et al.* 1995).

In Bangladesh there is no wildlife institution, which is badly needed for the conservation of the tiger as well as other wildlife of the country. A Wildlife Working Circle was established within the Forest Department in 1977 with the responsibility for wildlife and nature conservation and was headed by a Senior Conservator of Forests responsible directly to the Chief Conservator of Forests. This development was thwarted when the Wildlife Development Scheme (1977) was abandoned 'in the interest of the economy' in 1982. Due to the pressure from different communities, the Wildlife Working Circle was reformed in 1990s, but this was nothing but a reshuffling of the existing staff. Now the responsibility for wildlife conservation is under ordinary forestry officials who are not wildlife specialists. Another major issue of tiger or wildlife conservation in the country is the lack of strategy and national policy. To date, there is no separate policy for wildlife conservation in the country. It is worth mentioning that Bangladesh still has potential wildlife habitats throughout the country, so there is a great scope to link the wildlife, including the tiger, with ecotourism and agroforestry activities and projects for sustainable development through the formulation and adoption of strategy and national policy. In a developing country like Bangladesh, linking economic benefits to conservation is required, but it is difficult in a situation where wildlife is highly endangered, pressure on biomass resources is high, and stakeholders are many (Sekhar 2003). Since the Sundarbans is large and the human pressure is low, non-consumptive uses like ecotourism can be developed.

1.4 NEED AND OBJECTIVES OF THIS RESEARCH

1.4.1 Need of This Research

According to UNDP and FAO (1998), the tiger in the Sundarbans is a high priority species for research; the species has a very high ecotourism value. This research, conducted by myself and my assistants, was needed for the partial fulfilment of some of the major clauses of the draft Tiger Action Plan of Bangladesh (Bangladesh Forest Department 2000a). These are as follows:

> '**Clause 13(a). Population** There is no authentic knowledge on the population of the Bengal tiger in the Sundarbans. It is not known whether the population is increasing or decreasing and what is the actual number of the tiger in the Sundarbans. There is also no knowledge on the nature of breeding or breeding habitat of the tiger in the Sundarbans, so a continuous research initiative will have to be maintained for five years initially to gain knowledge on ecology and biology of the tiger including its other problems in the Sundarbans. Project cost of this component for five years = US $ 100,000.'

In this study prey density in the Sundarbans East WS has been estimated scientifically and based on this, the tiger density has been inferred. I have also studied the breeding and litter size of tigers, which formed the baseline information on these aspects. The relative density of tiger signs (for relative habitat use) can be used as a reference in temporal monitoring of tiger population trends.

> '**Clause 13(b). Habitat of the Tiger** The Sundarbans has good forest cover for the tiger. The forest is not easily accessible to people. Prey animals (spotted deer, wild boar, rhesus macaque, etc.) are also found in good numbers. However, there should be an ecological balance between plants and animals, predators and prey, which should be maintained according to the carrying capacity of the Sundarbans. For this purpose, continuous monitoring and studies need to be carried out for a period of five years. Project cost of this component for five years = US $ 100,000.'

The relative habitat use of tigers, and their prey selection, were studied in my project. In other words, the ecological requirements of tigers, and ecological balance and carrying capacity have been assessed. There was a serious lack of the knowledge on tiger ecology in the Sundarbans.

> '**Clause 13(g). Capacity Building** Basic knowledge on Wildlife Management is given to forest officials during their training in Forest Schools at Rajshahi and Sylhet, and in Bangladesh Forest Academy, Chittagong, but there is a need of further and advanced training on wildlife management among the forest officials. Presently Bangladesh Forest Department is facing acute problems due to shortage of officers and employees. The capacity building component may require US $ 500,000 within a period of three years.'

My project was required for the fulfilment of a PhD degree from the University of Cambridge, UK. This will be the first-ever PhD based on a project on the tiger, or on any wild cat, in Bangladesh. This can build the national capacity for tiger conservation in Bangladesh. I can share my experience with the forest and wildlife managers and can train other research students as well as the forest guards. Two seminars already organised in the forest office in Khulna, Bangladesh, so that I could disseminate my knowledge and experience with the forest and wildlife managers.

Support for the '**Clause 13(f). Habitat Development**', and '**Clause 13(h). Motivation and Public Awareness Campaign**' were also provided indirectly by my project, because my findings on the relative habitat use by tigers will be useful in habitat development for tigers and my interviewing of many local people has served as an awareness campaign, since I have tried to convince them of the need for conserving the tiger in the Sundarbans. Moreover, my findings will support tiger conservation in the following ways –

a) The findings on tiger ecology will be useful to manage properly the tiger, e.g. by the maintenance of prey base and key vegetation covers, through the government agency (Bangladesh Forest Department).
b) The findings on the rate of consumption of tiger prey by local people will be useful to know the actual level of poaching and will give an idea how to reduce the problem.

c) Since the tiger is at the top of the ecological pyramid of the mangrove ecosystem, the conservation of this species will ultimately lead to the conservation of the whole ecosystem, so my findings will be directly or indirectly useful in strengthening the conservation of the unique ecosystem and biodiversity of the Sundarbans. While doing fieldwork on tigers, work was also done on other wild cats and birds in the Sundarbans (see Khan 2004a, 2004b and 2004c in Appendices I, II and VI).

1.4.2 Objectives

The overall goal of this research project was to *provide baseline information on tiger ecology and other aspects relevant to tiger conservation in the Sundarbans mangrove forest of Bangladesh*. The specific objectives were as follows –

1. **Prey population structure and density** – To assess the population structure and evaluate the population density of different potential prey species; the absolute prey density gives the opportunity to infer tiger density.

2. **Prey selection** – To identify whether tigers have any preference for prey in terms of species, availability, age and health.

3. **Relative habitat use** – To assess the relative use of four different habitat types by tigers for their different activities.

4. **Breeding and litter size** – To determine the possible breeding pattern and litter size of tigers.

5. **Tiger-human interactions** – To provide clear picture of tiger-human interactions and their intensity, together with the consumption of tiger prey by local people.

CHAPTER 2 STUDY AREA AND GENERAL METHODS

2.1 STUDY AREA

2.1.1 Introduction

The study area for this project was the Sundarbans mangrove forest of Bangladesh, but the fieldwork was mainly concentrated in one of the three wildlife sanctuaries, i.e. Sundarbans East Wildlife Sanctuary (WS). This area is considered to be the richest part of the Sundarbans, because of the diversity of habitats and richness of large mangrove trees as a result of less salinity. The protein-intake survey was conducted in some selected families in ten different villages along the northern boundary of the Bangladesh Sundarbans, all located in Mongla Upazilla (sub-district) under Bagerhat district.

2.1.2 Bangladesh

Bangladesh is a small sub-tropical country in South Asia. The country became independent in 1971. Geographically the country is located between 20º34′-26º33′ N latitudes and 88º01′-92º41′ E longitudes. The Tropic of Cancer passes through the middle of the country. Bangladesh is almost entirely surrounded by India, which borders Bangladesh to the west, north and east. Bangladesh shares a portion of its south-eastern border with Myanmar (Burma). The Bay of Bengal lies to the south. The total area of the country is 147,570 km^2, where around 140 million people live. This is one of the most densely-populated areas in the world.

According to IUCN-Bangladesh (2000), the climate of Bangladesh is tropical monsoon, characterised by marked seasonal variations. Abundant rainfall during the monsoon (July-October) is followed by a cool winter period (November-February), then a hot and dry summer (March-June). In the hot season, the average maximum and minimum temperatures are 34ºC and 21ºC, respectively. The average maximum and minimum temperatures in winter are 29ºC and 11ºC, respectively. The rainfall in the region shows great temporal and spatial variations. It is estimated that 70-80% of the annual rainfall occurs during the monsoon season. The average annual rainfall recorded within Bangladesh varies from 1,100 mm in the extreme west to 5,690 mm in the north-eastern corner of the country.

Bangladesh has an exceptional hydrological setting. Three mighty rivers, the Ganges (Padma), the Brahmaputra (Jamuna) and the Meghna, drain a catchment extending over India, China, Nepal, Bangladesh and Bhutan. The total area of the Ganges-Brahmaputra-Meghna drainage basin is about 1,500,000 km^2, of which about 62% is in India, 18% in China, 8% in Nepal, 8% in Bangladesh, and 4% in Bhutan. Ninety percent of the total incoming water runs into the Bay of Bengal through the lower Meghna estuary of Bangladesh. The rate of water flow through Bangladesh is vast. The outflow is the second in the world after the Amazon river system in South America. In both breadth and total annual volume, the Padma-lower-Meghna river is the 3rd largest in the world.

Bangladesh can be divided into three main physiographic divisions – Tertiary hills, Pleistocene terraces and recent plains. The Tertiary hills are situated in Greater Chittagong and Chittagong Hill Tracts, and Sylhet areas. These hills are mainly formed of sandstone, shale and clay. The average altitude of the hills is 450 m. The highest peak of the country is Keokradong at 967 m. The Pleistocene terraces were formed 25,000 years ago. The total area of these terraces is about 13,500 km^2 spread in different areas of the country, but mainly in the central and north-eastern regions. The average height of the terraces from the adjacent floodplains is 6-25 m. The recent plains comprise 124,266 km^2 of the country (about 86%), i.e. the major portion of Bangladesh, and these can be further classified to piedmont, flood, deltaic, tidal and coastal plains.

According to the Forestry Master Plan (Ministry of Environment and Forests, Government of Bangladesh, 1993), there are 15.4% of the total area of the country are forests, of which 10.3% are classified and 5.1% are unclassified state forests, but according to unofficial sources, the natural forest of the country is as low as 5%. There are three classes of natural forests in Bangladesh: a) mangrove forests – situated in the south-west, b) mixed-evergreen forests – situated in the north-east and south-east, and c) moist deciduous forest – situated in the central, northern and north-western regions of the country (Figure 2.1). In the past three decades, the stock of forest trees has declined at an alarming rate. It is estimated that the forest cover has been reduced more than 50% since the 1970s. Estimates in 1990 revealed that Bangladesh has less than 0.02 ha forest land/person; one of the world's lowest forest to population ratios (World Resources Institute 1990). There are 14 protected areas in Bangladesh (Table 2.1), with a total area of 2,254.1 km^2, covering only 1.5% of the total area of Bangladesh.

The country has a rich biological heritage as a consequence of its location at the confluence of the three major biotic regions – the Himalayas, Indo-China and the Indian Peninsula (MacKinnon and MacKinnon 1986). A total of 259 inland fishes, 442 marine fishes, 22 amphibians, 108 inland reptiles, 17 marine reptiles, 391 resident birds, 240 migratory birds, 110 inland mammals and 3 marine mammals has been recorded in Bangladesh (IUCN-Bangladesh 2000)

Table 2.1 Protected areas of Bangladesh

Sl. no.	Name of the protected area	Geographical location	Name of the district in which located	Year of establishment/ notification	Area (km^2)
Wildlife Sanctuary (WS)					
1	Sundarbans East WS	21°47′-22°03′ N latitudes and 89°44′-89°56′ E longitudes	Bagerhat	1960 (part)/1996	312.3
2	Sundarbans South WS	21°39′-21°56′ N latitudes and 89°17′-89°30′ E longitudes	Khulna	-/1996	369.7
3	Sundarbans West WS	21°38′-21°58′ N latitudes and 89°00′-89°15′ E longitudes	Satkhira	-/1996	715.0
4	Char Kukri-Mukri WS	21°55′ N latitude and 90°38′ E longitude	Bhola	-/1981	0.4
5	Rema-Kalenga WS	24°05′ N latitude and 91°37′ E longitude	Habiganj	-/1996	18.0
6	Pablakhali WS	23°08′ N latitude and 92°16′ E longitude	Rangamati	1962/1983	420.9
7	Chunati WS	21°40′ N latitude and 92°07′ E longitude	Chittagong and Cox's Bazar	-/1986	77.6
8	Hazarikhil WS	22°40′ N latitude and 91°40′ E longitude	Chittagong	-/1974	29.3
National Park (NP)					
9	Madhupur NP	24°45′ N latitude and 90°06′ E longitude	Tangail	1962/1982	84.4
10	Bhawal NP	24°00′ N latitude and 90°20′ E longitude	Gazipur	1974/1982	50.2
11	Lawachara NP	24°15′ N latitude and 91°45′ E longitude	Moulvibazar	-/1996	12.5
12	Himchari NP	21°22′ N latitude and 92°02′ E longitude	Cox's Bazar	-/1980	17.3
13	Kaptai NP	22°30′ N latitude and 92°20′ E longitude	Rangamati	-/1974	30.3
Game Reserve (GR)					
14	Teknaf GR	21°00′ N latitude and 92°20 E′ longitude	Cox's Bazar	-/1983	116.2
					Total protected area = 2,254.1

(**Figure 2.1** Forested areas of Bangladesh → import from Maps and Illustrations folder.)

2.1.3 Sundarbans

The Sundarbans is the world's largest tidal mangrove forest (Chaudhuri and Choudhury 1994), which is about 6% of all mangroves on earth (Khan 2002). The word ‘mangrove’ (a combination of the Portuguese ‘mangue’ and English ‘grove’) can refer to an ecological group of holophytic plant communities belonging to 12 genera in 8 families, or a complex of plant communities fringing sheltered tropical shores, or more specifically by some authors, the vegetation formation below the high tide mark (Seidensticker and Hai 1978). The fragile and intricate mangrove ecosystem depends on many variable components, i.e. tides, salt content in water and soil, duration of sunlight, contents of sediment and organic matters in water, temperature and density of seawater and freshwater. The floral and faunal composition plays an important role in mangrove ecosystem. The Sundarbans is an essential and high-quality wildlife conservation area of regional and international importance (Seidensticker 2004). It has been identified as Level I Tiger Conservation Unit (TCU), because the habitat offers the highest probability of persistence of tiger population in the long-term (Wikramanayake *et al.* 1999).

The Sundarbans mangrove swamp is of recent origin, formed by the eroded soil from the Himalayas carried by the Ganges, Brahmaputra, Meghna and many other river systems. These deposited the sediments at the apex of the Bay of Bengal that gave rise to the Sundarbans. The most striking adaptations of the mangrove plants are various forms of aerial roots to meet the oxygen requirement for respiration (Hogarth 1999). The holophytic tree species mainly form the natural vegetation. The forest is more or less open and canopy height is commonly within 10 m from the ground. The forest floor is normally 0.9-2.1 m above the sea level (Tamang 1993). Three ecological zones, i.e. freshwater zone, moderately saline water zone, and saline water zone, can be distinguished according to salinity and species composition.

The total mangrove area of the world has been estimated to be around 166,700 km^2 (Choudhury *et al.* 2001) and the entire Sundarbans is about 10,000 km^2, of which roughly 60% lies in the south-west of Bangladesh (between 21°30′-22°30′ N latitudes and 89°00′-89°55′ E longitudes) and the other 40% in the south-east of the Indian state of West Bengal (between 21°32′-22°40′ N latitudes and 88°05′-89°00′ E longitudes)

(Hussain and Acharya 1994, Chaudhuri and Choudhury 1994) (Figure 2.2). The Bangladesh Sundarbans covers an area of about 6,000 km^2, of which 1,750 km^2 is under water as rivers and creeks (Hussain and Acharya 1994) (Figure 2.3). Only 61 km^2 of the total land area is bare ground, scrubland, grassland or clearings (Chaffey *et al.* 1985). The Indian Sundarbans is about 4,000 km^2, of which 1,781 km^2 is under water (Chaudhuri and Choudhury 1994).

The Bangladesh Sundarbans represents about 44% of the total forested area of the country, and contributes about 50% of the revenue in the forestry sector (Tamang 1993). The Sundarbans is obviously of great economic importance to Bangladesh as a prime source of a wide range of valuable natural products, such as timber for construction, fish, honey, nipa (*Nypa fruticans*) leaves for thatching, etc. (Blower 1985). It also has an important buffer function protecting the densely-settled agricultural areas to the north from the full force of cyclone and tidal waves by mitigating their destructive force (Helalsiddiqui 1998). The National Tourism Policy (NTP) 1992 of Bangladesh proposed that, because of its unique and diverse attractions of international renown, the Sundarbans should be developed as the springboard for the tourism industry for the country as a whole. The Sundarbans is a unique and complex natural ecosystem of value, not only for its multiple renewable resources, but also for its outstanding scientific and educational interest (Hussain and Acharya 1994).

A total of 1,397 km^2 of the three wildlife sanctuaries (Sundarbans East, Sundarbans South and Sundarbans West) of the Bangladesh Sundarbans form a UNESCO World Heritage Site (declared in December 1997). The Sundarbans East WS is one of these three sanctuaries (Figure 2.4), where my study was mainly concentrated. This is an area of 312 km^2 (5% area of the Bangladesh Sundarbans) at the south-eastern end of the Bangladesh Sundarbans, geographically between 21°47′-22°03′ N latitudes and 89°44′-89°56′ E longitudes. The land part represents four major habitat types, i.e. mangrove woodlands (70%), grasslands (10%), sea beaches (6%) and transitional zones 14%). Half of the Sundarbans East WS is under deep water in the form of estuaries and large rivers.

[**Figure 2.2** The Sundarbans of Bangladesh and India showing the National Park (NP) and Wildlife Sanctuaries (WS) → import from Maps and Illustrations folder.]

(**Figure 2.3** The Sundarbans of Bangladesh showing three Wildlife Sanctuaries (WS) → import from Maps and Illustrations folder.)

(**Figure 1.3** The Sundarbans East Wildlife Sanctuary of the Bangladesh Sundarbans → import from Maps and Illustrations folder.)

2.1.3.1 Climate

The mean maximum and minimum temperature in the Bangladesh Sundarbans are 31.2°C (April-May) and 21.5°C (December-January), respectively. The mean annual relative humidity varies between 70-80%. The mean annual rainfall varies from about 2,600 mm in the east to 1,600 mm in the west (Figure 2.5). There are about 120 rainy days in a year in the Bangladesh Sundarbans. The pH in river water varies from 6.5 to 8. Tides are twice daily and the average tidal time difference is about 12 hours and 25 minutes. In the Indian Sundarbans, on the other hand, the mean maximum and minimum temperatures are 29°C (June-July) and 20°C (December-January), respectively. The humidity is high (70-88%). The annual rainfall is as much as 2,790 mm on the outer coast, and 1,650-1,800 mm in the central and northern areas. The above-mentioned information is from various sources (e.g. Hussain and Acharya 1994, Rosario 1997, Chaudhuri and Choudhury 1994, this study).

In the Sundarbans East WS the meteorological data were recorded during the fieldwork of this study (September 2001-February 2003). The monthly mean highest and lowest temperature and humidity were 34.2ºC (October) and 10.7ºC (January), and 95% (August) and 49% (February), respectively. The highest and lowest monthly rainfall were 584 mm (June) and 0 mm (December, January, February), whereas the total annual rainfall in the year 2002 was 2,552 mm (Figure 2.6).

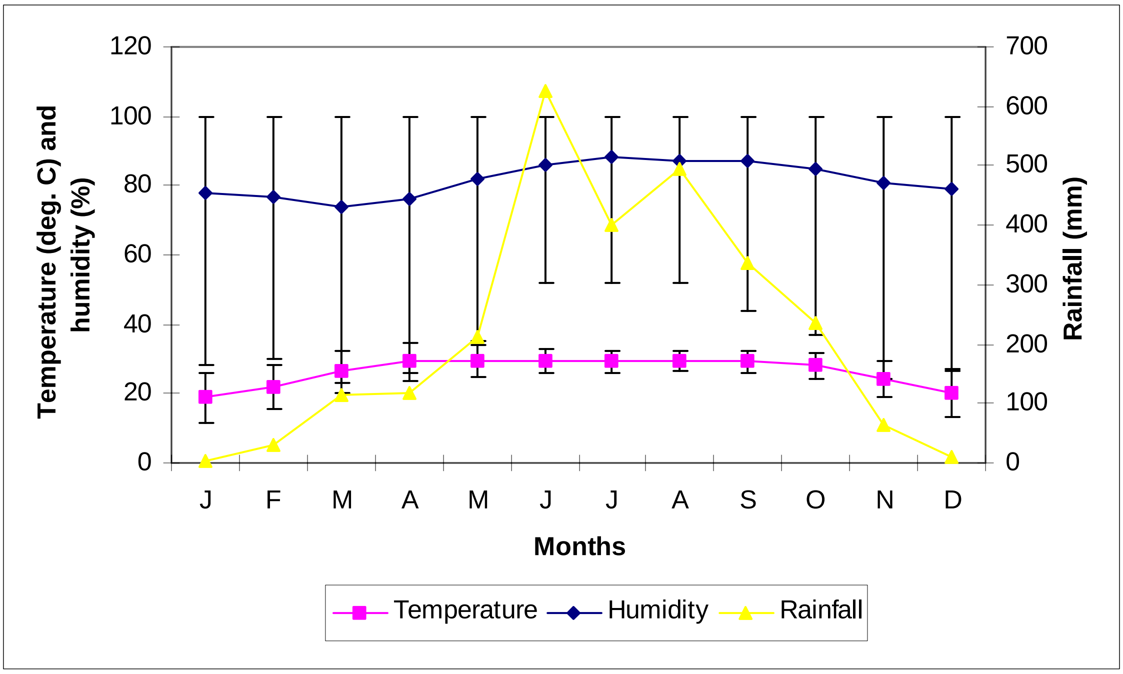


Figure 2.5 Monthly mean temperature, humidity and rainfall in the Bangladesh Sundarbans (average of 1990 to 1994) (temperature and humidity shown with mean maximum and minimum).

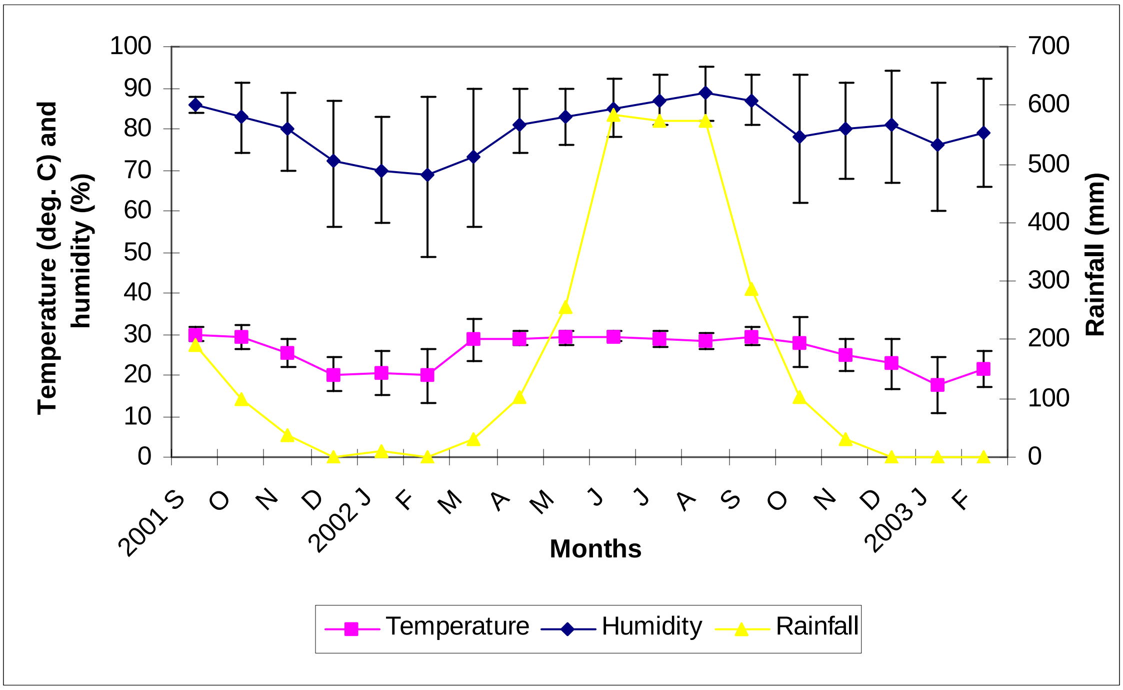


Figure 2.6 Monthly mean temperature, humidity and rainfall in the Sundarbans East Wildlife Sanctuary during the study period (temperature and humidity shown with mean maximum and minimum).

2.1.3.2 Biodiversity

Unlike other mangrove forests, the Sundarbans is rich in biodiversity, especially in mangrove-oriented species. One reason for the species richness, particularly of birds, is that the Sundarbans is a forest as well as a wetland with mudflats and sea beaches. That is why it can harbour both forest species and wetland species. However, there is no endemic species in the Sundarbans (Seidensticker 2004).

The mangrove tree species are generally of two types: 1) basic mangroves growing along the areas inundated by high and medium tides, able to tolerate high salinity in water, mainly the members of the families Rhizophoraceae and Myrsinaceae; and 2) associated or back mangroves, growing on comparatively higher and firmer ground, and less tolerant to high tides and salt, mainly the members of the families Sterculiaceae, Verbenaceae, Lythraceae, Meliaceae and Palmae. Rich and diverse associated mangrove community is seen in the Sundarbans. No other mangrove forest in the world offers such a variety of associate mangrove species (Choudhury *et al.* 2001).

The Sundarbans is grouped into tropical moist forest after the Holdridge (1964) system, because this forest is located at the south of the Tropic of Cancer, near the line. Although there are many reports on the species diversity of major flora of the Sundarbans, the reports on the minor flora are extremely limited. So far, 34 species of algae have been recorded in the Bangladesh Sundarbans, which include varieties of *Vaucheria*, *Cladophorella* and *Boodleopsis* (Islam 1976, Hussain and Acharya 1994).

Prain (1903) identified a total of 334 species of plants (of which 27 are common trees) belonging to 245 genera of spermatophytes and pteridophytes from the Sundarbans and adjoining areas. At least 123 species of these are found to occur at present in the Bangladesh Sundarbans (Hussain and Acharya 1994) (see Appendix VII for a list of common plants). The Bangladesh Sundarbans support about 80% of the global mangrove tree species. There are 22 families of tree species, at least 6 species of Rhizophoraceae, 3 of Avicenniaceae, 3 of Meliaceae, 2 of Combretaceae and 2 of Sonneratiaceae in the Bangladesh Sundarbans (Hussain and Acharya 1994). *Heritiera fomes*, *Excoecaria agallocha* and *Sonneratia apetala* are the three commonest tree species. Among the shrubs or scandant shrubs there are 12 species in 7 families. Moreover, there are 11 species of climbers in 6 families that have been recorded so far. Graminae, Palmae and Pandanaceae families represent the monocotolydenous herbs.

Other than these species, there are many epiphytes like *Hoya parasitica*, *Dischidia numularia*, 13 species of Orchidaceae, 7 epiphytic ferns including *Lycopodium* and *Psilotum* (Hussain and Acharya 1994).

The Indian part of the Sundarbans is relatively less diversified in floral species. According to Chaudhuri and Choudhury (1994), a total of 36 true mangrove species, 28 mangrove associates and 7 obligatory mangrove species have so far been reported, which represents a total of 29 families. Among them there are 30 trees, 20 shrubs and 20 herbs. *Excoecaria agallocha* and *Ceriops decandra* are the commonest tree species in the Indian Sundarbans.

Among the fauna, there are few reports on the zooplankton. In the Bangladesh Sundarbans, Mahmood *et al.* (1987) recorded 23 species of ichthyoplanktons in 19 families in the south-western part of the Bangladesh Sundarbans. Zafar and Mahmood (1989) recorded the zooplankton in the same region as belonging to 13 taxa, i.e. copepods, amphipods, mysids, aceters, chaetognaths, polychaetes, lucifers, hydromedusae, shrimp larvae, finfish larvae, crab larvae, squilla larvae and horse-shoe crab larvae.

Considerable research has been done on zooplankton in the Indian Sundarbans. According to Chaudhuri and Choudhury (1994), the taxonomic groups of the zooplankton community of the Indian Sundarbans include holoplankters (crustaceans and non-crustaceans) and meroplankters (mainly composed of the larvae of marine invertebrates). Among the holoplankters, the groups so far recorded are: Copepoda, Mysidacea, Sergestidae, Amphipoda, Cladocera, Ostracoda, Cumacea, Chaetognatha, Hydromedusae and Ctenophora. Among the meroplankters, the phyla so far reported are: Cnidaria, Annelida, Arthropoda, Echinodermata, Mollusca, Phoronida, Nemertea, Bryozoa, Hemichordata and Chordata.

Among aquatic invertebrates, 24 species of shrimps in 5 families, 7 of crabs in 3 families, 2 of gastropods, 6 of pelecypods and 8 of locust-lobsters have been recorded from Bangladesh Sundarbans (Hussain and Acharya 1994). A total of 12 species of arthropods, 7 of dermepterans, 25 of odonatans, 5 of neuropterans and 9 lepidopterans have been recorded in the Indian Sundarbans by the Zoological Society of India and are presumed to be present in the Bangladesh portion as well (Hussain and Acharya 1994). According to Chaudhuri and Choudhury (1994), the Indian Sundarbans support 4 species of sea anemones, at least 19 species of benthic crabs, 3 of hermit crabs, at least

2 of horseshoe crabs, 61 of gastropods, 30 of polychaetes, about 80 of nematodes, 1 of acorn worm (which discovered very recently), at least 46 of benthic insects, 4 of amphipods, 14 of ciliate parasites of bivalves and gastropods of which 7 are new to science, and many species of parasites of fish and mammals.

The Sundarbans is exceptionally rich in fish species diversity, which made the region an important commercial fishing ground. The Bangladesh Sundarbans support 53 species of pelagic fish in 27 families and 124 of demersal fish in 49 families (Hussain and Acharya 1994). On the other hand, 250 species of fish have been recorded in the Indian Sundarbans (Chaudhuri and Choudhury 1994).

In the Bangladesh Sundarbans, a total of 425 species of vertebrate wildlife (amphibians to mammals) have been recorded, of which 8 are amphibians, 53 are reptiles, 315 are birds and 49 are mammals (Hussain and Acharya 1994) [see Appendices VI (Khan 2004d) and VIII for the vertebrate wildlife recorded during this study]. Of the 17 species of snakes found in the Bangladesh Sundarbans, 10 are sea snakes (Sarker and Sarker 1988). There are 4 species of marine turtles recorded in the Bangladesh Sundarbans, of which olive ridley turtle (*Lepidochelys olivacea*) is the commonest. The total bird species (315) recorded in the Bangladesh Sundarbans is about half of the total bird species recorded in Bangladesh. Among these 315 species, 84 are known to be migratory. Of the 12 species of kingfishers found in Bangladesh, 8 are found in the Sundarbans (Hussain and Acharya 1994, Khan 2004d). According to Seidensticker and Hai (1983), the Bangladesh Sundarbans and adjacent area support 32 species of shorebirds. Only in the Sundarbans East WS, which is 5% of the entire Bangladesh Sundarbans, a total of 198 species of birds were found, including 4 globally-threatened species, of which 134 (68%) were resident and the rest 64 (32%) migrant (Khan 2004d). The overall species diversity index value was found quite high (3.865 in Shannon-Wiener formula), but it was higher in summer (3.973) than in winter (3.299) (Khan 2004d).

In the Indian Sundarbans, 8 species of amphibians, 57 of reptiles, 161 of birds and 40 of mammals have been recorded (Chaudhuri and Choudhury 1994). Of the 57 species of reptiles, 12 belong to the order Chelonia, 44 to Squamata and 1 to Crocodilia. The common bird groups in both Bangladesh and Indian Sundarbans are herons, egrets, storks, kingfishers, eagles, kites, owls, waders, ducks, etc. Among the terrestrial mammals, the most common species are spotted deer (*Cervus axis*), rhesus macaque

(*Macaca mulatta*) and wild boar (*Sus scrofa*). The tiger (*Panthera tigris*) is the supreme predator and the flagship species of the Sundarbans.

2.1.3.3 Flagship and Threatened Species

Heritiera fomes is the flagship species among the flora of the Sundarbans. *H. fomes* dominated areas are considered as the richest parts of the Sundarbans. This species is dominant in the Bangladesh Sundarbans, mainly in the eastern part, while it is uncommon in the Indian Sundarbans and may be considered as a threatened species. To some extent, this species is the indicator of the level of natural-resource exploitation, since it is the most important commercial species.

In the Bangladesh Sundarbans, Heinig (1892) and Prain (1903) reported 4 common species of *Bruguiera*, but the recent survey confirmed the presence of only one species (*B. parviflora*). Moreover, some other plants like *Cynometra*, *Amoora cuculata*, *Rhizophora* spp. are threatened due to unregulated felling (Hussain and Acharya 1994). *Rhizophora* is on the brink of extinction in the Indian Sundarbans. The other species which may be considered as threatened are *Aegiceras corniculatum*, *Heritiera fomes*, *Kandelia kandal*, *Nypa fruticans*, *Sonneratia acida* and *S. caseolaris* (Chaudhuri and Choudhury 1994, Khan 2002).

The tiger is the supreme flagship species of the Sundarbans. This large carnivore is at the top of the ecological pyramid of the mangrove ecosystem, and the conservation of the tiger will lead to the conservation of the unique biodiversity of the Sundarbans. The tiger is a globally Endangered (IUCN 2003) and nationally (in Bangladesh) Critically Endangered species (IUCN-Bangladesh 2000).

Another flagship species in the Sundarbans is the estuarine crocodile (*Crocodylus porosus*). This species has been identified as a Critically Endangered species in Bangladesh (IUCN-Bangladesh 2000). Khan (1982) arbitrarily estimated about 200 individuals in the Bangladesh Sundarbans on the basis of different visits. Decline of crocodile population has been observed in the Sundarbans, possibly due to indiscriminate killing (Hussain and Acharya 1994, Chaudhuri and Choudhury 1994). Over the last couple of decades, an average of six people have been killed annually by crocodiles in the Indian Sundarbans. The rivers and grassy riverbanks in the Sundarbans are excellent habitats for estuarine crocodiles.

Other than the tiger, the Sundarbans tract provides extensive habitats for some globally-threatened species. These are river terrapin (*Batagur baska*), olive ridley turtle (*Lepidochelys olivacea*), masked finfoot (*Heliopais personata*), white-rumped vulture (*Gyps bengalensis*), greater spotted eagle (*Aquila clanga*), lesser adjutant (*Leptoptilos javanicus*), Oriental stork (*Ciconia boyciana*), fishing cat (*Prionailurus viverrinus*), Ganges river dolphin (*Platanista gangetica*) and hoary-bellied Himalayan squirrel (*Callosciurus pygerythrus*).

Among the fauna of the Sundarbans, at least four species have become extinct since the beginning of the 20th century. These are Javan rhinoceros (*Rhinoceros sondaicus*), wild buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*) and hog deer (*Axis porcinus*) (Hendrichs 1975, Blower 1985, Tamang 1993, Hussain and Acharya 1994, Chaudhuri and Choudhury 1994, Hogarth 1999). These species, except the hog deer (Khan 2004e; see Appendix IX for details), have also become extinct from Bangladesh. Baker (1887) killed three rhinoceros in the Sundarbans in 1881. According to the Bengal District Gazetteer (1908), the rhinoceros became 'rare' as early as 1908 and was restricted in the southern Sundarbans. There are three specimens of the rhinoceros in the collection of the Indian Museum, Calcutta (Groves and Chakraborty 1983). Two of the specimens have recorded collecting site: Chillichang creek and Mathabhanga river (Barisal district, now in Bangladesh). The buffalo was 'fast disappearing' at the same time (1908) and was found only in the 'waste lands of the Backergunge portion of the Sundarbans (eastern Sundarbans)'. Groups of 8-10 wild buffalos were sighted in tall elephant grasses (*Typha elephantina*) of the riverbanks in Sarankhola Range, Bangladesh Sundarbans, until 1925-1930 (M.M.H. Khan unpubl. data; based on interviewing local people). Jerdon (1874) mentioned the occurrence of the swamp deer for the eastern Sundarbans. In 1914, the Bengal District Gazetteer mentioned that the hog deer is 'not uncommon', but being very shy, are seldom seen along the banks of streams in the northern Sundarbans. Curtis (1933) also noted the hog deer in the northern areas of the Sundarbans. Moreover, some experts believe that leopard (*Panthera pardus*) (Curtis 1933), gaur (*Bos frontalis*) and marsh crocodile (*Crocodylus palustris*) (Blower 1985) were once found at the edge of the Sundarbans.

2.1.3.4 Human Life

Except few villages in the Indian part, there is no permanent human settlement in the Sundarbans; but other than the coast in the south, the entire forest is surrounded by villages. The people of these villages mainly depend on the natural resources of the Sundarbans, but there are temporary sheds in the Sundarbans in harvest season. The Bangladesh Sundarbans provide employment for over 350,000 people working as 'Bawalis' or woodcutters, 'Mouals' or honey gatherers, 'Jaleys' or fishermen, and nipa-leaf (*Nypa fruticans*) and thatching grass (*Imperata* spp.) collectors (Tamang 1993).

It is evident that the earliest settlers in the Lower Bengal, i.e. the bordering areas of the Sundarbans, were of Negroid stock (Das 1981), followed by Proto-Australoid and Homo-Alpinus groups. Human artefacts, including some old and new stone age weapons, provide archaeological evidence of the presence of humans in the region as early as 150,000-40,000 BC (Chaudhuri and Choudhury 1994). The Aryans (Proto-Nordic) invaded the area much later. The recent mass settlement in this basin was started in the early 19th century (Chaudhuri and Choudhury 1994). From the very beginning, the principal occupations of the settlers of this area are woodcutting, fishing and honey gathering.

Archaeologists discovered the ruins of a walled city, 6 km^2 area, in the north of the Indian Sundarbans. It dates to a period between the Maurya (4^{th}-3^{rd} century BC) and Gupta (6^{th}-4^{th} century BC) ages (De 1999). During the 10^{th} century AD, Srichandra founded the Chandra dynasty in the north-east of the Bangladesh Sundarbans which was known as Chandradweep (Choudhury *et al.* 2001). Ruins of ancient temples and watch-posts are seen in Adachai area of the Bangladesh Sundarbans. About a hundred years ago, there were small salt-farms in Katka and Kochikhali areas of the Sundarbans. Ruins of earthen pots that people once used, and the mounds of their shelters, still exist (M.M.H. Khan pers. obs.).

The culture and religion developed in this area have absorbed the Sundarbans and its plants and animals. The tiger is a prominent figure in the culture and religion of this area. There are traces of both animist and totemist characteristics of primitive religions in the religion and culture of the societies around the Sundarbans. The folk religion flourished around five foundations: 1) worship of a village God, 2) cult of ancestors, 3) fertility cult and phallic cult, 4) totem worship (plants), and 5) magic (Chaudhuri and

Choudhury 1994). Traces of these are still found in the communities living around the Sundarbans.

2.1.3.5 Threats

The Sundarbans today is about half the size it was two centuries ago (Curtis 1933, Choudhury 1968, Hussain and Acharya 1994). The mangrove ecosystem of the Sundarbans has grown in a delicate balance between the terrestrial and the marine ecosystems. Water salinity plays an important role to maintain this balance. The threats to the ecosystem and biodiversity of the Sundarbans are from different sources, some are anthropogenic and some are effects of climatological and deltaic changes/evolution. The anthropogenic factors are relatively easy to control.

Over-exploitation of the natural resources to meet the requirements of the growing population is a major threat to the Sundarbans. The mangrove forest has been reduced over the last 200 years for the expansion of agricultural lands and human settlements. However, the encroachment and fragmentation have been successfully stopped as a result of the successive growth of national and global awareness for biodiversity conservation, especially in the Sundarbans. The ODA (Overseas Development Authority, UK) (1985) inventory documented over-exploitation in the Bangladesh Sundarbans due to excessive harvesting (legal and illegal). It was reported that two economically-important species, i.e. *Heritiera fomes* and *Excoecaria agallocha*, had been depleted by 40% and 45% respectively since the 1959 inventory. A similar trend was observed in the Indian Sundarbans: a total of 322 km^2 of tidal mangroves was reported to be destroyed during 1960-1980 (Chaudhuri and Choudhury 1994). The scattered mangrove woodlands in the private lands around the Sundarbans used to serve as buffer zones. These lands have been almost entirely converted for prawn culture (Khan 2002). The effect of prawn culture is not only restricted to the buffer zones. The local people collect tiger prawn (*Penaeous monodon*) fry from the Sundarbans, when many non-target fish and crustacean fry are destroyed. The collection normally contains only 0.2% of the target prawn larvae, but the rest are non-target prawn larvae, finfish larvae and macrozooplankton, which are thrown away on the riverbank and destroyed (Sarkar and Bhattacharya 2003). There is no legal exploitation of the wildlife in the Sundarbans, but spotted deer (*Cervus axis*) is subjected to severe poaching. There is a good demand for its meat and hide. In the local markets, one kilogram of deer meat is sold for US $ 2-3, a high price (Khan 2002). The deer is quite common and easily visible, and hence much easier to poach. Tiger poaching is also reported rarely, but it is restricted due to the shy nature of the tiger and its thin distribution over the Sundarbans tract.

Changes in water salinity due to alteration of freshwater flow affects the mangrove communities. Mangrove species distribution is strongly influenced by the extent of freshwater influx either from rainfall or from rivers (Bunt *et al.* 1982). This is evident from the dominance of *Heritiera fomes* in the eastern Sundarbans (less saline area) and dominance of *Excoecaria agallocha* in the western Sundarbans (more saline area). Palaeontological evidence indicates that *H. fomes* and other less saline-tolerant plant species were abundant in the western Sundarbans about five thousand years ago (Blasco 1975), when the water was probably less saline. Some purely non-mangrove plant species like *Albizia procera*, *Mangifera indica*, *Artocarpus heterophyllus*, *Ficus* sp., *Phoenix sylvestris*, etc. are rarely seen in the eastern Sundarbans (M.M.H. Khan pers. obs.). The phenology and viability of mangrove seeds and propagules largely depend on salinity. The wildlife in the mangroves shows similar pattern; the feeding and breeding, as well as distribution, are related to salinity. The main reasons for the alteration of the flow of river water are construction of barrages and embankments, as well as the cuts to drive the flow in different directions. Two notable interventions are the Farakka barrage in the Ganges in West Bengal, India, and the Halifax cut between the Madhumati and Nabaganga rivers in Bangladesh. The Ganges-Kobodak irrigation project in Bangladesh, consisting of 38.8 km of flood-protection embankments and 1,655 km of large and small channels is another major intervention. About 3,700 km of earth embankments have been constructed in the upstream of the Bangladesh Sundarbans, enclosing 13,000 km^2 of land, to control saline water intrusion into agricultural fields. Over the last two centuries, a number of drainage systems have been constructed in the upstream of the Indian Sundarbans which have caused ecological changes in the Indian Sundarbans.

The sea-level rise due to global warming is a serious threat to the Sundarbans. The predicted rise of 83 cm by the year 2050 might be disastrous for the Sundarbans (WHO 1986). However, huge sediment supply from the upstream and the natural process of deltaic development might balance the sea level rise. The mangroves tend to migrate landward in the face of gradual sea level rise, but this process will be difficult in the Sundarbans area because human settlements and crop fields dominate the entire upstream area. Stable sea is needed for the existence of mangroves. There was no large mangrove swamps in the Holocene period or before because the seas were unstable (Hussain and Acharya 1994).

Although siltation has a positive role to combat sea level rise, siltation itself poses a real threat to the Sundarbans. Siltation blocks the creeks and consequently the nutrient cycle of the mangrove ecosystem. Creeks are in effect the blood vessels of the Sundarbans. Moreover, excessive siltation may result in respiratory shock (by blocking pneumatophores) and nutrient stress that reduce the growth or even cause death of the plants. Patches of dying *Heritiera fomes*, *Sonneratia apetala*, *Xylocarpus mekongensis* and *Bruguiera sexangula* are seen in the Sundarbans which are the results of excessive siltation.

Although still minor, pollution is a growing threat to the Sundarbans, with at least 20 insecticides, 18 fungicides and 2 rodenticides, together with different types of fertilisers being used in Bangladesh. These agro-chemicals are carried downstream in the Sundarbans and incorporated into the food chain with biological magnification at higher trophic levels (Hussain and Acharya 1994). Industrial waste is indiscriminately thrown into the river the upstream of the Bangladesh Sundarbans. Khulna Newsprint Mill alone continuously discharged about 4,500 m^3/ha of wastewater (ESCAP 1987). Oil spills in the Sundarbans from Mongla port (at the immediate upstream of the Bangladesh Sundarbans), as well as from ships and motorboats, are occasionally reported. Layers of black oil are seen in the water and ground as well as in the lower vegetation in the Sundarbans. In 1994, oil spills from a cargo ship caused instant mortality of mangrove seedlings, grasses, fish, shrimps and many other organisms. In the Indian Sundarbans, untreated sewage discharges from Calcutta are a considerable threat for the Sundarbans downstream.

Natural disasters like cyclones also cause a lot of damage to the Sundarbans, which are far from human control. About one-tenth of the global tropical cyclones occur in the Bay of Bengal (Gray 1968, Ali 1980). Many large trees are blown down and others face excessive loss of branches and leaves. After the most catastrophic cyclone in 1988, about 9,200,000 ft^3 of timber and 5,800,000 ft^3 of firewood were collected from the damaged trees in the Bangladesh Sundarbans. Deaths of many wildlife, including eight tigers, were also recorded (Bangladesh Forest Department 2000b).

2.1.3.6 Conservation

Despite excessive human pressure on the natural resources of the Sundarbans, the area is still relatively intact. This is mainly due to natural inaccessibility, fear of man-eating tigers and growing concern for biodiversity conservation. Moreover, the maximum capacity and effort of the Forest Department is involved to manage the forest and patrol regularly. Until now, relatively healthy fauna exists in the Sundarbans (Salter 1984). The Sundarbans is not only a unique national asset, but also of great international importance. As Seidensticker and Hai (1983) pointed out: ‘In the Sundarbans, tigers, deer, forest, and men are linked inseparably and so must be their management.’

The entire Sundarbans was declared a Reserved Forest as early as 1875-1876 (Hussain and Acharya 1994). Entry without permission was prohibited from that time. Moreover, fishing or collection of natural resources became subject of permits, and paying revenue to the Government through the Forest Department. The first working plan, including prescriptions for biodiversity conservation, came into force during 1893-1894. Subsequently, Curtis (1933), Chowdhury (1962) and some other experts prepared different working plans for the Sundarbans.

In order to conserve the biodiversity of the Bangladesh Sundarbans, the Government of Bangladesh established three wildlife sanctuaries (Sundarbans East, Sundarbans South and Sundarbans West) in 1977. Previously these three sanctuaries totally covered an area of 324 km^2. The total area was increased to 1,397 km^2 in 1996 and declared a World Heritage Site by UNESCO in December 1997. The wildlife sanctuaries are undisturbed breeding grounds, primarily for the protection of wildlife, inclusive of all natural resources such as vegetation, soil and water.

The Government of Bangladesh, with other international/national partners, took several projects in the Bangladesh Sundarbans. The outputs are scientific and realistic guidelines and initiatives for biodiversity conservation. Several projects were taken specifically for the tiger. Some major projects are: The Sundarbans Wildlife Management Plan: Conservation in the Bangladesh Coastal Zone, Integrated Resource Development of the Sundarbans Reserved Forest, Development of Wildlife

Conservation and Management, Project Tiger, Forest Resource Management Project (FRMP), and Sundarbans Biodiversity Conservation Project (SBCP).

Some scattered short-term studies in the Bangladesh Sundarbans gave valuable information, which played important roles to make long-term conservation projects successful, e.g. Hendrichs (1975), Whitaker (1982), Salter (1984), Blower (1985), Khan (1986b, 1987), Sarker (1986), Alcom and Johnson (1989), Moll (1990), Nuruzzaman (1990), etc.

The wildlife of the Bangladesh Sundarbans is protected under Bangladesh Wildlife Act 1974, and hence should not be killed or captured. Small-scale captive breeding programme for spotted deer and estuarine crocodile has been initiated at Karamjal, northern Sundarbans. Moreover, special measures have been taken to conserve the habitats of estuarine crocodile in Mrigamari and some other areas.

On the other hand, the entire Indian Sundarbans and the surrounding area is a Biosphere Reserve in order to protect the biosphere in its natural state. The total area is 9,630 km^2 of which mangrove forests cover 4,264 km^2 (Chaudhuri and Choudhury 1994). The main objectives of the Biosphere Reserve are to: 1) conserve diversity and integrity of plants, animals and micro-organisms; 2) promote research on ecological conservation and other environmental aspects; and 3) provide facilities for education, awareness and training for effective participation of the people living around the biosphere reserve. This reserve has four zones, i.e. core zone, manipulation zone, restoration zone and development zone. This reserve supports the largest single tiger population in India (Chaudhuri and Choudhury 1994). Other than the tiger, this reserve supports a number of threatened species like fishing cat, estuarine crocodile, olive ridley turtle, river terrapin, monitor lizards (*Varanus* spp.), etc. (Chaudhuri and Choudhury 1994). The wildlife is protected under the Wildlife Protection Act 1972.

There is one national park and three wildlife sanctuaries inside this Sundarbans Biosphere Reserve in India. Moreover, the Sundarbans National Park, one Wildlife Sanctuary (Sajnakhali) and some other areas are under the Project Tiger area (2,585 km^2; declared in 1973). The two main objectives of Project Tiger are to: 1) ensure maintenance of a viable population of tigers in India for scientific, economic, aesthetic, cultural and ecological values; 2) preserve for all time, areas of such biological importance as national heritage for the benefit, education and enjoyment of the people. After the establishment of Project Tiger area, the tiger population in the area has increased, or at least remained stable (Chaudhuri and Choudhury 1994). The Sundarbans National Park was declared in 1989 and the total area is 1,330 km^2. The area has been recognised as a World Heritage Site for its unique wilderness. Three Wildlife Sanctuaries are Sajnakhali, Lothian Island and Holiday Island. These were established in 1976. The total area covered by these three sanctuaries is 406 km^2. The sanctuaries support *Ceriops*, *Excoecaria*, *Avicennia*, etc. plant species. The areas mainly serve as the refuge for the tiger and its prey, i.e. spotted deer, wild boar, rhesus macaque, etc.

Under the Integrated Wasteland Project, the Government of West Bengal (India), with its partners, has initiated the ecological rehabilitation of 248 km^2 degraded forests and 28 km^2 of cleared land and mudflats in the Indian Sundarbans. The major objectives comprised afforestation, conservation of fragile areas, development of pasture, soil conservation, minor irrigation, cottage industries, and other socio-economic and ecological components.

In order to maintain healthy population of estuarine crocodile and olive ridley turtle, the Government of West Bengal has taken extensive captive breeding and re-introduction programmes. The estuarine crocodile scheme was initiated in the Indian Sundarbans in 1976. Based at Bhagabatpur in Lothian Island, it has become one of the principal crocodile breeding centres in India. The main focus of this centre is to reduce high mortality at the egg and newly-hatched stage. By 1990, this centre released more than 197 crocodiles in the Indian Sundarbans (Chaudhuri and Choudhury 1994). The same centre and Saptamukhi hatchery also engaged in artificial breeding and re-introduction of the olive ridley turtle. Banerjee (1985) reported that of 117 hatchlings that emerged from artificial nests at Bhagabatpur, 99 healthy hatchlings were released in water and 18 were segregated for further study.

The future of the biodiversity of the Sundarbans depends on the proper management of the entire area, especially the protected areas, the restoration and breeding programmes, and finally the national and international initiatives to save this unique and fragile ecosystem for the future generations.

2.2 GENERAL METHODS

2.2.1 Introduction

The general methods to collect and analyse data are described in this section and the specific methods used to study the prey density, prey selection, relative habitat use by tigers, breeding and litter size of tigers, and tiger-human interactions are discussed in the respective chapters.

The success of any research project depends to a large extent on the amount of forethought devoted to decision-making, before the observer even begins to look at his/her animal (Dunbar 1975). Hence, it is important to formulate good research plans and select appropriate methods before starting the formal data collection. It is also important to have the flexibility to adjust to the situation encountered.

2.2.2 Logistic Setup

A small houseboat (locally known as ‘jali boat’) and much smaller dinghy were rented for the entire study period. The houseboat was actually a locally-modified lifeboat of a big ship, which is safe in strong waves (quite common in the southern Sundarbans, near the sea) and is suitable for a few people to live inside. The dinghy was a locally-made wooden boat suitable for navigation in narrow creeks.

Varied types of equipment were used during the fieldwork and at the laboratory. A list of equipment and their respective uses are given below –

1. Garmin 12XL GPS (global positioning system): used to find directions, measure the lengths of transects and record the geographic locations of key points.
2. Bushnell Yardage Pro 800 infrared rangefinder: used to measure the sighting distance of prey groups/individuals from the basal line of transects.
3. Compass: used to find directions and measure the sighting angle of prey groups/individuals from the basal line of transects.

4. Nikon FG camera body with Sigma 28-105 mm and Nikkor 300 mm lenses, and Nikon SB-24 flashgun: for taking photographs.
5. Tasco 7-21 X 40 binoculars: for general observation of wildlife.
6. Lark JPT-2 (range: 0.1-200 g) beam balance: used to measure the weights of tiger scats.
7. Maximum-minimum thermometer, humidity meter, rain gauge and measuring cylinder: used to get the temperature, humidity and rainfall data.
8. Standard data sheets and notebooks: used to record the data.

2.2.3 Research Team Formation

Four experienced and physically-fit local men were employed as Field Assistants to assist me in the field. These people normally work in the Sundarbans and hence have profound experience with the tiger and its prey. One of them was an ex-poacher who quit poaching after surviving from a man-eating tiger attack. He (Abdur Rahman) and his three colleagues once went to the Sundarbans to poach trees when a tiger attacked them. Although he survived by defending himself with an axe, one of his colleagues had a serious injury and died the next day.

Three of the four Field Assistants always accompanied me in the forest while doing transects, scat collection, kill observation, and other activities, and one was always left in the houseboat (floating research camp) to take care of it and cook food for the team.

Two local schoolteachers were employed as Research Assistants to visit 50 local families in 10 villages in Mongla Upazilla (sub-district) under Bagerhat district, in order to record their daily protein intakes. The reason why the schoolteachers were selected is that they are acceptable to the local people, who do not hesitate to tell the truth about their consumption of all protein items, including tiger prey, to such reputable people, as opposed to ‘outsiders’.

2.2.4 Reconnaissance Survey

The reconnaissance survey was conducted in August 2001 in a few potential areas of the Bangladesh Sundarbans and some villages in the buffer zone. The areas visited were Burigoalini, Dhangmari, Sarankhola, Supati, Chandeshawr, Kochikhali, Katka, Dubla Island, Hironpoint and Mandarbari. Supati, Chandeshawr, Kochikhali and Katka are in the Sundarbans East Wildlife Sanctuary (WS), Hironpoint is in the Sundarbans South WS, Mandarbari is in the Sundarbans West WS, and the rest of the areas are not in any sanctuary. During the reconnaissance survey tiger signs and prey were commoner in the Sundarbans East WS. Moreover, the area was more diverse and relatively more suitable in terms of accessibility, local support from the forest offices and security. Based on these, the Sundarbans East WS was selected for intensive fieldwork.

A number of villages close to the Sundarbans were also visited in order to select some to conduct protein intake survey (in order to know what proportion of tiger prey people consume) on the local people. Finally, 10 villages in Mongla Upazilla (sub-district), several kilometres away from Mongla town were selected, mainly because of the convenience of communication. The selected villages were Colabari, Gaabbunia, Joymoni, Bouddamari, Burburia, West Chila, South Chila, Goalbunia, Gilar Khalkul and South Haldibunia. These villages were very close from my route to the main study site (Sundarbans East WS) and I had to stop off in Mongla town anyway, so it was convenient for me to monitor and supervise the activities of two Research Assistants in these villages while going to and returning from the main study site.

Although the entire Sundarbans, including buffer zone, was available for interviews, most of the interviewing took place in areas on the way to and from the Sundarbans East WS, and in the Sundarbans East WS. Since there is no permanent settlement in the Bangladesh Sundarbans, people who work there actually come from different villages located in the buffer zone. Some scattered visits to high tiger-human conflict areas (e.g. Burigoalini) and some other important areas of the Sundarbans (e.g. Sarankhola) were also planned to conduct interviews.

Based on the experience of the reconnaissance survey, which was a trial of the field application of methods, some necessary changes were made in the research design and methods. Although I had prior experience of the Sundarbans, it was limited to exploration.

2.2.5 Work Schedule

I worked in Cambridge from October 2000 to June 2001 (9 months), when I reviewed relevant literature, and selected research objectives and scientific methods. Then I went to Bangladesh, sought permission from Bangladesh Forest Department, and completed the logistic setup. The reconnaissance survey was conducted in August 2001, and monthly fieldwork started in September 2001, which continued until February 2003 (for 18 months). The effort was roughly uniform in different seasons, so that seasonal effects are equally represented in the data. From my home in Tangail (central Bangladesh; two hours drive from Dhaka) it took two days road travel to reach Mongla town. From there I used to visit local villages to arrange Research Assistants to collect data on protein intakes by local people. I bought supplies in Mongla for the next two weeks and loaded them on the houseboat. The next morning (travel in the Sundarbans is not allowed at night) we started by houseboat, with the dinghy tied to the stern, through the rivers and creeks of the Sundarbans and finally reached the main study site (Sundarbans East WS) in the afternoon. About two weeks were spent monthly in line-transect sampling for prey density and tiger signs as well as collecting scats, studying kills and interviewing people. Then it took three days to return to Tangail. I always brought with me dried scats and prey jaws of tiger kills to analyse and measure them at home. It took over three days to do these in a make-shift laboratory at home. The remaining five days of the month were spent in data entry and preliminary analysis, as well as in relaxation. Apart from this routine, some visits were made to different areas of the Sundarbans and the villages in the buffer zone to interview local people. An outline of the work schedule (while in Bangladesh) is given in Table 2.2.

Table 2.2 Time-budget for different activities in every month while in Bangladesh (September 2001-February 2003)

Monthly activity	**Days of the month**																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1. Tangail to Mongla road travel	█	█																												
2. Guide Research Assistants at the villages in Mongla Upazilla, and shopping for supplies			█	█																										
3. Mongla to Sundarbans East WS waterway travel					█																									
4. Line-transect sampling, scat collection, kill study, interviewing						█	█	█	█	█	█	█	█	█	█	█	█	█	█											
5. Sundarbans East WS to Tangail return journey																				█	█	█								
6. Scat analysis and study of jaws of tiger kills																							█	█	█					
7. Data entry and preliminary analysis of monthly data																										█	█	█	█	█

2.2.6 Data Collection

Data were collected directly in the field following different standard methods. It is very difficult to study quantitatively any animal in the Sundarbans, because the area is very inhospitable and impenetrable to people. Since working in the Sundarbans requires a houseboat and some field assistants, it is also very expensive. The fear of man-eating tigers, poisonous snakes [king cobra (*Ophiophagus hannah*), monocellate cobra (*Naja kaouthia*), binocellate cobra (*Naja naja*), etc.] and bandits are some of the sources of fear to people. During my fieldwork I had the experience of being chased by a tiger and once stepped over a king cobra; it is the largest poisonous snake in the world that can kill an elephant with its lethal bite.

The data were collected by following the methods –

2.2.6.1 Line-transect Sampling for Prey

The population estimation of large herbivores and many other animals are popularly done by line-transect sampling (Eberhardt 1978, Burnham *et al.* 1980, Drummer and McDonald 1987, Buckland *et al.* 1993, Lancia *et al.* 1994, Buckland *et al.* 2001, Thomas and Karanth 2002). Transects were randomly located throughout each of the four different habitat types (mangrove woodlands, grasslands, sea beaches, and transitional zones) in the Sundarbans East WS. Whenever a group/individual of a prey animal was sighted, records were taken on five parameters: 1) sighting distance, 2) sighting angle from the basal line of the transect, 3) name of the prey species, 4) group size, and 5) group composition. Details of this method are in Chapter 3.

2.2.6.2 Scat Analysis and Kill Study

Scat analysis has been applied extensively in carnivore food-habit studies either alone (Norton *et al.* 1986, Emmons 1987, Rabinowitz 1989, Karanth and Sunquist 1995, Hersteinsson and Macdonald 1996, Ranawana *et al.* 1998) or in combination with data from predator kills (Schaller 1967, 1972; Kruuk 1972, Sunquist 1981, Johnsingh 1983). In the laboratory I broke each of the scats and carefully soaked them to separate prey remains. The remains were then identified by comparing with the reference collection. In the field the kills were observed and records were taken on the name of the species killed, age and health. Details of these methods are in Chapter 4.

2.2.6.3 Line-transect Sampling for Tiger Signs

Sign surveys via line-transect sampling have been successfully done by many specialists (Gibson and Hamilton 1983, Garshelis *et al.* 1999, Cuesta *et al.* 2002, Augeri 2004 in prep.). I used this method to record the relative density of tiger signs in four major habitat types (mangrove woodlands, grasslands, sea beaches and transitional zones) available in the Sundarbans East WS. Transects were randomly located throughout each of the four different habitat types. Since the width of the transect was fixed (5 m), there was no need to record sighting distance and sighting angle. The types of signs recorded were: 1) movement, 2) feeding, 3) resting, 4) defaecation, 5) interaction, 6) scratch-scent-urinal, and 7) 'others' (hunting, drinking, etc.). Details of this method are in Chapter 5.

2.2.6.4 Male-female and Mother-cub(s) Observations

Tiger male-female and mother-cub(s) interactions, and calls were treated as the indicators of breeding peak of tigers. Since the male-female and mother-cub(s) could be identified from pugmarks (Panwar 1979, Das and Sanyal 1995, Singh 1999), records were taken on male-female and mother-cub(s) interactions in different months on the basis of signs. These data were enriched by data from interviewing local people. People were asked about the sighting months of tiger male-female and mother-cub(s) interactions. The number of cubs was always recorded during sign observations and interviewing. Moreover, tiger calls were recorded in the field, because tigers call more often during the peak mating period than any other time (Sunquist and Sunquist 2002). Details of these methods are in Chapter 6.

2.2.6.5 Interviewing, Forest Department Records and Newspaper Reports; Protein Intake Survey

Information was mainly collected by interviewing local people, but relevant newspaper reports and Forest Department records were also used to enrich the data on tiger-human interactions. Information was collected in these ways by many people in studying interactions between big cats and humans (Beier 1991, Oli *et al.* 1994, Saberwal *et al.* 1994, Baogang *et al.* 1999, Nyhus and Tilson 2004). In order to get primary data on the intake of different animal protein by local people, two of my Research Assistants visited 50 local families every day and recorded the quantity and market price of different animal protein items (including those coming from tiger prey) consumed by each of the families. Details of these methods are in Chapter 7.

2.2.7 Data Analysis

Since there was no electricity in the field, it was not possible to enter data into the computer while I was in the field. Moreover, I was too exhausted at the end of the day and could not do anything but review raw data, and write *ad libitum* notes, general observations and other experiences in my diary.

Every month I spent the last five days at home in Tangail where I entered monthly data on the computer as much as possible and conducted preliminary analysis in order to have an idea of monthly results. After completing fieldwork I returned to Cambridge where I completed data entry and started analyses. All data were entered into spreadsheets of either Microsoft Excel or Statistical Package for the Social Sciences (SPSS; Nie *et al.* 1975). All diagrams were plotted using Microsoft Excel.

Almost all of the statistical nomenclatures used in this dissertation followed those of Siegel and Castellan (1988). The homogeneity of variance and normality of the data were checked before doing any statistical test. Non-parametric analyses were mainly used, because the independence and distribution of these kinds of ecological data are questionable (Siegel and Castellan 1988). Test probabilities of all statistical tests were two-tailed.

The non-parametric Chi-square (χ^2) test was most commonly done in order to examine whether some non-normally distributed frequencies were significantly different from each other or not. The non-parametric Kruskal-Wallis (H) test was also done to examine whether different means were significantly different or not. The Pearson correlation (*r*) model was used to measure the form of relationship between two variables. This model aims at fitting a straight line in a scatterplot, showing the relationship between two variables under test (Kent and Coker 1992). In all statistical tests, the level of significance was at 95%.

CHAPTER 3 PREY POPULATION STRUCTURE AND DENSITY

3.1 INTRODUCTION

Prey depletion is a major factor driving the current decline of wild tigers (Seidensticker 1986, Rabinowitz 1993, Karanth and Stith 1999) and hence the status of the prey species is a crucial indicator of the status of the tiger. The prey population density and biomass have been used to investigate the complex relationship between a species and its environment (Brown 1984) and inter-specific relationships in a community (Sinclair *et al.* 1990). The prey species are more visible and relatively easy to study than the carnivores that prey on them. Tigers in the mangroves of the Sundarbans are least known to scientists, because they are extremely elusive.

The conservation of large herbivores is crucial, because, apart from being important economic, nutritional and aesthetic resources, large herbivores directly and indirectly affect forest structure, regeneration, and consequently other species (Norton-Griffiths 1979, Crawley 1983, Kortlandt 1984, Owen-Smith 1987, Karanth and Sunquist 1992). Large cervids comprise nearly three-quarters of the biomass contribution to tiger diets in most parts of its geographic range (Sunquist *et al.* 1999). Although there are a few estimates of large prey species population in the Sundarbans of Bangladesh, these were not produced by any proper scientific method. Lack of reliable estimates of the prey species in the Sundarbans required a scientific estimate of the prey population structure and density, which will serve as baseline information for proper management of the wildlife resources of that area. Moreover, the scientific estimate of the prey population can be used to compare the prey biomass richness of different habitats and to infer the carnivore density. Proportions of different age-sex classes of a prey population denote the status of the population, indicating whether it is increasing, decreasing, or remaining stable (Schaller 1967).

The general objective in this Chapter is to *assess the population structure and evaluate the population density of different potential prey species in the Sundarbans*. The specific questions are –

1. What are the grouping tendencies of different prey species?
2. What is the status of age-sex classes of different prey species?
3. What is the group size, group density and individual density of different prey species?
4. What is the biomass density of different prey species?
5. Based on the prey density, what is the inference of tiger density?

3.2 METHODS

3.2.1 Prey Grouping Tendencies, Age-sex Classes, Group Size, Group Density and Individual Density

Line-transect sampling (Eberhardt 1978, Burnham *et al.* 1980, Drummer and McDonald 1987, Buckland *et al.* 1993, Lancia *et al.* 1994, Buckland *et al.* 2001, Thomas and Karanth 2002) has been used extensively for estimating animal densities for a variety of taxa and habitats (Varman *et al.* 1995) and it is a popular method of studying animal density of visible animals like large herbivores. Unlike sampling methods based on fixed-width transects, the line-transect method does not assume that all objects within a specified width are detected. Rather the assumption is that objects on the line are seen with probability of 1 and that the number of objects sighted away from the line decreases in some way (Varman and Sukumar 1995).

Line-transect sampling methods rely on four basic assumptions that must be met to ensure valid results: 1) animals are detected at their initial location, 2) all animals located on (or above) the transect line are detected, 3) distances are measured accurately and 4) transects are located randomly in the habitat (Buckland *et al.* 2001, Thomas and Karanth 2002, Morrogh-Bernard *et al.* 2003). During this study, three local assistants and I concentrated on detecting animals at their initial location in order to meet assumption 1. The sighting distance of the centre of the group was recorded by using a rangefinder. If the group moved away before measuring the sighting distance, the rangefinder was targeted to any 'object' or the ground at the initial location of the group. Transects were conducted independently in four different habitat types in order to avoid bias of differential visibility. In order to satisfy assumption 2, four people conducted the sampling, so that all animals exactly on the transect line (and all animals at a reasonable distance from the base transect line) were located. Examination of prey-group sighting histograms produced by DISTANCE did not provide evidence that groups were missed at zero distance. The line length and the sighting distance of animal groups were measured by using a GPS unit and an infrared rangefinder, but the accuracy of these were ±15 m and ±1.8 m, respectively. The GPS readings were always taken in relatively open areas in order to acquire more satellite connections, i.e. more accurate readings. Since the Sundarbans is generally a flat land, the aerial distance was a close representation of the actual distance covered in line-transects. Obstacles were avoided as much as possible while using the rangefinder. These ensured that assumption 3 was adequately met. All transects were located randomly throughout each of the four habitat types in the study area in order to fulfil assumption 4, but a very few areas (negligible in comparison to the total area) were avoided because of extreme inaccessibility or there were many rivers and creeks.

The sample sizes for all species, except wild boar (*Sus scrofa*) and lesser adjutant (*Leptoptilos javanicus*), were more than the minimum recommended of 40 groups (Burnham *et al.* 1980), which means that the results are statistically reliable. The sample size for wild boar was 24, but for lesser adjutant it was 37, which was close to the minimum recommended sample size.

It is said that at least 15-20 transects are required (in each habitat type when different habitats are compared) for reliable estimates of variance (Thomas and Karanth 2002, Karanth *et al.* 2003). In this study, this assumption was met more than adequately since a total of 352 transects of variable lengths were placed in the four different habitat types (189 in mangrove woodlands, 63 in grasslands, 32 on the sea beaches and 68 in transitional zones).

A total of 466.8 km was covered by all line-transects in 18 months (September 2001-February 2003), i.e. the average length of each transect was 1.3 km (range 0.5-3.6 km) and the monthly average of distance covered by transects was 25.9 km. The sampling effort was uniform for different seasons of the year. The work was mainly conducted in the mornings (0600-1000 h) and afternoons (1500-1900 h) when the animals were most active and visible. Moreover, because animals are more active during low tide, tide condition was also considered while doing transects. Since many parts of this mangrove forest were very dense and there were many rivers and creeks, it was not possible to make very long transects. Stratified random sampling (Buckland *et al.* 1993) was designed; hence, at first four habitat types of the Sundarbans East Wildlife Sanctuary (WS) were demarcated on the basis of vegetation maps (prepared by Sundarbans Biodiversity Conservation Project, Bangladesh Forest Department) and my preliminary survey. The maps were based on recent satellite images and aerial photographs. Then the transect lines were placed randomly throughout each of the four habitat types. This was done by putting some random points on the map to start the transects, but the directions of transects were chosen from the starting points on the basis of accessibility. Few areas were not suitable for making transects due to inaccessibility and only those areas had to be avoided. Transects in each month were normally placed at a distance great enough apart to avoid the same prey group being detected on two neighbouring transects, although this is not usually critical (Buckland *et al.* 1993). A minimum of 4.5 km of transects were established in every month in each of these four habitat types. The four major habitat types were defined as follows –

1) Mangrove woodlands – areas with mangrove trees like *Heritiera fomes*, *Excoecaria agallocha*, *Sonneratia apetala*, etc., covering about 70% of land area of the Sanctuary and including narrow creeks because these are intertwined with mangrove woodlands.
2) Grasslands – open meadows with *Imperata cylindrica*, *Acrostichum aureum*, *Myriostachya wightiana*, etc., covering about 10% of land area of the Sanctuary.
3) Sea beaches – relatively open sandy and muddy areas along the seaside, covering about 6% of land area of the Sanctuary.
4) Transitional zones – areas that fell in none of the above-mentioned three categories, such as areas between mangrove woodlands and grasslands, covering about 14% of the land area of the Sanctuary.

My three local assistants and I walked along transects at a roughly uniform speed of 1.3 km/h and carefully detected the prey groups. A compass and a GPS (Garmin 12XL) were used to make sure that our walk was straight. The data collected for each prey species included the perpendicular line length traversed and the number of groups of animals detected. The length of each transect (in km) was calculated by using a GPS.

For each detection of the animal groups, the group size, sighting distance (in m, by using a Bushnell Yardage Pro 800 infrared rangefinder), and sighting angle (by using a compass) (Burnham *et al.* 1980, Karanth and Sunquist 1992, Buckland *et al.* 1993, Kumar 2000, Buckland *et al.* 2001) were recorded. Animal groups were used as the analytical unit since individual data tend to underestimate true variance (Southwell and Weaver 1993).

Although the observed 'groups' were actually 'clusters' (Burnham *et al.* 1980), which do not always represent the social groups, a large number of observations made it adequate for population estimation (Karanth and Sunquist 1992). Prey species groupings were categorised as solitary animals, family associations (2-3 individuals) consisting of pairs or adult females with their juveniles and young, small groups (4-10 individuals), medium groups (11-30 individuals) and large groups (30+ individuals) (Karanth and Sunquist 1992). Age-sex classes were recorded whenever the animals could be observed adequately. Individual animals were classified as adult males, adult females, juveniles [smaller than adults; in case of spotted deer (*Cervus axis*) these were mainly yearlings], and young (smaller than juveniles, commonly in close association with parents; in case of spotted deer these were mainly fawns) on the basis of the physical characteristics described elsewhere (Schaller 1967, Prater 1971, Eisenberg and Lockhart 1972, Mishra 1982a, Grimmett *et al.* 1998, Daniel 2002). The number of spotted deer fawns (young) sighted in different months was tested statistically (non-parametric χ^2 test) in order to examine whether the monthly-counts were significantly different or not.

DISTANCE 4.0 software (www.ruwpa.st-and.ac.uk/distance) was used to analyse the data derived from line-transects to determine the mean group size [E(S)], group density (DS: no. groups/km^2), individual density (D: no. individuals/km^2) and total population (N) of each of the potential prey species, together with their standard errors (SE), in the land area of the Sundarbans East WS. This automated technique uses distance-sampling data (in this case: total transect length, number of animal groups observed, group size and the perpendicular distance of each group from the transect base line) to estimate density, and is reliable where transect lengths are known accurately (Cassey and McArdle 1999). DISTANCE attempts to fit several possible models to the data in order to estimate the effective transect strip width, and selects the model with the best fit according to the Akaikes Information Criterion (AIC; Buckland *et al.* 1993). Different models were selected to achieve best results. Since the visibility was different in four different habitat types, the group size and density estimates for spotted deer were performed independently for each habitat type, but the estimates could not be done independently for other prey species, because of the low number of observations. Since half of the Sanctuary (also the entire Sundarbans) is under deep water, in the form of estuaries and large rivers (the prey species frequently cross these water bodies), half of the density of the land area was considered as the overall density for the Sanctuary, so that the result could be compared with other estimates. Moreover, the density estimate of only the land area could be misleading (over-estimate) about the overall density in the Sundarbans.

3.2.2 Prey Biomass Density

The number of individuals of each prey species per unit area multiplied by their average weight provides an estimate of the biomass supported by a certain habitat, a useful index for ultimately determining the optimum carrying capacity of the range (Schaller 1967, Berwick 1974, Karanth and Sunquist 1992, Khan *et al.* 1995). It also provides a picture of the relative proportions of biomass contributed by different species in the community (Mckay and Eisenberg 1974, Johnsingh 1983). The mean biomass density (kg/km^2) of prey in the study area was calculated by multiplying the mean individual density (D) of each species by its average unit weight, which was estimated from published data on body weights. Since half of the Sanctuary is under deep water, half of the density of the land area was considered as the overall density for the Sanctuary. Spotted deer, wild boar and rhesus macaque (*Macaca mulatta*) weights were from Karanth and Sunquist (1992), who estimated the average unit weight of these species from other published sources (Schaller and Spillett 1966, Schaller 1967, Eisenberg and Seidensticker 1976, Tamang 1982, Johnsingh 1983). Johnsingh (1983) divided the individual density according to the sex ratio of that particular species and then multiplied this by the average weight of the male and female. Karanth and Sunquist (1992) directly multiplied the individual density with the average unit weight of the species, which was done in this study. In case of lesser adjutant, red junglefowl (*Gallus callus*) and ring lizard (*Varanus salvator*), the minimum adult weights were considered from recent data on the websites (www.ndngrd.com, www.international.tamu.edu, www.animaldiversity.ummz.umich.edu). Over-estimation of the biomass density, caused by attributing to the young the weight of an adult, is more or less compensated for by the underestimation of the weight of the oldest individuals (Bourliere 1963). The mean biomass densities of prey were calculated in this way by many authors (e.g., Johnsingh 1983, Karanth and Sunquist 1992).

3.2.3 Tiger Density

The predator and prey species normally live in balance, hence the status of the prey is an indicator of the status of the predator that prey on them. A positive correlation between tiger and prey densities was described quantitatively in a number of studies (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993, Karanth *et al.* 2004). Tiger densities in protected habitats are likely to be mediated chiefly by prey abundance rather than inter-specific social dominance and competitive exclusion (Karanth *et al.* 2004). Thus, it is possible to infer tiger density from its prey abundance. Since the tiger is the only large carnivore in the Sundarbans, the prey density is a good predictor of tiger density.

Based on the reports of Karanth and Stith (1999), and Karanth *et al.* (2004), it was assumed that tigers crop about 10% of large ungulate populations annually at a kill rate of 50 prey animals/tiger/year. Thus, based on large ungulate prey density P_s, the tiger density T_s in the location *s* (Sundarbans East WS) can be inferred from the following equation –

$$T_s = \frac{0.10}{50} P_s \delta_s$$

where δ_s is a mean one random variable (since this is a multiplicative model, $\delta_s = 1$).

It is known that the southern part of the Sundarbans has a higher density of tigers than the northern part (Sarker 1982, Khan 2004a). In the Bangladesh Sundarbans, all three Sanctuaries are located in the south, and in the Indian Sundarbans, the core area of the Sundarbans Tiger Reserve is situated in the south. Assuming that the northern half of the entire Sundarbans has a tiger density half that of the southern half, an arbitrary figure of the total tiger population has been inferred.

3.3 RESULTS

Potential tiger prey species sighted in the Sundarbans East WS were spotted deer, barking deer (*Muntiacus muntjak*), wild boar, rhesus macaque, Oriental small-clawed otter (*Aonyx cinerea*), lesser adjutant, red junglefowl, ring lizard, grey lizard (*Varanus bengalensis*), etc. However, barking deer, Oriental small-clawed otter and grey lizard were seen only a few times during the fieldwork and hence nothing could be concluded about their population structure and density.

3.3.1 Prey Grouping Tendencies

The grouping tendencies of the potential prey species of the tiger in the Sundarbans East WS shows that the spotted deer is a highly-social animal (Table 3.1) and seems to prefer living in groups, where 73% of my observations were groups of varying size. The largest group had 94 individuals in a grassy meadow, but this was perhaps a temporary merger of a few groups while grazing and was probably not the social group. While grazing herds come close together and sometimes apparently form a congregation of even 300 deer, once they leave the grazing ground, or are alarmed, they split into their original groups. During this study, buck or doe-fawn herds were rarely sighted. The largest buck herd was 13 individuals and the largest doe-fawn herd was 26 individuals. The rhesus macaque is also basically a group-living animal: 54% of the observations were groups of varying size (Table 3.1). Although a large percentage (46%) of singles were sighted, most of them were stray males. The largest group had 39 individuals. The wild boar (72% observations), lesser adjutant (85% observations), red junglefowl (86% observations) and ring lizard (96% observations) were mainly seen solitary.

Table 3.1 Grouping tendencies of different prey species in the Sundarbans East Wildlife Sanctuary. Here n = total number of groups observed

Species	**Range**	**n**	**% groups in each group size class**				
			1	**2-3**	**4-10**	**11-30**	**30+**
Spotted deer	1-94	434	24	31	30	11	4
Wild boar	1-5	25	72	20	8	-	-
Rhesus macaque	1-39	98	46	21	25	6	2
Lesser adjutant	1-5	39	85	10	5	-	-
Red junglefowl	1-3	77	86	14	-	-	-
Ring lizard	1-2	80	96	4	-	-	-

3.3.2 Prey Age-sex Classes

Only 10% of the observed spotted deer groups and 11% of the rhesus macaque groups could not be classified on the basis of age-sex, because the individual animals could not be observed properly. All age-sex classes of the wild boar and red junglefowl were identified, but the sex of lesser adjutant and ring lizard could not be identified because of their lack of sexual dimorphism. Regarding the age distributions, the proportion of pre-reproductive age classes (juveniles and young) were 28% in spotted deer, 21% in wild boar, 29% in rhesus macaque, 4% in lesser adjutant, 1% in red junglefowl and 11% in ring lizard (Table 3.2). The male-female ratio was 47:100 in spotted deer, 72:100 in wild boar, 87:100 in rhesus macaque and 175:100 in red junglefowl, respectively (Table 3.2). Thus, there were more females than males for spotted deer, wild boar and rhesus macaque, but less females than males for red junglefowl. This sex ratio might be biased due to differences in male-female visibility, especially for red junglefowl where the male is bigger and more brightly coloured and hence more visible than the female.

Table 3.2 Proportions of different age-sex classes in different prey species in the Sundarbans East Wildlife Sanctuary. Here n = total number of animals classified

Species	**n**	**% in each category**		
		Adult (♂ + ♀)	**Juvenile**	**Young**
Spotted deer	1,972	72 (23 + 49)	21	7
Wild boar	43	79 (33 + 46)	16	5
Rhesus macaque	336	71 (33 + 38)	23	6
Lesser adjutant	49	96	4	-
Red junglefowl	90	99 (63 + 36)	1	-
Ring lizard	92	89	10	1

Statistical analysis shows that the number of spotted deer fawns (young) sighted during the study period (n = 138) are significantly different across months ($\chi^2 = 47.74$, df = 17, $p < 0.001$). The number of deer fawns counted in every month shows that fawns are probably born throughout the year, but about 85% are born during January-July (Figure 3.1), i.e. late winter and early summer. No diagram has been produced on the sightings of young of other prey species, because of small sample sizes.

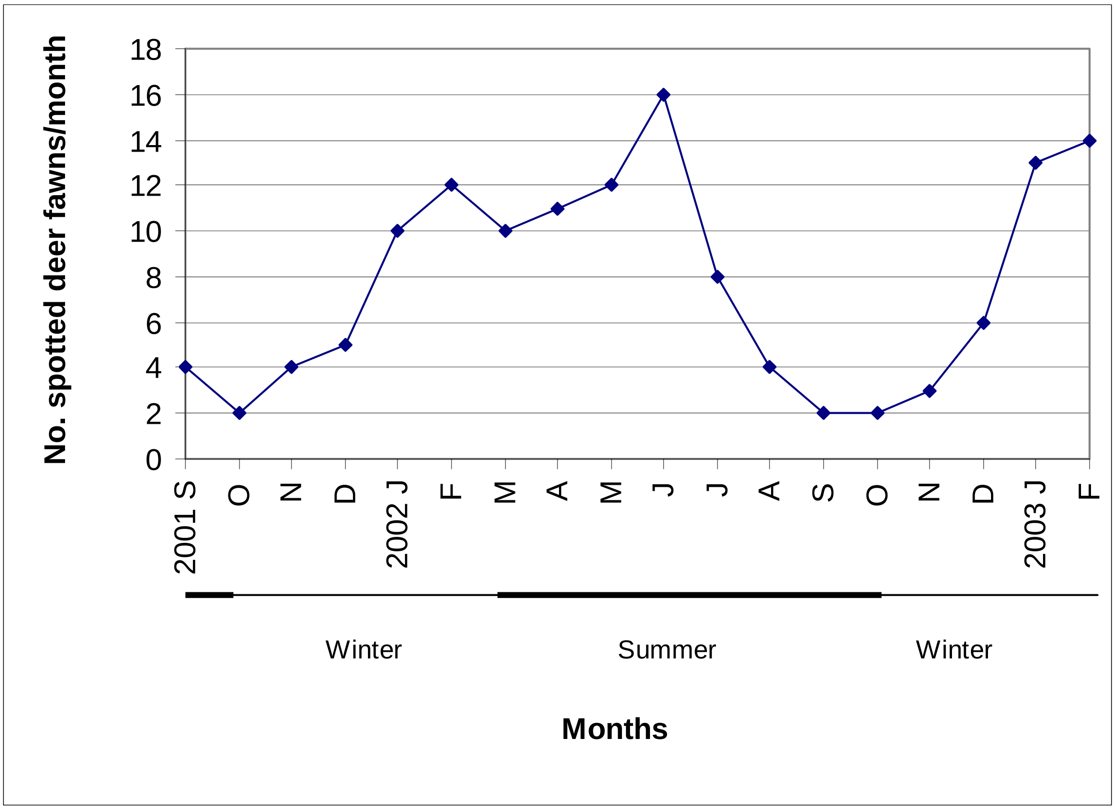


Figure 3.1 Number of sightings of spotted deer fawns (young) in different months in the Sundarbans East Wildlife Sanctuary.

3.3.3 Prey Group Size, Group Density and Individual Density

Estimates of the mean group size, group density, individual density and total population of different prey species on the land of the Sundarbans East WS (156 km^2) are given in Tables 3.3 and 3.4. Since 50% of the total area of this Sanctuary is under deep water in the form of estuaries and large rivers, the overall prey density in the Sanctuary is about half of the figures mentioned in Tables 3.3 and 3.4, i.e. the overall individual densities were spotted deer 20.9, wild boar 0.5, rhesus macaque 6.5, lesser adjutant 0.6, red junglefowl 7.0 and ring lizard 7.9/km^2.

The spotted deer density was much lower on the sea beach (5.8/km^2) compared to the other three habitat types. The highest density was in the transitional zones (56.3/km^2). It is evident that the spotted deer is the dominant prey species in the Sundarbans.

Table 3.3 Spotted deer density on the land of the Sundarbans East Wildlife Sanctuary. Here L = total length of transect lines, n = number of observations, E(S) = group size, DS = group density (no. groups/km^2), D = individual density (no. individuals/km^2), N = total population, and se = standard error

Habitat type	Total area (km^2)	DISTANCE model selected	L (km)	n	E(S) (±se)	DS (±se)	D (±se)	N (±se)
Mangrove woodland	110	Half-normal/ Hermite	209.7	246	5.3 (±0.5)	7.9 (±2.0)	41.6 (±12.3)	4,577 (±1,349)
Grassland	15	Uniform/ Cosine	89.8	83	7.8 (±1.1)	6.0 (±1.2)	46.8 (±11.7)	702 (±175)
Sea beach	10	Uniform	81.4	11	3.5 (±1.1)	1.7 (±0.8)	5.8 (±3.2)	58 (±32)
Transitional zone	21	Half-normal	85.9	70	6.3 (±0.9)	9.0 (±1.6)	56.3 (±13.0)	1,183 (±273)
Grand total/ Overall	**156**	**-**	**466.8**	**410**	**5.7**	**7.3**	**41.8**	**6,520**

N.B. Overall E(S) is the mean of E(S)s in four different habitat types, overall D is the grand total population divided by the total area, and overall DS is overall D divided by overall E(S). If DS is multiplied with E(S) it does not show the exact figure of D in this table, because all numbers have been converted to one decimal place from two decimal places.

Table 3.4 Wild boar, rhesus macaque, lesser adjutant, red junglefowl and ring lizard density on the land of the Sundarbans East Wildlife Sanctuary. Here L = total length of transect lines, n = number of observations, E(S) = group size, DS = group density (no. groups/km^2), D = individual density (no. individuals/km^2), N = total population, and se = standard error

Species	Total area (km^2)	DISTANCE model selected	L (km)	n	E(S) (±se)	DS (±se)	D (±se)	N (±se)
Wild boar	156	Uniform/Cosine	466.8	24	1.4 (±0.2)	0.6 (±0.2)	0.9 (±0.3)	139 (±41)
Rhesus macaque	156	Uniform/Cosine	466.8	94	4.1 (±0.7)	3.2 (±0.6)	12.9 (±3.2)	2,009 (±491)
Lesser adjutant	156	Hazard rate	466.8	37	1.2 (±0.1)	0.9 (±0.3)	1.1 (±0.4)	178 (±59)
Red junglefowl	156	Uniform/Cosine	466.8	73	1.2 (±0.1)	12.1 (±3.5)	14.0 (±3.6)	2,181 (±565)
Ring lizard	156	Hazard rate	466.8	76	1.0 (±0.0)	15.1 (±3.3)	15.7 (±3.4)	2,441 (±537)

N.B. If DS is multiplied with E(S) it does not show the exact figure of D in this table, because all numbers have been converted to one decimal place from two decimal places.

3.3.4 Prey Biomass Density

Prey biomass density estimate in the Sundarbans East WS (Table 3.5) shows that the bulk of prey biomass is the spotted deer, which is 94.7% of the total standing prey biomass. Three mammalian prey species (spotted deer, wild boar and rhesus macaque) together form 98.6% of the standing prey biomass (Figure 3.2).

Table 3.5 Biomass density of different prey species in the Sundarbans East Wildlife Sanctuary

Species	Weight (kg)/ individual	Biomass density (kg/km^2) on the land	Overall biomass density (kg/km^2) in the Sanctuary
Spotted deer	47[1]	1,965	983
Wild boar	32[1]	29	15
Rhesus macaque	4[1]	52	26
Lesser adjutant	4[2]	4	2
Red junglefowl	0.6[3]	8	4
Ring lizard	1[4]	16	8
Total	**-**	**2,074**	**1,038**

N.B. [1]Source: Karanth and Sunquist (1992). [2]Source: <www.ndngrd.com>. [3]Source: <www.international.tamu.edu>. [4]Source: <www.animaldiversity.ummz.umich.edu>.

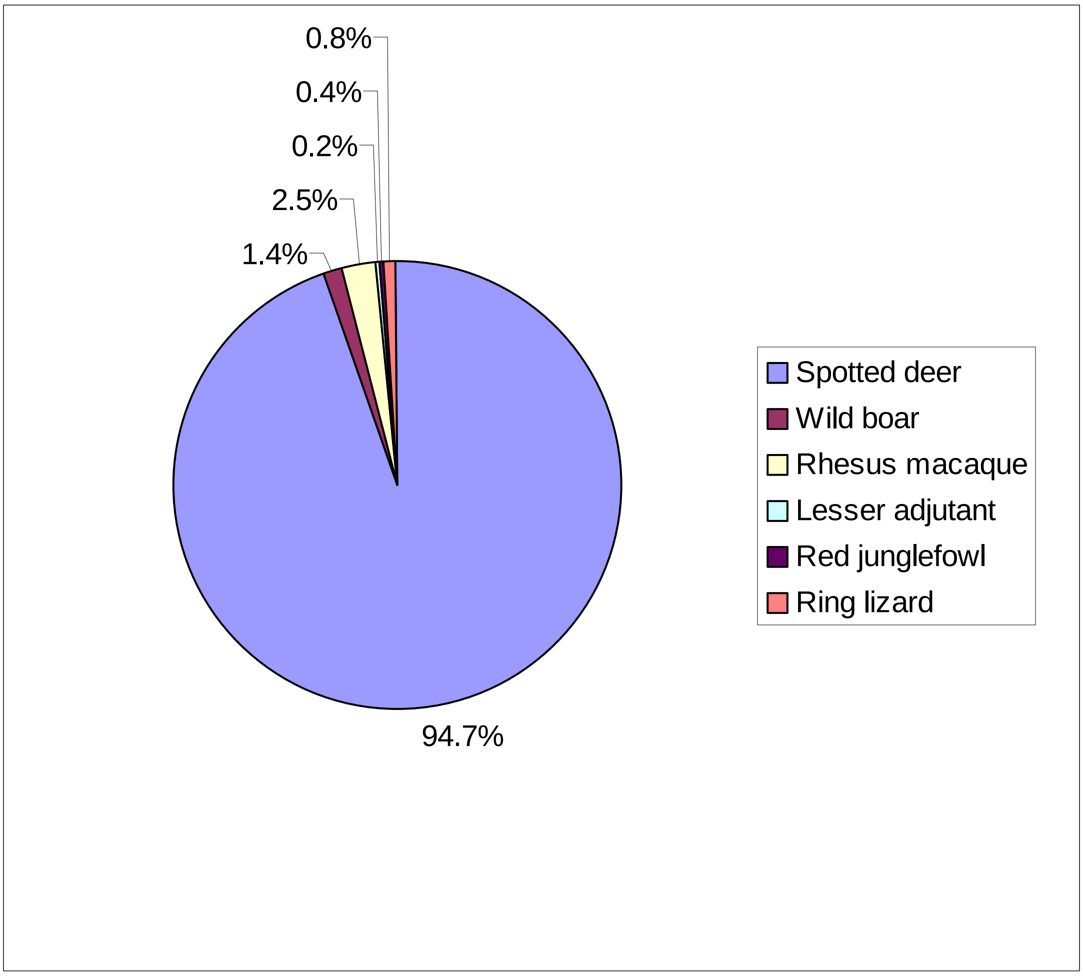


Figure 3.2 Proportions of the standing biomass density of different prey species in the Sundarbans East Wildlife Sanctuary.

3.3.5 Tiger Density

Large ungulate prey density (i.e. spotted deer and wild boar) on the land of the Sundarbans East WS was calculated at 42.7 individuals/km^2, but because 50% of this Sanctuary is under water, the overall density in the Sanctuary (312 km^2) stands at 21.4 individuals/km^2. All three Sanctuaries in the Bangladesh Sundarbans, and the entire Sundarbans itself, have roughly 50% of the area under deep water in the form of estuaries and large rivers. Both the tiger and its prey frequently cross these water bodies. Based on the overall density of large ungulate prey, the tiger density in the Sundarbans East WS was inferred at 4.3 tigers/100 km^2 (excluding cubs). Using this inference of tiger density in a high density area (southern Sundarbans), and assuming that the northern half of the Sundarbans has half of this density, I arbitrarily assume that there might be around 323 tigers (excluding cubs), to a rounded figure 300 tigers, in the entire Bangladesh and Indian Sundarbans (ca. 10,000 km^2) – more specifically: 200 in the Bangladesh part (ca. 6,000 km^2) and 100 in the Indian part (ca. 4,000 km^2). Since the inference on total population of tigers was based on too many assumptions, this should not be treated as a scientific estimate.

3.4 DISCUSSION

3.4.1 Prey Grouping Tendencies

Prey animals that live solitary or in small groups are more vulnerable to predation (van Orsdol 1981), because they do not have a communal alarming system and they cannot successfully distract the predator's attention from a particular individual as a target. Hence, it is important to know prey grouping tendencies, which are related to the tiger's hunting success.

Tamang (1993) reported an average group size of the spotted deer at 5.4 in the Bangladesh Sundarbans. My estimate of the average group size is very close to his estimate, but the proportions of different group sizes were quite different. According to Tamang (1993), the proportions of the spotted deer in group sizes of 1, 2-3, 4-10, 11-30 and 30+ are 6, 36, 46, 11 and 1%, respectively. Only for groups of 2-3 and 11-30, the ratios are similar to my findings (see Table 3.1).

According to Islam (2001) and Reza *et al.* (2002a), the mean group sizes of spotted deer are 10.8 and 7, respectively, in the southern part of the Sundarbans East WS, which are higher than my estimate of group size. Reza *et al.* (2002a) mentioned a range of group sizes from 2 to 137, i.e. no solitary deer were sighted, but Tamang (1993) and I estimated the proportions of group size of one animal as 6% and 24% of all observations. According to Hendrichs (1975), in the Sundarbans the social unit of the spotted deer population is the single animal except females with their offspring. This supports the fact that in the Sundarbans, spotted deer are very commonly seen solitary. The mean group size of the wild boar was estimated by Reza *et al.* (2002a) as 2 (range = 1-15), which is again higher than my estimate. Reza *et al.* (2002a) mentioned that the average group size of the rhesus macaque is 11.9, with a range of 3-41, i.e. no solitary macaques were sighted. Like spotted deer and wild boar, the estimate for the rhesus macaque is also higher than my estimate, but the highest proportion of group size 1 (46%) was found in my study compared with other group size classes (see Table 3.1).

Eisenberg and Lockhart (1972) found less than 4% solitary individuals and 38% of groups of 3-6 individuals of spotted deer in Wilpattu, Sri Lanka. I found a much higher percentage (24%) of solitary individuals in the Sundarbans East WS, but groups of 3-6 were commoner, hence the average group size was 5.7.

Karanth and Sunquist (1992) reported the grouping tendencies of the spotted deer, wild boar, rhesus macaque and other prey species in the tropical forests of Nagarhole, India. They found the highest percentage (37%) of group size 4-10 in spotted deer, highest percentage (51%) of group size 1 in wild boar and highest percentage (56%) of group size 4-10 in rhesus macaque. In comparison to these findings, I found the highest percentage (31%) of group size 2-3 in spotted deer, highest percentage (72%) of group size 1 in wild boar and highest percentage (46%) of group size 1 in rhesus macaque. It is notable that all three species have smaller group sizes in the Sundarbans. This is probably an adaptation of these species to adjust to the mangrove habitat, which is very different from other habitat types. Hendrichs (1975) mentioned that in the Sundarbans, spotted deer and rhesus macaque may live in groups; wild boar live singly, but do congregate into groups at times.

In Panna, India, Chundawat (2001) reported that the mean group size of spotted deer is 4.0, which is smaller than the group sizes in other tiger ranges (Karanth and Sunquist 1992, Kumar 2000), but in the Sundarbans I found slightly larger group size of the spotted deer. Chundawat (2001) found the highest percentage of spotted deer in group size 2-3 (43.0%) and of wild boar in group size 1 (60.9%), which are similar to my findings. In Bhadra, India, however, Jathanna *et al.* (2001) found much smaller group sizes of the spotted deer (2.8). Both Chundawat (2001) and I agree with the statement that smaller group size could be an indicator of poor resource availability and lack of habitat suitability, which could also have a negative effect on the reproductive success of the population (Jarman 1974).

3.4.2 Prey Age-sex Classes

Tigers have selectivity for prey age-sex classes (Schaller 1967, 1972; Hornocker 1970, Mech 1970, Curio 1976, Vitale 1989, Johnsingh 1993, Karanth and Sunquist 1995, Miquelle *et al.* 1996; this study, see Chapter 4). Hence, the feeding behaviour of tigers is related to the availability of prey in different age-sex classes.

In this study the female spotted deer were found commoner than males. Hendrichs (1975) found a similar result (male-female ratio: 40:100) in the Sundarbans. Though yearling sex ratios are equal among ungulates, the adult sex ratios seem female-biased (Chundawat 2001, Karanth and Sunquist 2002). This is probably because males are more vulnerable to the predator due to their injuries from intra-specific aggression, lack of alertness during rut and dispersal behaviour (Schaller 1967, Tamang 1982, Johnsingh 1983, Karanth and Sunquist 1992). Otherwise, the larger male ungulate might attract the tiger more often than the smaller females of the same prey species, or males are less secretive and wary than females. The male-female ratio in India was 70.5:100 in Kanha (Schaller 1967), 84:100 in Bandipur (Johnsingh 1983), 72:100 in Nagarhole (Karanth and Sunquist 1992) and 41:100 in Panna (Chundawat 2001). In Hawaii, USA, the ratio of introduced deer was very similar to these (77:100; Nichols 1960). Although the composition of herds is usually mixed, spotted deer have a tendency to form two other kinds of associations: 1) buck (adult male) herds and 2) herds consisting of does (adult females) with small fawns (Schaller 1967). These types of herds were rarely seen in the Sundarbans.

In comparison to a 'good' population of prey in Nagarhole, India (Karanth and Sunquist 1992), the ratio of individuals of the pre-reproductive class (juveniles and young) in the spotted deer and wild boar were lower in the Sundarbans, which may indicate a lower optimum density for this habitat. In Nagarhole, the ratio of individuals of the pre-reproductive class of spotted deer and wild boar were 38% and 31%, respectively, whereas in the Sundarbans the ratios were 28% and 21%, respectively. According to Hendrichs (1975), however, the ratio of the pre-reproductive age class of the spotted deer is even lower (15%) in the Sundarbans. In Kanha, Bandipur, and Panna of India, the ratio of spotted deer of less than two years old were 53% (Schaller 1967), 44% (Johnsingh 1983) and 25% (Chundawat 2001), respectively, i.e. the ratio of pre-reproductive age class of the spotted deer in the Sundarbans is lower than in most of other ranges.

According to Schaller (1967), the spotted deer fawns are born primarily during the cool season (November-February) at a time of diminishing food resources, and they continue to suckle during the hot season, many being weaned or almost weaned at the onset of the rains in June. He also mentioned that newborn fawns were seen during every month of the year, but over two-thirds of them were born during the first half. In Bandipur, India, Johnsingh (1983) reported that the peak of the sightings of fawns were during May-July after the summer rains and sprouting of grass. My findings roughly agree with these: I found a higher number of fawns during January-July, with the highest in June (Figure 3.1).

3.4.3 Dominant Prey Species

The tiger is mainly dependent on the dominant prey species, because the dominant prey provides the bulk of available prey biomass. The density and distribution of tigers are often shaped by the dominant prey species. Thus identifying the dominant prey is often the first step towards understanding the carrying capacity for tigers in a particular area.

The spotted deer is the dominant and most gregarious prey species in the Sundarbans; it is primarily a grazer (Mishra 1982a). One possible reason for its abundance is that it is virtually the only grazing ungulate there. Historically, there were Javan rhinoceros (*Rhinoceros sondaicus*), wild buffalo (*Bubalis bubalis*), and swamp deer (*Cervus duvauceli*) in the Sundarbans. Because these species are extinct due to hunting over the last hundred years, the entire grazing niche is open for the spotted deer without competition. Although there are barking deer in the Sundarbans, they are selective feeders that feed on rich but scarce food items such as shoots and fruits (Karanth and Sunquist 1992). They are rare in the Sundarbans probably because of the scarcity of such food. In respect of food availability, the wild boar population should be higher than my estimate. It feeds on a variety of plant and animal foods like roots, tubers, fruits, insects, carrion, etc. (Prater 1971), which are plentiful in the Sundarbans. Notably, the poaching of wild boar by people is very low, because the majority of local people are Muslims who do not eat pork. One possible reason for relatively low density of the wild boar is that it is more vulnerable to hunting by the tiger, which perhaps likes the wild boar meat, probably as a change of the very common prey animal (spotted deer) (see Chapter 4). In the Sundarbans, the wild boar is commonly solitary (mean group size 1.4), hence there is no alarming signal from other members of the group as in the spotted deer herd. Moreover, it was observed in the field that the wild boar is less careful than the spotted deer. The spotted deer was also found to be the dominant prey species in Bandipur (Johnsingh 1983) and Nagarhole (Karanth and Sunquist 1992) in India and many other habitats.

3.4.4 Comparison of Prey Density in Some Tiger Ranges

A comparison of prey density among different tiger ranges is actually a comparison of the carrying capacity for tigers, because tigers live in a balance with the prey population (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993). A comparison of large herbivore prey biomass density, and the individual densities of spotted deer and wild boar in some tiger ranges in the Indian sub-continent, is shown in Figures 3.3 and 3.4. The tiger ranges compared are Nagarhole (Karanth and Sunquist 1992), Bandipur (Johnsingh 1983) and Kanha (Schaller 1967, Newton 1987) in India, Chitwan (Tamang 1982) in Nepal, and Sundarbans East (this study) in Bangladesh. It is clear that the total herbivore biomass density is much lower in the Sundarbans in comparison to other tiger ranges of the Indian sub-continent (Figure 3.3). The herbivore prey species diversity is also much lower in the Sundarbans, but the individual density of spotted deer and wild boar, the two common prey species in all the tiger ranges compared, is not too bad in the Sundarbans (Figure 3.4). Notably, one reason for high herbivore biomass density in

Nagarhole and Bandipur is the inclusion of wild Asian elephants (*Elephas maximus*). There are 6,890 kg/km^2 of elephant in Nagarhole and 10,440 kg/km^2 in Bandipur. Moreover, in Nagarhole, a total of 350 kg/km^2 of prey biomass and in Kanha a total of 2,925 kg/km^2 of prey biomass are domestic herbivores.

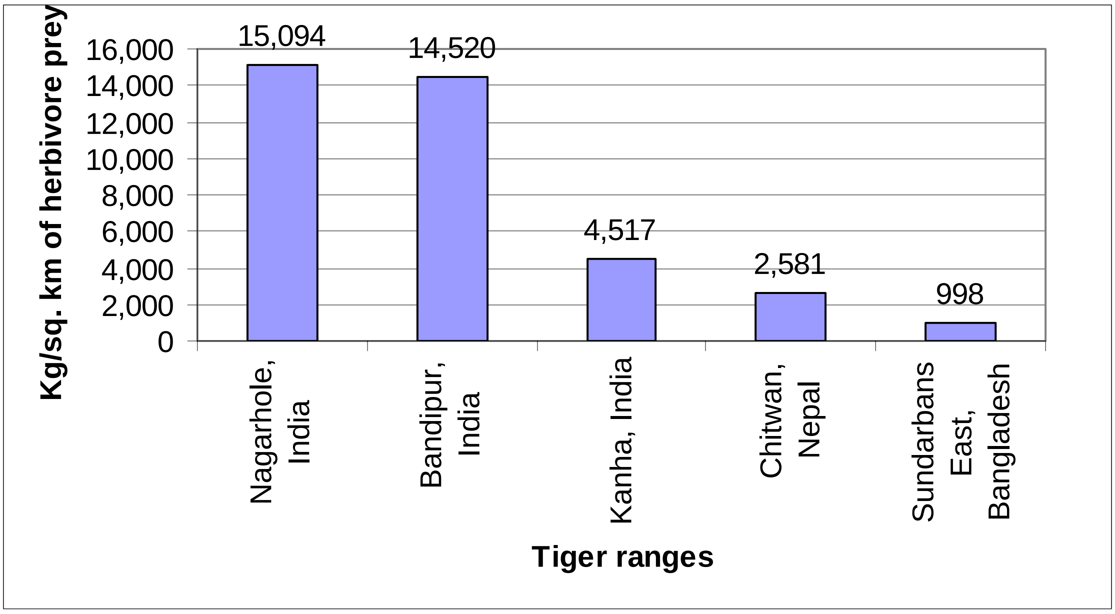


Figure 3.3 Comparison of the total large herbivore prey biomass density in some tiger ranges in the Indian sub-continent.

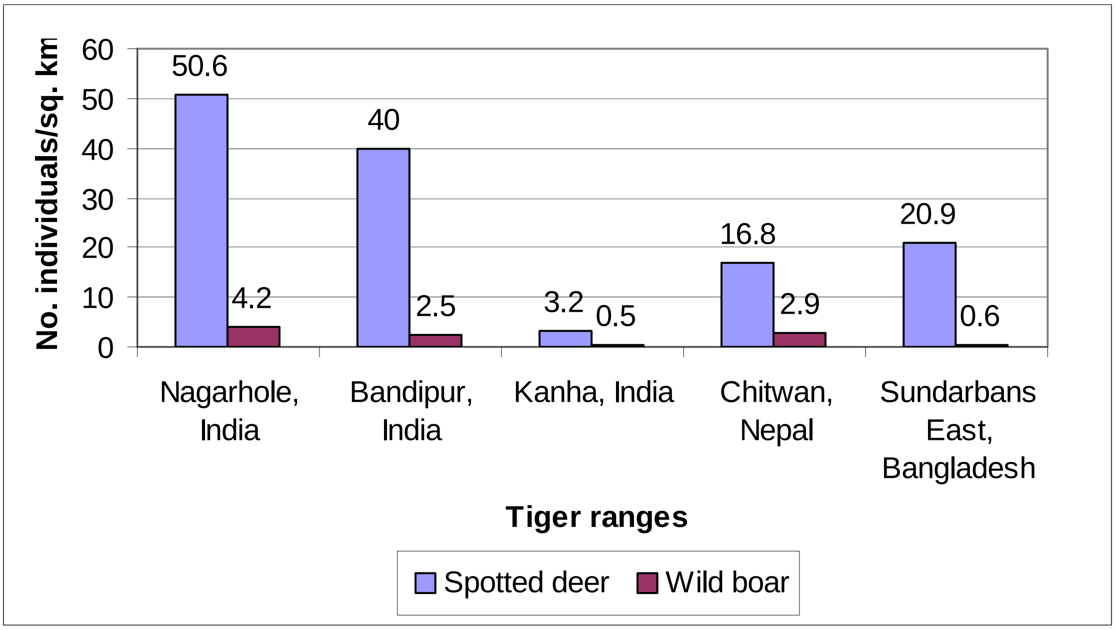


Figure 3.4 Comparison of the individual density of spotted deer and wild boar in some tiger ranges in the Indian sub-continent.

3.4.5 Comparison of Prey Density Estimates in the Bangladesh Sundarbans

The comparison of different estimates of prey density in the Bangladesh Sundarbans is important to show that the density estimates are variable, and some of them could be misleading.

There are some estimates of the density of large prey species (Hendrichs 1975, Khan 1986b, Tamang 1993, Islam 2001, Niamatullah 2001, Reza *et al.* 2002a) in the Bangladesh Sundarbans, but very few could properly follow any scientific method, so the results were basically 'guesstimates' on the basis of animal sightings. Some of the estimates (Islam 2001, Niamatullah 2001, Reza *et al.* 2002a) ended up overestimating the prey density for two reasons: 1) biases in methods and 2) water bodies were not considered in density estimation. The results of different estimates of population density were compared in Table 3.6. The highest density of the spotted deer is in grassland-forest mosaic in the southern part of the Sundarbans East WS. This was probably because the spotted deer preferred grasses to the other plant species for their food (Dolon 2003). Islam (2001), Niamatullah (2001) and Reza *et al.* (2002a) claimed to use line-transect sampling, but could not satisfy the basic assumptions of the theory as described in Burnham *et al.* (1980), Buckland *et al.* (1993), Buckland *et al.* (2001), and Thomas and Karanth (2002). The distance of the animal groups and the length of transects were estimated arbitrarily without using a rangefinder and a GPS. There are also examples of counting prey animals from creeks, which are not straight, violating the basic principle of line-transect sampling (K.U. Karanth pers. comm. 2002).

Table 3.6 A comparison of estimates of the individual density of the potential prey species of tigers in the Bangladesh Sundarbans

Individual density (no. individuals/km²)								Method	Reference
Spotted deer	**Barking deer**	**Wild boar**	**Rhesus macaque**	**Oriental small-clawed otter**	**Lesser adjutant**	**Red junglefowl**	**Ring lizard**		
20	-	5	10	5	-	20	-	General observation	Hendrichs 1975
13.2	-	-	17.1	-	-	-	-	General observation	Khan 1986b
23	7.4	11	-	-	-	-	-	General observation, pellet count for deer density	Tamang 1993
77.9	-	-	-	-	-	-	-	Line-transect sampling	Islam 2001
77.9	-	8.7	23.9	-	-	-	-	Line-transect sampling and pellet count in high density area	Niamatullah 2001
70.4	-	7.9	15.8	-	-	-	-	Line-transect sampling in high density area	Reza *et al.* 2002a
20.9 [41.8]	-	0.5 [0.9]	6.5 [12.9]	-	0.6 [1.1]	7.0 [14.0]	7.9 [15.7]	Line-transect sampling in high density area	This study

N.B. In case of the results of 'this study', the numbers in square brackets are the densities on land only.

3.4.6 Correlation Between Prey Density and Tiger Density

A positive correlation between prey and tiger densities was established by a number of researchers (Schaller 1967, Sunquist 1981, Seidensticker and McDougal 1993, Karanth *et al.* 2004). The survival of a tiger population is directly correlated with the status of large prey species. Based on field surveys of prey abundance, as measured by number of deer faecal pellet groups/10 m^2, the minimum number of pellet groups required to support breeding tigers is 0.5 groups/10 m^2 (Smith 1993). This converts to 3.8 sambar (*Cervus unicolor*)/km^2 (Smith *et al.* 1999a).

Karanth *et al.* (2004) demonstrated quantitatively the correlation between tiger and prey densities in India. Poaching of tigers (WWF 1999), isolation of populations (Seal *et al.* 1994, Wiese *et al.* 1994), and habitat loss (Mountfort 1981, Panwar 1987, Thapar 1992) are traditionally cited as the major factors driving the tiger's decline. Karanth and Stith (1999) established that prey depletion is a critical determinant of tiger population viability, but it is a neglected factor.

Tiger biomass, in relation to large herbivore prey biomass, is higher in the Sundarbans compared with other tiger ranges in the Indian sub-continent (Table 3.7), probably because there are no other large carnivores [i.e. leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), hyena (*Hyaena hyaena*) or Asiatic wild dog (*Cuon alpinus*)] to compete for large prey animals. Moreover, all the wild tigers directly observed (n = 15, see Appendix V) during this study were thinner than in other populations of the same sub-species, so probably they have forced to live at relatively low biomass. According to Sankhala (1978a), tigers in the Sundarbans are smaller than other populations of the same sub-species. This is probably the adaptation of the tiger to live in such a tough mangrove habitat where they face a lot of mud and water. The relatively high tiger biomass density in the Sundarbans could also be because my inference of tiger density could be an over-estimate, because I have assumed that the biomass of individual large ungulates, and tiger kill rate, in Indian forests and in the Sundarbans are not variable (see Section 3.4.7).

The superior tiger habitats (e.g. Nagarhole or Bandipur in India, where the prey density is high) can support a biomass of 7-10 kg of tiger/km^2 (Karanth 1987). From a density point of view, the Sundarbans probably cannot be designated as a superior tiger habitat, but a large unfragmented habitat ensures the survival of a large unfragmented tiger population.

Table 3.7 Comparison of the biomass density of large herbivore prey species and the tiger in some tiger ranges in the Indian sub-continent

Area	Major habitat types	Tiger biomass density (kg/km^2)	Herbivore prey biomass density (kg/km^2)	Ratio of tiger and herbivore prey biomass density
Nagarhole, India	Deciduous forest	13.4	15,094 (Karanth and Sunquist 1992)	1:1,126
Bandipur, India	Dry forest and woodland	13.5	14,520 (Johnsingh 1983)	1:1,076
Kanha, India	Moist forest and grassland	13.2	4,517 (Schaller 1967, Newton 1987)	1:342
Chitwan, Nepal	Moist forest and grassland	6.6	2,581 (Tamang 1982)	1:391
Sundarbans East, Bangladesh	Mangrove forest and grassland	4.9	998 (this study)	1:204

* Following Karanth (1987), the mean weight of one tiger was considered 113 kg; this was multiplied by the individual density of the tiger estimated by Karanth and Nichols (2000) for Nagarhole, Bandipur and Kanha; by Sunquist (1981) for Chitwan, and this study for Sundarbans East. N.B. The herbivore prey biomass density in Nagarhole and Bandipur are much higher due to the inclusion of the Asian elephant. Moreover, the herbivore prey biomass included domestic cattle in Nagarhole and Kanha.

3.4.7 Comparison of Tiger Density Estimates in the Bangladesh Sundarbans

According to Karanth *et al.* (2004), tigers prey almost exclusively on large ungulates and they are socially dominant over other carnivores. Consequently, tiger densities in protected habitats are likely to be mediated chiefly by prey abundance rather than inter-specific social dominance and competitive exclusion. Therefore, Karanth *et al.* (2004) proposed a mechanistic model that predicts tiger density as a function of prey density. In this model they have represented prey availability in terms of ungulate numbers rather than biomass, because the body masses of individual ungulates killed by tigers (20-1,000 kg) and the proportion of the kill actually consumed are both highly variable factors (Karanth and Sunquist 2000).

Following Karanth *et al.* (2004) I have used the large ungulate prey density estimate to infer the tiger density (4.3 tigers/100 km^2) in the Sundarbans East WS. Since the average biomass of the individual large ungulates (spotted deer and wild boar) in the

Sundarbans is lower than that in Karanth *et al.*'s (2004) study areas in India [there are gaurs (*Bos frontalis*), sambars, wild buffaloes, etc. in the Indian forests], my inference of tiger density would be lower if the prey biomass were considered. Moreover, Karanth *et al.* (2004) considered tiger kill rate at 50 large prey animals/tiger/year, which I have followed, but according to Panwar (1990) the kill rate is 72 spotted deer equivalent/tiger/year. If the latter rate was considered, the tiger density in the Sundarbans East WS would be lower than what I inferred. Both of the above-mentioned cropping rates were for tigers in India, so it might be different in the Sundarbans.

If my inference of tiger density is compared with other density estimates (Table 3.8), it is clear that most other estimates (Hendrichs 1975; Bangladesh Forest Department and Department of Zoology, University of Dhaka, 1982; Bangladesh Forest Department 1992, 2004; Tamang 1993, Reza 2000) over-estimated the tiger density in the Sundarbans. Most of the estimates were based on pugmark censuses – the method which is strongly criticised by most of the tiger scientists (see Karanth *et al.* 2003). Although Seidensticker's (1987a) estimate of 250 adult tigers in the entire Sundarbans, i.e. 150 adults (60%) in the Bangladesh Sundarbans, was mainly based on the tiger density in Chitwan, Nepal, this is one of the most realistic figures. The tiger density in Chitwan was estimated scientifically through long-term radio-telemetry (Smith 1984, Smith *et al.* 1987b). Based on camera-trappings, Karanth and Nichols (2000) scientifically estimated the tiger density in many parts of India, which replaced many fictitious figures on tiger populations, but the estimated density in the Indian Sundarbans (0.8 tigers/100 km^2) might be an under-estimate due to low number of photo 'captures'. It is very difficult to 'capture' the Sundarbans tiger via the camera-trap, because they rarely follow any specific trail and hence their route is very unpredictable.

I collected a total of 20 specimens of tiger hairs (fallen hairs) from the resting spots of tigers in 5 m wide line-transects (conducted to know the relative habitat use by tigers) in order to calculate tiger density based on DNA fingerprinting. Two samples were analysed as a test, but the DNA extraction was not good enough. One reason for this failure was that the naturally fallen hairs had poor follicles and some had no follicles at all.

Table 3.8 Estimates of tiger population in the Bangladesh Sundarbans

Estimated population	Estimated density (no./100 km^2)	Method	Reference
350	(5.8)	Interviewing	Hendrichs 1975
450	(7.5)	Pugmark study	Bangladesh Forest Dept. & Dept. of Zoology, Univ. of Dhaka 1982
(150 adults) [original result: 250 adults in the entire Sundarbans]	(2.5 adults)	Density estimate based on Chitwan (Nepal) density	Seidensticker 1987a
359	(6.0)	Interviewing	Bangladesh Forest Department 1992
362	(6.0)	Pugmark study	Tamang 1993
(720)	(12.0) in the high density area [original result: 2 adults, 1 juvenile, 1 cub residents; 1 adult, 1 juvenile transients in 20 km^2 area]	Pugmark study	Reza 2000
(50)	0.8 in the Indian Sundarbans	Camera-trapping	Karanth and Nichols 2000
ca. 500	(8.3)	Pugmark study	Bangladesh Forest Department 2004
ca. 200	4.3 (excluding cubs) in the high density area	Inferred on the basis of prey density	This study

N.B. The values in the round brackets were not reported by the authors, but were calculated in relation to the area in order to make a better comparison.

3.5 SUMMARY

- This study was conducted to determine the population structure and evaluate the population density of different potential prey species of the tiger in the Sundarbans East Wildlife Sanctuary (WS) of Bangladesh.

- In order to know the population structure and density, the line-transect sampling method was used in the field. The individual densities were then converted to prey biomass densities by multiplying the mean weight of the species. The tiger density was inferred on the basis of large ungulate prey density.

- The spotted deer and rhesus macaque were identified as more social prey species (more than 50% observations were groups of varying size), but other prey species like wild boar, lesser adjutant, red junglefowl and ring lizard were mainly solitary (in more than 50% observations).

- The percentage of pre-reproductive age classes (juveniles and young) were slightly lower than in many other ranges. There were more females than males in case of spotted deer, wild boar and rhesus macaque, but less females than males in case of red junglefowl. About 85% of the spotted deer fawns were seen during January-July. The number of fawns sighted was significantly different across months.

- The mean group size of spotted deer was 5.7, wild boar 1.4, rhesus macaque 4.1, lesser adjutant 1.2, red junglefowl 1.2 and ring lizard 1.0, respectively. The overall individual density (no./km^2) and biomass density (kg/km^2) were 20.9 and 983 for spotted deer, 0.5 and 15 for wild boar, 6.5 and 26 for rhesus macaque, 0.6 and 2 for lesser adjutant, 7.0 and 4 for red junglefowl, and 7.9 and 8 for ring lizard. This means that the spotted deer is the dominant prey species both in terms of individual density and biomass density.

- Using the prey density estimate, the tiger density was inferred at 4.3 tigers/100 km^2 (excluding cubs). If this is the scenario of a high-density area, then we might expect only about 200 tigers in the Bangladesh Sundarbans.

CHAPTER 4 PREY SELECTION

4.1 INTRODUCTION

The acquisition of food is a fundamental component of every predator's daily existence. Hence knowledge of food selection is critical to understanding life history strategies and developing sound conservation recommendations (Miquelle *et al.* 1996). The role tigers play as top predators is vital to regulating and perpetuating ecological processes and systems (Sunquist *et al.* 1999, Terborgh 1999).

The evolutionary fitness of any predator, whether it is a spider catching insects or a lion hunting buffalo, depends on the quality and quantity of its diet (Sunquist and Sunquist 1989). Predatory strategies are shaped and refined by natural selection to maximise nutrient intake within the bounds of a wide range of biologically-relevant ecological constraints (Sunquist and Sunquist 1989, Clutton-Brock and Harvey 1983). The scenario gets complicated when several predatory species hunt in the same area, resulting in a joint demand for a limited prey source. One way in which such competition can be reduced is for the predators to occupy different habitats or territories or use the same area at different times (Schaller 1972).

Carnivores often regulate or limit the numbers of their prey, thereby altering the structure and function of entire ecosystems (Schaller 1972, Smuts 1978, Estes *et al.* 1998, Berger *et al.* 2001, Terborgh *et al.* 2002). Large carnivore prey selection is a complex phenomenon (Bekoff *et al.* 1984, Kruuk 1986, Sunquist and Sunquist 1989). The hypotheses so far proposed to explain prey selection by predators indicate that the energetic benefits for the predator and proximate mechanisms of selection shape the overall prey selection by predators (Griffiths 1975, Curio 1976, Taylor 1976, Stephens and Krebs 1987, Temple 1987, Karanth and Sunquist 1995).

Prey selection by large carnivores has been studied thoroughly in tropical forests (Schaller 1967, Johnsingh 1983, Rabinowitz and Nottingham 1986, Emmons 1987, Rabinowitz 1989, Karanth and Sunquist 1995), tropical savannas (Kruuk 1972, Schaller

1972, van Orsdol 1982, Prins and Iason 1989, Packer *et al.* 1990, Mills and Shenk 1992, Stander and Albon 1993, Scheel 1993), temperate forests (Bergerud *et al.* 1983, Messier 1991, Gasaway *et al.* 1992, Huggard 1993, Miquelle *et al.* 1996) and other ecosystems. Moreover, non-experimental field studies of large carnivores have contributed significantly to the understanding of prey selection (Errington 1967, Mech 1970, Hornocker 1970, Kruuk 1972, Schaller 1972, Sankhala 1978a, Thapar 1992, Matthiessen 2000). However, spatial and temporal scales involved in predation studies preclude strictly experimental approaches in the field (Taylor 1984, Karanth and Sunquist 1995).

The analysis of food habits provides practical and immediately useful information for the management of a particular species and occasionally aids law enforcement and management needs (Korschgen 1971). The existence of a large carnivore like the tiger directly depends on the existence of large prey species, because, on average, a tiger has to kill a large prey in every seven days (Seidensticker and McDougal 1993). The general objective in this Chapter is to *identify whether tigers in the Sundarbans have any preference for prey in terms of species, availability, age and health*. The specific questions are –

1. What are the proportions of different prey species in tiger scats and kills?
2. Do tigers sometimes ingest non-food items?
3. Does prey availability has any effect on prey selection?
4. What are the proportions of kills in different age and health classes?
5. Does the availability of the spotted deer in different age classes have any effect on the selection of it of different ages?

4.2 METHODS

4.2.1 Scat Analysis

Scat analysis is a popular and useful method to understand prey selection by carnivores. This has the great advantage that material is sometimes easy to collect and does not involve destruction of animals from the study population (Reynolds and Aebischer 1991). The method has been extensively applied in carnivore food habit studies either alone (Koppikar and Sabnis 1979, Norton *et al.* 1986, Emmons 1987, Rabinowitz 1989, Oli 1991, Karanth and Sunquist 1995, Hersteinsson and Macdonald 1996, Ranawana *et al.* 1998, Ramakrishnan *et al.* 1999, Khorozyan and Malkhasyan 2002) or in combination with data from predator kills (Schaller 1967, 1972; Kruuk 1972, Sunquist 1981, Johnsingh 1983). The method has been reviewed (Putman 1984, Reynolds and Aebischer 1991) in order to get more accurate information on food habits.

In this study the scat samples were collected from the field while conducting line-transect sampling for tiger signs in four major habitat types (mangrove woodlands, grasslands, sea beaches and transitional zones). Since the tiger is the only large carnivore in the Sundarbans, tiger scats could be identified without any confusion. The samples were sun-dried whenever necessary and preserved in a tagged polythene bag. At the end of every month, the specimens were brought to the laboratory for analyses. At first each of the scats were classified according to the volume, and weighed by using a Lark JPT-2 (range: 0.1-200 g) beam balance. Big scats were weighed in several parts. Then each scat was broken and carefully soaked in the water to separate prey remains, such as hairs, bones, hooves, teeth, feathers, etc. All these different items were studied, with the unaided eye and with a magnifying glass, as well as under a light microscope if necessary, and were identified by comparing with the reference collection (from different species of kills and from captive animals) by using features such as structure, colour and medullary configuration to identify prey species (Koppikar and Sabnis 1976, Amerasinghe 1983, Karanth 1993c, Kitsos *et al.* 1995, Ranawana *et al.* 1998, Ramakrishnan *et al.* 1999). The remains of one prey species in one scat were considered as frequency one. If there were prey remains of two species in a scat (which was a rare case; found only in few scats), the frequency was divided into 0.5 for each prey species. The non-food items were recorded when the item formed more than 50% of the scat volume (Schaller 1967, Johnsingh 1983), but these were excluded while estimating diet composition and the biomass of food consumed (Reynolds and Aebischer 1991). Reynolds and Aebischer (1991) defined non-food items in the scats as remains of ingesta that have little or no nutritive benefit (i.e. soil and sungrass in this study).

To determine whether the scat sample size is sufficient, the method was followed from Mukherjee *et al.* (1994), who studied the effect of scat sample size on frequency of occurrence in scats of a given prey species and identified the minimum reliable sample size (MRSS) as that which does not cause any further change in a prey with increase in sample size. For this, a total of ten different scat samples (n = 21, 23, 26, 29, 34, 41, 50, 66, 100 and 145) were taken and checked for the corresponding changes in the percentage of the frequency of the tiger's staple prey, spotted deer (*Cervus axis*) in the Sundarbans, in each sample.

Frequencies of scats across different size and weight classes, frequencies of different prey in scats, and frequencies of soil-containing scats (more than 50% of the volume) across months were tested statistically (non-parametric χ^2 test) in order to examine whether the frequencies were significantly different or not.

Although both scats and kills of tigers were studied, only the data from scat analysis were used to calculate the relative numbers of different prey killed by following the regression established by Ackerman *et al.* (1984). This gives an unbiased estimate of the proportions of both larger and smaller species. Although the frequency of occurrence of prey species in carnivore scats is a commonly-used parameter in the study of carnivore food habits, if prey size is highly variable (as in this study), the frequency of occurrence can considerably distort the relative numbers of different prey species in the diet (Panwar 1990, Karanth and Sunquist 1995). Thankfully, the frequency of occurrence of different prey species in the scats of tigers can be converted to the relative biomass and numbers of different prey taken, which represents the actual selectivity pattern (Floyd *et al.* 1978, Ackerman *et al.* 1984, Karanth and Sunquist 1995). In the light of the previous approaches (Schaller 1967, Johnsingh 1983, Putman 1984, Emmons 1987, Jasic *et al.* 1993, Karanth and Sunquist 1995), the methods developed by Ackerman *et al.* (1984) for the puma (*Puma concolor*), to convert the frequencies of occurrence into relative biomass and numbers of individuals killed, were used. Assuming that the digestive system and the degree of carcass use of the tiger is comparable to that of the puma, the following regression was used to relate live weight of prey killed (X) to the weight of that prey represented in one field-collectable tiger scat (Y) –

$$Y = 1.980 + 0.035\,X$$

The average number of collectable scats produced by a tiger from an individual animal of each prey species ($\lambda_i = X/Y$), and the relative numbers of each prey killed were computed from the above equations (Ackerman *et al.* 1984). The relative numbers were then converted to relative biomass by multiplying with the minimum adult weight.

4.2.2 Prey Selectivity Index

Based on the relative numbers of six potential prey species killed by tigers and the abundance (no. individuals/km^2) of these species in the habitat, the index of selectivity was computed to know the ranking of the species, i.e. to know which are more preferable prey species in relation to their abundance. Since this is simply a ratio, the results are very similar for prey numbers and prey biomass. According to Sourd (1983) (see Julliot 1996 for application), the selectivity index (S) used to compare the abundance of each edible prey species in the habitat and its proportion in the tiger diet was calculated by using the equation mentioned below –

$S = (PC_{sp} – PA_{sp})/(PC_{sp} + PA_{sp})$

Here PC_{sp} = proportion of one particular prey species in the tiger diet as a percentage of the relative number of that prey species in the tiger diet, and

PA_{sp} = proportion of the same prey species available in the habitat as a percentage of the individual density of that prey species in total prey population.

The species was then considered as –

a) a high-ranking species, when $S > 0.3$ (PC_{sp} at least double than PA_{sp}),
b) a middle-ranking species, when S lies between –0.3 and 0.3 (PC_{sp} similar to PA_{sp}),
c) a low-ranking species, when $S < –0.3$ (PC_{sp} at least half than PA_{sp}), and
d) an uneaten species, when $S = –1$ ($PC_{sp} = 0$, non-used edible species)

4.2.3 Kill Study

The kills of tigers were studied in order to assess prey selection by tigers. Clues like odour, alarm calls of prey, tiger signs and tiger calls were useful to locate the kill. Similar clues were followed by Karanth and Sunquist (1995 and 2000) in Nagarhole, India, to locate the kills. Crows and vultures are good advertisers of tiger kills in most of the tiger ranges of the Indian sub-continent (Schaller 1972, Johnsingh 1983, Karanth and Sunquist 1995), but the dense vegetation and the rarity of crows and vultures in the Sundarbans forced us to depend mainly on odour and dragging signs. In addition to the species of prey killed, if the kill was relatively intact, the age class and health of the killed individual was recorded on the basis of the size and colour of the animal, sexual characters, etc. Whenever possible, the colour and texture of femur marrow fat were examined in order to record the health condition of the kill more accurately (Schaller 1967, Sinclair and Duncan 1972, Riney 1982). The lower jaws were collected whenever available, and taken to the laboratory where the total length and diastema length were measured, and used to classify the kills into age categories as adult, juvenile/yearling and young/fawn on the basis of eruption and wear of premolar and molar teeth (Schaller 1967, Riney 1982, van Lavieren 1983). The frequencies of spotted deer kills across different age and health classes were tested statistically (non-parametric χ^2 test) to examine whether the frequencies were significantly different or not.

Selectivity of the tiger predation for age classes of the spotted deer was assessed by Ivlev's selectivity index (D) (Okarma *et al.* 1997, Khorozyan and Malkhasyan 2002) –

$D = (fE – fL)/(fE + fL – 2fEfL)$

Here fE = fraction of a given age class among spotted deer eaten by tigers (adult = 0.765, yearling = 0.176 and fawn = 0.059; ages identified on the basis of the eruption of the teeth; see Table 4.5), and fL is the fraction of a given age class in the habitat (adult = 0.722, yearling = 0.205 and fawn = 0.073; see Chapter 3). The positive or negative value of D for a certain age class means that the individuals of that age class were positively or negatively selected.

4.3 RESULTS

4.3.1 Scat Volume and Weight, and Minimum Sample Size

All the dried scats were classified on the basis of volume and weight. In terms of relative volume, there were no significant difference in the frequencies of small, medium and large scats (χ^2 = 0.68, df = 2, p = 0.713), but medium-sized scats were the commonest (36.6%). On the other hand, classes based on dry weight shows that there were significant differences in the frequencies of scats in three different weight classes (χ^2 = 25.00, df = 2, p < 0.001), but relatively lightweight (<100 g) scats were the commonest (51.0%) (Table 4.1). The mean weight of dried scats was 124.9 g (n = 145, range = 10.6-406.6 g, sd = 94.8).

Table 4.1 Scat size of the tiger on the basis of volume and weight

Relative volume			**Weight**		
Class	**No.**	**%**	**Class**	**No.**	**%**
Small	46	31.7	<100 g	74	51.0
Medium	53	36.6	100+ to 200 g	46	31.7
Large	46	31.7	200+ g	25	17.3

The results of the test for minimum sample size of the scats required for actual presentation of the proportions of different prey species in the scats is illustrated in Figure 4.1. It is evident that even 34 samples are sufficient to represent adequately the occurrence of the spotted deer in the tiger diet, which stays virtually steady-state regardless of the larger sample size.

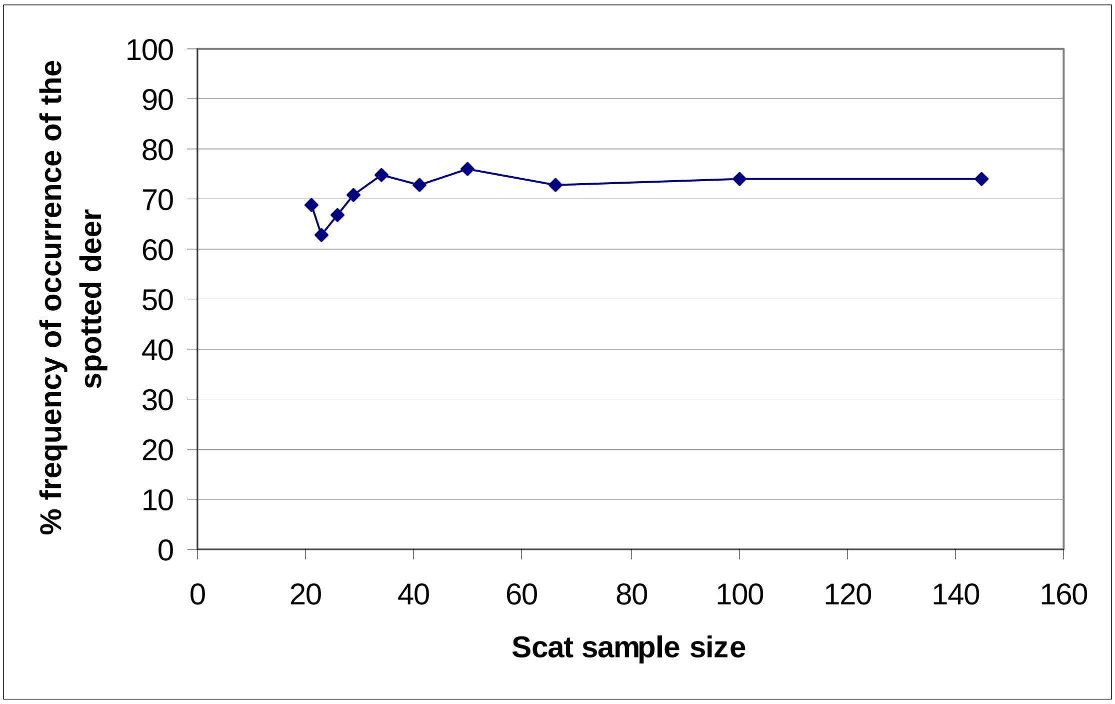


Figure 4.1 The relationship between the sample size of tiger scats and the percentage of the frequency of occurrence of the spotted deer in scats in the Sundarbans East Wildlife Sanctuary.

4.3.2 Prey Selection

The frequency of occurrence of different prey species in scats and kills (Table 4.2) shows that, excluding zero values, the frequencies of different prey species were significantly different (in scats: $\chi^2 = 545.71$, df = 7, $p < 0.001$; in kills: $\chi^2 = 316.15$, df = 6, $p < 0.001$). On average, spotted deer was the most frequent (78%), but tigers also consumed wild boar (*Sus scrofa*), rhesus macaque (*Macaca mulatta*), Indian crested porcupine (*Hystrix indica*), leopard cat (*Prionailurus bengalensis*), Ganges river dolphin (*Platanista gangetica*; died in the fishing net, which was thrown away and floated to the bank, and finally eaten by the tiger), lesser adjutant (*Leptoptilos javanicus*), red junglefowl (*Gallus gallus*), mud crab (*Scylla serrata*) and ring lizard (*Varanus salvator*), which together form the rest of the frequency percentage (Table 4.2). Since the prey sizes were considerably variable, the frequency of occurrence does not represent the relative numbers of different prey animals killed by tigers. Hence, the frequency of occurrence in scats was converted to the relative numbers of prey animals killed. The result shows that in terms of relative numbers of prey animals killed, spotted deer was still the most frequently consumed, but the percentage decreases to 29.9% (Table 4.3). The larger prey species contributed relatively more to the diet of tigers, even if their relative numbers in the diet were low.

Table 4.2 Occurrence of different prey species in scats and kills of tigers

Prey species	Frequency in scats	% frequency in scats	Frequency in kills	% frequency in kills	% total frequency in scats and kills
Spotted deer	108	74.5	66	84.6	78.0
Wild boar	16	11.0	2	2.6	8.1
Rhesus macaque	8	5.5	1	1.3	4.0
Indian crested porcupine	2	1.4	0	0	0.9
Leopard cat	1	0.7	0	0	0.5
Ganges river dolphin (dead)	0	0	1	1.3	0.5
Lesser adjutant	3	2.1	5	6.4	3.6
Red junglefowl	1	0.7	1	1.3	0.9
Mud crab	1	0.7	0	0	0.4
Ring lizard	0	0	2	2.5	0.9
Unidentified	5	3.4	0	0	2.2

Table 4.3 Estimated average number of collectable scats produced from individual prey animals and relative numbers of different prey species killed by tigers in the Sundarbans East Wildlife Sanctuary

Prey species	Weight (kg)	Frequency of occurrence in scats	No. of collectable scats produced/ kill	Total no. of animals eaten to provide collected-scats	Relative no. of prey animals killed (%)
Spotted deer	47.0[1]	108	13.1	8.2	29.9
Wild boar	32.0[1]	16	10.3	1.6	5.8
Rhesus macaque	4.0[1]	8	1.9	4.2	15.3
Indian crested porcupine	8.0[2]	2	3.5	0.6	2.2
Leopard cat	3.0[3]	1	1.4	0.7	2.6
Lesser adjutant	4.0[4]	3	1.9	1.6	5.8
Red junglefowl	0.6[5]	1	0.3	3.3	12.1
Mud crab	0.3[6]	1	0.2	5.0	18.3
Unidentified	5.0[7]	5	2.3	2.2	8.0

N.B. Mainly the minimum adult weights of the prey species were considered.
[1]Source: Karanth and Sunquist (1992). [2]Source: Karanth and Sunquist (1995). [3]Sourse: Prater (1971). [4]Source: <www.ndngrd.com>. [5]Source: <www.international.tamu.edu>. [6]Source: local crab collectors. [7]Source: arbitrarily assumed; as in Karanth and Sunquist (1995).

When relative numbers of different prey animals consumed by tigers were converted to the relative biomass, it shows that spotted deer forms the bulk of the diet and wild boar is the second-most consumed (Figure 4.2). These are the two species on which tigers in the Sundarbans are thriving. Other species, like rhesus macaque, lesser adjutant, etc. are the supplement, but form a very small proportion of the tiger diet.

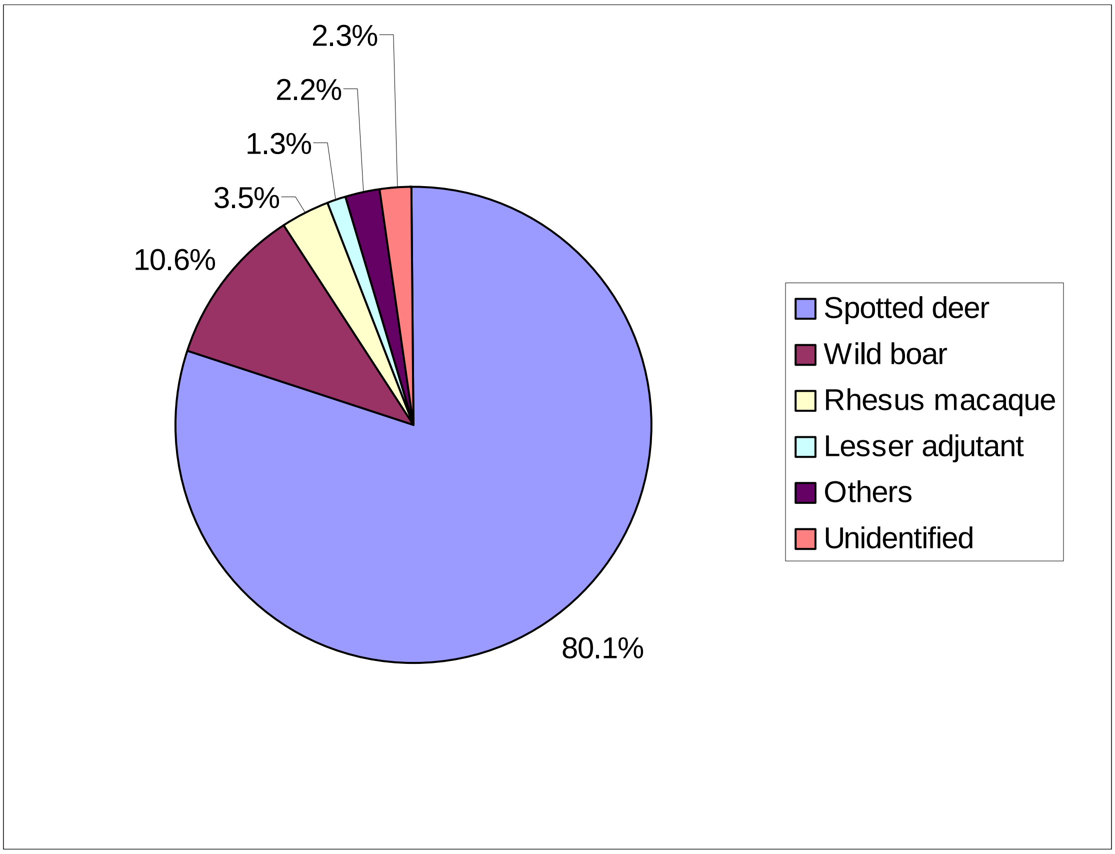


Figure 4.2 Proportions of the relative biomass of different prey species consumed by tigers in the Sundarbans East Wildlife Sanctuary.

4.3.3 Non-food Items in Scats

Other than the prey animal remains, 74 (51%) scat samples had large quantities of soil (more than 50% of the volume). Sungrass (*Imperata* sp.), and rarely leaves, were also found in a number of scats, but only one scat (collected in January 2002) had sungrass more than 50% of the volume. In almost all cases the soil was very hard in the scat, probably due to contraction in the intestine. The occurrence of scat samples with more than 50% soil in different monthly periods was significantly different ($\chi^2 = 27.19$, df = 8, $p = 0.001$). More than 80% of the scats with soil were found in winter/dry season (October-March), with the peak in November-December (ca. 15%), which indicates a strong seasonality in soil ingestion by tigers (Figure 4.3). The monthly total collection of scats was almost equally proportional in different seasons, so it was assumed that the scat availability was uniform across seasons. The presence of a large amount of soil proves that these were not accidentally ingested, but neither soil nor sungrass were considered as food items of tigers.

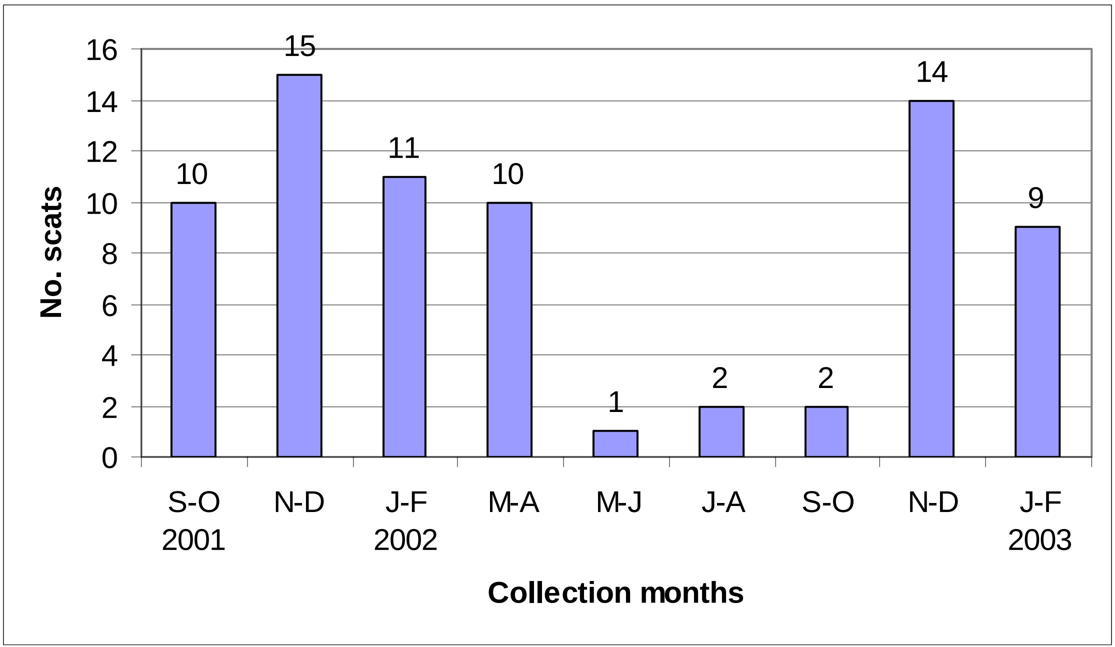


Figure 4.3 Monthly occurrence of tiger scats with soil consisting of more than 50% of the volume in the Sundarbans East Wildlife Sanctuary.

4.3.4 Prey Abundance Versus Prey Selection

The prey density (see Chapter 3) was compared with prey selection to know whether there is any relationship between abundance and selection. In terms of individual density, in general, the selection was proportional to the abundance of different prey species (Figure 4.4). For spotted deer, the consumption of individuals was lower than the abundance in comparison to wild boar, rhesus macaque, lesser adjutant and red junglefowl. Although the ring lizard was common, there was no trace of it in scats, but two kills were found during the fieldwork.

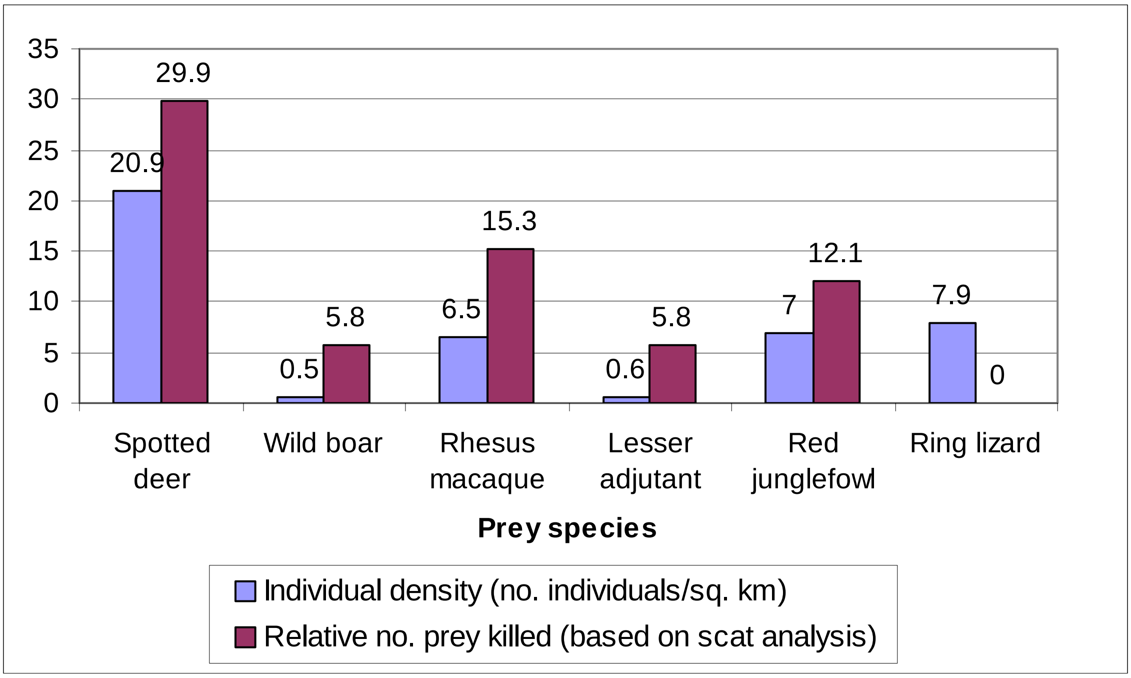


Figure 4.4 A comparison of prey abundance and prey selection by tigers, in terms of the number of individuals, in the Sundarbans East Wildlife Sanctuary.

When the biomass abundance of different prey species (see Chapter 3) was compared with the relative biomass of different prey species consumed by tigers (relative numbers of different species killed multiplied by their minimum adult weights), it shows a very strong positive relationship (Figure 4.5). In general, the prey biomass selection of tigers is mainly dependent on the prey biomass abundance in the habitat. In other words, the spotted deer forms the bulk of prey biomass, hence it also forms the bulk of biomass consumed by the tiger. However, the consumption of wild boar and lesser adjutant biomass were much higher in comparison to their abundance (Figure 4.5).

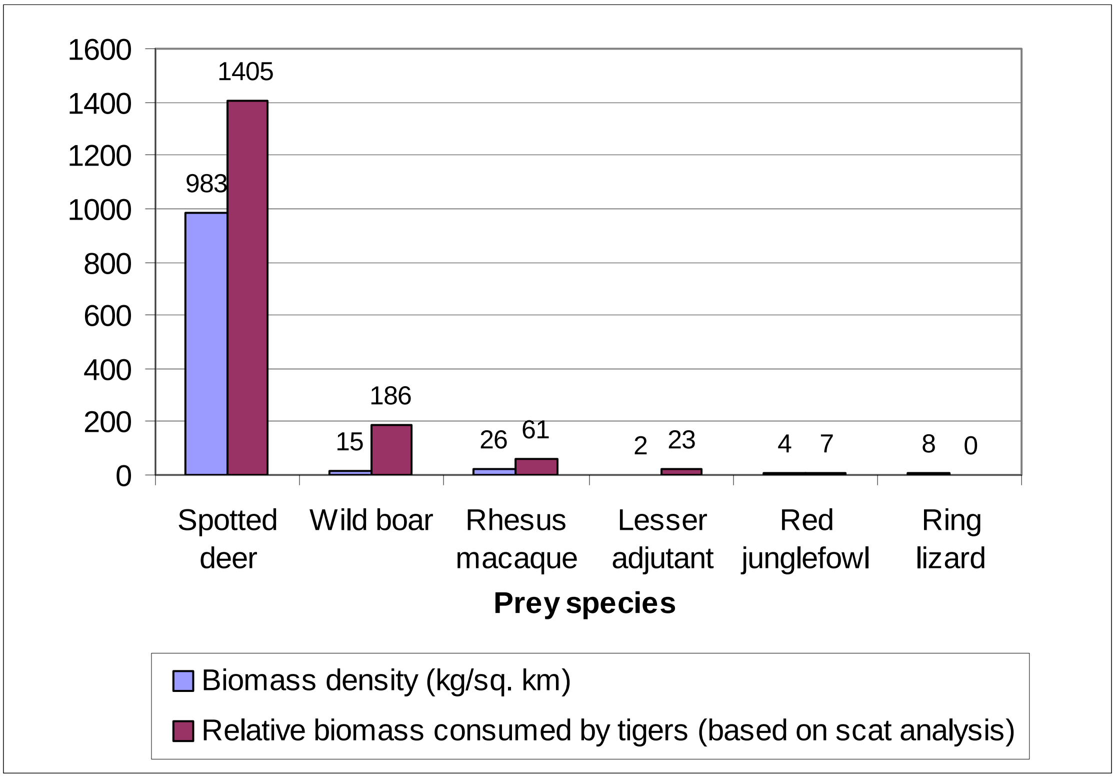


Figure 4.5 A comparison of prey abundance and prey selection by tigers, in terms of biomass, in the Sundarbans East Wildlife Sanctuary.

Based on the number of individuals, the selectivity index (S) for six potential prey species shows that wild boar and lesser adjutant were high ranked; spotted deer, rhesus macaque and red junglefowl were middle ranked; and ring lizard was a non-used species (Table 4.4). It is notable that the two least-available prey species were highest in the ranking, i.e. rates of their selectivity by tigers were highest in comparison to their abundance.

Table 4.4 Prey species ranking based on selectivity index

Prey species	**Proportion consumed (PC_{sp}) (% relative no.)**	**Proportion in the habitat (PA_{sp}) (% total prey density)**	**Selectivity index (S)**	**Rank of the prey species**
Spotted deer	43.4	48.2	–0.05	Middle
Wild boar	8.5	1.1	0.77	High
Rhesus macaque	22.2	15.0	0.19	Middle
Lesser adjutant	8.5	1.4	0.72	High
Red junglefowl	17.4	16.1	0.04	Middle
Ring lizard	0	18.2	–1.00	Non-used

4.3.5 Age and Health of Kills

The measurements of the total length of lower jaw and diastema of the spotted deer revealed that the mean lengths of a lower jaw bone and a diastema are 18.7 cm (n = 34, range = 12.0-21.7 cm, sd = 2.1) and 5.0 cm (n = 34, range = 3.2-6.3 cm, sd = 0.8), respectively. Other than the spotted deer, only two intact lower jaws of the wild boar were found. The lower jaw lengths of these two specimens were 20.5 and 21.7 cm, and the total diastema length in both cases was 0.5 cm.

The age classes of the killed spotted deer were identified both on the basis of observation of intact kills and on the eruption of teeth in the lower jaw. Most of the kills were adult animals, based both on the frequency of fresh kills (56.5%) and eruption of teeth (76.5%) (Table 4.5).

I tried to determine the age of kills by counting tooth cement rings (Ashby and Santiapillai 1986, Ballard *et al.* 1995, Landon *et al.* 1998). The first lower molar teeth of few kills were vertically sectioned and polished, but no distinct annuli were found. This was probably because the Sundarbans is basically an evergreen habitat and there is no sharp seasonal difference.

Table 4.5 Age of spotted deer kills based on observation of kills and on the eruption of teeth in the lower jaw

Age based on kills			Age based on eruption of teeth		
Class	**No.**	**%**	**Class**	**No.**	**%**
Adult	26	56.5	Adult	26	76.5
Yearling	11	23.9	Yearling	6	17.6
Fawn	9	19.6	Fawn	2	5.9

Records of the health of killed spotted deer show that most of the kills had good condition before they were killed (78.8%) (Table 4.6).

Table 4.6 Condition of spotted deer kills

Condition		
Class	**No.**	**%**
Good	52	78.8
Moderate	14	21.2
Bad	0	0

4.3.6 Abundance and Selection of Spotted Deer in Different Age Classes

Comparison of the abundance and selection of spotted deer in three relative age classes shows that, in general, the maximum number of kills were adult animals. The abundance of adult spotted deer was also higher, i.e. more than double the abundance of yearling or fawn. The age of kills was identified, both on the basis of the kill itself and on the eruption of teeth on the lower jaw. In both respects, kills followed the same pattern of abundance, i.e. the selection of adult animals was more than double that of the selection of yearling or fawn (Figure 4.6).

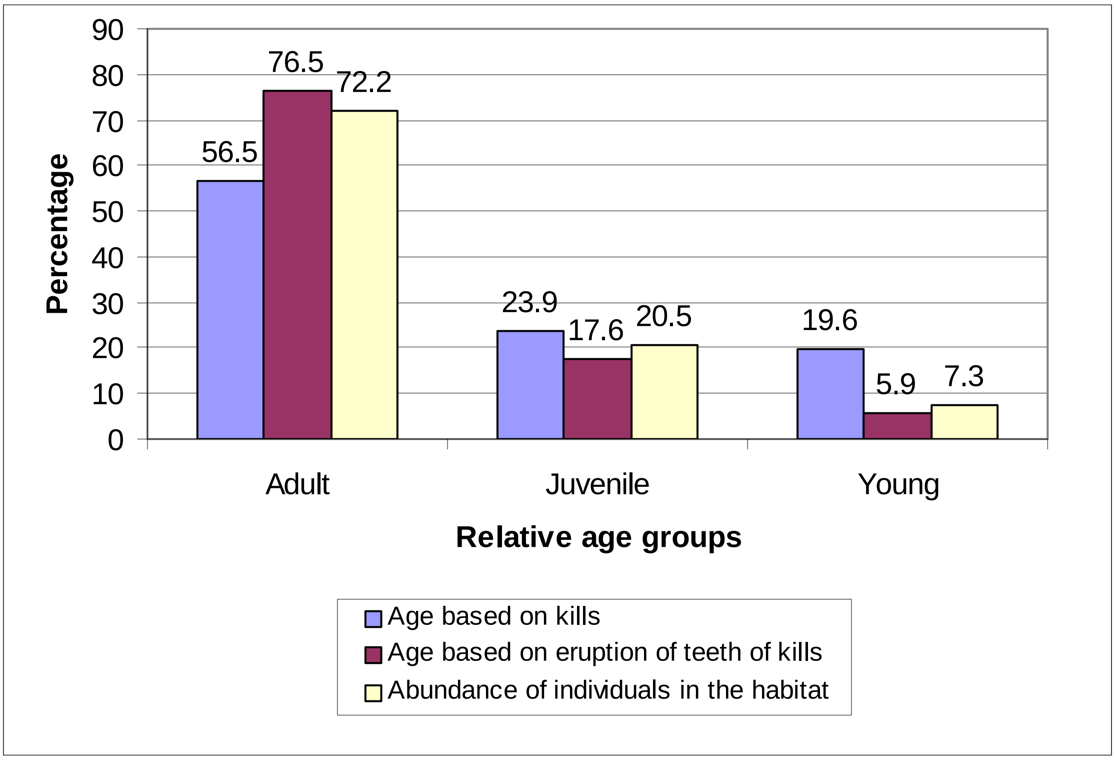


Figure 4.6 Abundance and selection of spotted deer in different age classes in the Sundarbans East Wildlife Sanctuary.

Based on Ivlev's selectivity index, the values of D for adult, yearling and fawn age classes of the spotted deer were calculated at 0.112, –0.094 and –0.113, respectively. Since the value is positive only for adult age class and negative for yearling and fawn classes, it can be concluded that the adult spotted deer were positively selected, whereas the yearling and fawn spotted deer were negatively selected. In other words, the predation was higher than the abundance of adults, but lower than the abundance of yearling and fawn.

4.4 DISCUSSION

4.4.1 Prey Selection

Across its global range, the tiger's principal prey consists of large herbivores, but it is supplemented by macaques, langurs, smaller mammals, birds, lizards, fish, etc., and occasionally humans (Nowell and Jackson 1996, De 1999). Tigers will also attack young of elephants and rhinos (Nowell and Jackson 1996), and sometimes kill and eat leopards and their own kind, as well as other carnivores, including bears, weighing up to 170 kg, which they attack in their winter dens (Heptner and Sludskii 1972). They readily eat carrion (Schaller 1967).

While studying prey selection by tigers, more emphasis was given to scat data, because scat samples portray predator diets more accurately, whereas the kill samples underestimate proportions of smaller prey and young individuals (Karanth and Sunquist 1995, Miquelle *et al.* 1996). Even in the scats, the smaller prey are believed to be under-represented, because these are consumed completely without leaving a trace in the faecal material, which causes the underestimation of the role of these prey in a predator's diet (Bothma and le Riche 1984, Karanth and Sunquist 1995, Khorozyan and Malkhasyan 2002). Floyd *et al.* (1978) and Oli *et al.* (1993), however, think that smaller prey contain a relatively high proportion of indigestible matter, and their remains are over-represented in scats.

The findings of scat analysis during this study fully agree with Schaller's (1967) statement that most scats contain the remains of only one prey species, but a few contain two different items. The corrections (by using the regression of Ackerman *et al.* 1984) applied to frequencies of occurrence of different prey species in scats were found useful to overcome biases caused by the differences in prey size (Floyd *et al.* 1978, Ackerman *et al.* 1984, Karanth and Sunquist 1995). Most of the earlier predation studies (Schaller 1967, Sunquist 1981, Norton *et al.* 1986, Rabinowitz 1989; Johnsingh 1983, 1993) did not use corrected frequencies.

The preference for large prey species (spotted deer), as found in this study, supports the hypotheses related to foraging theory (Stephens and Krebs 1987), which suggest that predators may select species containing the most 'profitable' prey, as measured by the ratio of energy gain to handling time (MacArthur and Pianka 1966, Schoener 1971, Pulliam 1974, Werner and Hall 1974, Charnov 1976, Scheel 1993, Karanth and Sunquist 1995). For large felids the most profitable prey type would seem to be the largest available prey that could be safely killed, but the importance of search time, encounter rates, and the energetic costs of capture for various prey types also need to be considered (Sunquist and Sunquist 1989). Large carnivore species must rely upon the energy sources that occur in large food items, unless they can collect smaller prey with great efficiency (McNab 1963); carnivores usually prey upon herbivores of about their own size and weight (Bourliere 1963). Tiger and leopard (*Panthera pardus*) usually catch the kill when it is large enough to afford more than one meal (Johnsingh 1983). The vertebrate predators would be selective 'energy maximisers' in prey-rich habitats, but would be non-selective 'number maximisers' in habitats where large prey are scarce (Griffiths 1975).

It has been reported that tigers prefer to hunt larger prey species (>176 kg), especially when there are other carnivores like leopards and Asiatic wild dogs (*Cuon alpinus*) in the same habitat (Schaller 1972; Karanth and Sunquist 1995, 2000; Bagchi *et al.* 2003). Although leopards are able to hunt larger prey species, they rarely kill prey of more than 50 kg (Pienaar 1969, Schaller 1972, Rabinowitz 1989). In the Sundarbans, tigers mainly hunt the largest available prey species, i.e. the spotted deer.

The spotted deer is the largest and dominant prey of tigers in the Sundarbans. Although it is relatively very common in the Sundarbans East WS, it is not very common in the rest of the Sundarbans. The spotted deer was also one of the main prey of tigers in other tiger ranges in the Indian sub-continent (e.g. Schaller 1967, Johnsingh 1983, Panwar 1990, Karanth and Sunquist 1995, Ramakrishnan *et al.* 1999), but according to Gogate and Chundawat (1997), sambar (*Cervus unicolor*) and nilgai (*Boselaphus tragocamelus*) are the two main prey species in Panna, India, although the spotted deer is also found there. In the Russian Far East, according to Abramov (1962), wild boar forms the highest percentage of kills (30-35.7%). More recent and more complete work on the tiger food habits in the Russian Far East (Miquelle *et al.* 1996), however, found that elk (*Cervus elaphus*) and wild boar were consistently the two key components of the tiger diet, together accounting for 84% of kills. Moreover, tigers killed an average of 4.3 pet dogs and 4.2 domestic livestock/year.

Reza *et al.* (2001a) analysed 52 scat samples, which were collected from the Katka-Kochikhali area of the Sundarbans East WS. They reported that, on average, the percentage by weight of spotted deer, wild boar and rhesus macaque hairs, unidentified animal parts and soluble material were 69, 15, 5, 4 and 6, respectively, which was different from the findings of this study. Reza *et al.*'s (2001a) methods were questionable, because they had weighed hair samples collected from each scat and the results were based on relative weights of hair samples of three mammalian prey (spotted deer, wild boar and rhesus macaque). Since the weight and size of hairs of these three species are not uniform, the relative weights of hair samples in scats do not accurately represent either relative biomass or relative numbers of different prey species consumed. Moreover, hairs are not uniformly distributed on the skin of these three species. For example, the wild boar has fewer hairs than spotted deer and rhesus macaque. No other scat study of large cats used this method, not even Ranawana *et al.* (1998), whom Reza *et al.* (2001a) claimed to follow. They have found the mean weight of scat as 122 g and the spotted deer as the principal prey, which was generally the same as in this study.

According to Tamang (1993), the principal prey of the tiger in the Sundarbans are spotted deer and wild boar, but tigers are opportunist feeders and there are records of predation of rhesus macaque, barking deer, otters, small carnivores, birds (mainly red junglefowl), monitor lizards (*Varanus* spp.), other reptiles, frogs, fish, crabs, and occasionally humans. My findings generally agree with this.

In the Sundarbans the tiger prey heavily on the spotted deer population, hence it might play the key role in shaping the deer population and perhaps even their average body size (since larger individuals are hunted more often than others). Predator-prey interactions affect population dynamics of individual species and community structure (Gasaway *et al.* 1992, McLaren and Peterson 1994, Estes and Duggins 1995, Macdonald *et al.* 1999, Baker *et al.* 2001). Other researchers have observed that increased predation risk leads to decreased body mass (hence fecundity), and decreased food levels lead to increased mortality of the prey (McNamar and Houston 1987, Ludwig and Rowe 1990, Brown 1992). The survival rate of the spotted deer depends mainly on the predation by tigers. Studies in North America revealed that predation by even a small number of puma can affect bighorn sheep (*Ovis canadensis*) survival rates (Wehausen 1996, Ross *et al.* 1997), and population-level effects may be exacerbated if female bighorn sheep are preyed upon heavily (Hayes *et al.* 2000).

In Kanha, India, spotted deer remains were found in the highest percentage of tiger scats (52.2%) as well as tiger and leopard kills (43.0%) (Schaller 1967). Johnsingh (1983) found that spotted deer and sambar were the two main prey species for tigers in Bandipur, India. These two species represented 39% and 30.5% in scats, and 26.3% and 36.8% in kills. Bagchi *et al.* (2003) found similar results in Ranthambhore, India, where sambar and spotted deer were represented in 47% and 31% scats. For the spotted deer, the reason for under-representation in kills could be due to fawn kills, which could be fully eaten by the tiger within hours and therefore go undetected by observers

(Johnsingh 1993). In Panna, India, Gogaet and Chundawat (1997), and Chundawat (2001) found that sambar, nilgai and spotted deer contribute over 65% of the occurrence in scats, but tigers also killed over 60 cattle annually. In Eravikulam, India, where the spotted deer is absent, Rice (1986) reported that sambar is the main prey of the tiger, which is represented in 94% of the scats. In Melghat, India, however, the sambar had the highest percentage (34.2%) of the scats, but the spotted deer is also found there (Koppikar and Sabnis 1979). In Bandipur, India, tiger kills over 100 kg class formed 42% (Johnsingh 1993). Karanth and Sunquist (1995) identified spotted deer and sambar as the two main prey species in Nagarhole, India. They have found the remains of these two species in 31.2% and 24.9% of the scats, but 10.4% and 28.6% in kills, respectively. Based on the scat data, the relative numbers of these two prey species killed by tigers were calculated at 22.8 and 11.4, respectively. Karanth and Sunquist (1995) also reported that the biomass estimates based on these data show that spotted deer, sambar, gaur (*Bos frontalis*), wild boar, barking deer (*Muntiacus muntjak*) and hanuman langur (*Semnopithecus entellus*) comprised 97.6% of the biomass killed by tigers. In contrast, I have found that the spotted deer alone was 80.1% of the biomass and the three mammalian species together provided 94.2% of the biomass consumed by tigers in the Sundarbans.

In Melghat, India, Koppikar and Sabnis (1979) analysed 91 tiger scats and reported that sambar is the main diet (34.2%). Although the tiger also prey on the cattle, the percentage of cattle in the tiger diet is very low (1.1%)in comparison to the abundance.

In Huai Kha Kheng, Thailand, Rabinowitz (1989) worked on food habits of the tiger. Based on the analysis of 38 scats he concluded that barking deer (*Muntiacus muntjak*) is the commonest prey species, comprising 42% of the frequency of occurrence in the scats. Other common prey species are crestless Himalayan porcupine (*Hystrix hodgsoni*), wild boar, hog badger (*Arctonyx collaris*), sambar and Phayre's langur (*Trachypithecus phayrei*).

4.4.2 Non-food Items in Scats

Other than typical food items, soil and sungrass have been reported in tiger scat samples (Powell 1957, Schaller 1967, Johnsingh 1983, Reza *et al.* 2001a, this study). During this study, soil was found in huge quantities (more than 50% of the volume) in 51% of the scat samples, which is the highest proportion of soil-containing scats ever reported. Schaller (1967) reported that scats with soil and grass (more than 50% of the volume) represented 3.8% and 2.3% of all types of items eaten by tigers in Kanha, India. He found most of the soil-contained scats during October-December, i.e. early winter, and suggested a seasonal incidence of soil-eating. A similar trend was found in this study, in which more than 80% of the soil-containing (more than 50% of the volume) scats were found in winter (October-March), with the peak in November-December (ca. 15%). In Bandipur, India, Johnsingh (1983) found that out of 36 scats, three contained soil and two contained grass (more than 50% of the volume). Reza *et al.* (2001a) mentioned the occurrence of an average 6% weight of scats composed of soil in the Sundarbans, but in this study, soil was found to constitute more than half of the volume of 51% of scat samples. This means that the percentage of weight of soil was definitely much higher than 6%. The soil was also found in the scats of leopard (Johnson *et al.* 1993, Ranawana *et al.* 1998) in the Indian sub-continent.

I have also found sungrass in few samples of tiger scats, but only one sample had sungrass more than 50% of the volume. Other than the tiger, grass was also found in the scats of snow leopard (*Uncia uncia*) (Oli 1993), fishing cat (*Prionailurus viverrinus*) (Haque and Vijayan 1993) and Asiatic wild dog (Johnsingh 1983) in the Indian sub-continent. In Huai Kha Khaeng, Thailand, Rabinowitz (1989) found grass in 50% of the large cat scats (237 leopard scats and 38 tiger scats). Small amount of plant materials were found in scats of the big cats [jaguar (*Panthera onca*) and puma] in South America (Taber *et al.* 1997).

Experts suggest that the presence of soil in leopard scats may have resulted either coincidentally from feeding and possible digging activities associated with predation upon rodents or ingested as a dietary supplement. Some species of mammals and birds often ingest soil to meet some mineral requirements. Murie (1944) found that several wolf droppings contained both grass and round worms, and he suggested that the vegetation may act as a scour. In Kanha, India, one grass-blade-rich tiger dropping had a tapeworm (Schaller 1967). These findings suggest that the ingestion of soil and sungrass blades by tigers are probably to meet nutrient requirements, to scour the digestive system for internal parasites and/or for better digestion.

4.4.3 Prey Abundance Versus Prey Selection

In Nagarhole, India, Karanth and Sunquist (1995) studied prey selection by tiger, leopard and Asiatic wild dog. They concluded that all three predators selected prey species non-randomly when prey abundance was estimated both on group densities and individual densities. Their results showed that tigers preferred gaur significantly more, but avoided hanuman langur. The under-representation of spotted deer and barking deer in the tiger's diet may reflect avoidance of smaller prey, or may have resulted from the diurnal activity patterns of these two prey species (Johnsingh 1983). When measuring selectivity towards the three size classes of prey, Karanth and Sunquist (1995) noted that the probability of any predator encountering a prey animal in a particular size class was also conditional upon the encounter probability with a group containing a prey of that size. In the Sundarbans, I have also found that tigers non-randomly selected the prey species and the largest and commonest available ungulate (spotted deer) forms the bulk of the diet.

In Bandipur, India, tiger scat and kill data reveal that proportionately fewer spotted deer were killed than were present in the population (Johnsingh 1983, 1993). Although the spotted deer constitute 69% of the total prey population (excluding porcupine, hare and peafowl), it was represented in only 26% of kills and 39% of scats. This can be attributed to the anti-predator behaviour of the spotted deer, which assemble in open areas to spend the night, where they are relatively less vulnerable to tiger predation. In contrast, the sambar was only one-fifth as abundant as the spotted deer, but tigers preyed proportionately more on the sambar (Johnsingh 1983, 1993). This was supported by the study in Chitwan, Nepal, where tigers were reported to kill the sambar more often than predicted on the basis of abundance, and suggested that this large (150-250 kg) prey was selected, or that they were more vulnerable than the smaller but more abundant spotted deer and hog deer (*Axis porcinus*) (Sunquist 1981). In Panna, India, Gogate and Chundawat (1997) also reported similar findings, that is, although nilgai was the commonest and hanuman langur was the third commonest prey species, both have been identified as less used by tigers.

The spotted deer was virtually the only large prey in the Sundarbans, hence it is difficult to compare my conclusions with those of Johnsingh (1983, 1993) or Sunquist (1981). The diagrams prepared on the basis of abundance and consumption (Figures 4.4 and 4.5), in terms of both numbers and biomass, of the six commonest prey species indicate that, in general, prey size together with the abundance is the most important factor driving the prey consumption. There are many other factors involved in tiger predation, such as anti-predator behaviour, detectability, 'profitability' in terms of energy gain, etc. Where predation is implicated in the regulation of prey populations, anti-predator behaviour will probably play a role in the process (Abrams 1989, 1999; Matsuda and Abrams 1994, Hik 1995). Anti-predator behaviours have an important role in determining patterns of species coexistence (Kotler 1984, Brown 1989, Hughes *et al.* 1994). On the other hand, detectability/visibility is considered an important component of bighorn sheep (*Ovis canadensis*) predation by puma in North America (Risenhoover and Bailey 1985, Gionfriddo and Krausman 1986).

Based on prey selectivity in comparison to abundance, the index of selectivity of the six potential prey species in the Sundarbans East WS identified wild boar and lesser adjutant as the two highest-ranking species. These two species, however, contribute little in biomass abundance and biomass consumed by tigers in the Sundarbans, so highest-ranking species should not be confused with commonly-preyed species. Since both wild boar and lesser adjutant are largely solitary (see Chapter 3), they are more vulnerable to tiger predation. According to van Orsdol (1981), lion hunting success varied with the size of prey group; single and paired prey were more easily caught than those in larger groups. Moreover, tigers probably preferred wild boar and lesser adjutant as a change in common prey item (spotted deer). Although the ring lizard was common, it has been identified as a non-used species (there was no trace of it in scats) probably because, like most mammalian species, tigers are reluctant and to some extent afraid of reptiles.

4.4.4 Selectivity for Age-sex Classes

Predators may preferentially select sub-standard (juveniles and young) animals, because they are less adapted to escape (Hornocker 1970, Mech 1970, Schaller 1972, Curio 1976, Vitale 1989). Although tigers in Nagarhole, India, killed substantial proportions of sub-standard prey animals, they also preyed heavily upon standard animals (Karanth and Sunquist 1995). Karanth and Sunquist (1995) found relatively high proportions of sub-standard prey animals killed by tigers and, based on Temple's (1987) study, they concluded that the relative vulnerability of ungulate prey species to solitary ambush predators might depend more on prey anti-predator behaviour than on prey size. They reported that young animals were killed by tigers roughly in proportion to abundance among spotted deer, sambar and wild boar, but gaur young were taken in greater than expected proportions. Similarly, Miquelle *et al.* (1996) reported that tigers predominantly killed adult elk and wild boar, but young comprised 30-36% of the kills.

In this study most of the tiger kills were adult animals, which does not agree with above-mentioned findings. There was no tendency to prefer sub-standard or young animals, probably because there was no prey as big as the gaur. It may not be 'profitable' to hunt young spotted deer instead of the adult because of size. The adult spotted deer is not too big to pose any challenge to the tiger and in the Sundarbans there is enough cover for the tiger to ambush. The findings from tiger kills and their jaws, however, could be adult-biased, because young and juvenile animals are smaller and they are more commonly eaten completely by predators (Schaller 1967, Sunquist 1981, Johnsingh *et al.* 1991). Moreover, the kill detectability by the researcher is normally large-animal-biased (Ruggiero 1991). During my study, great care was taken to minimise this bias.

Male deer are said to be more susceptible to tiger predation (Johnsingh 1993). Schaller (1967) found tigers killed more sambar males [male-female ratios: in the kills – 120:100 (n = 11), in the population – 30:100]. Johnsingh (1993) also reported the male-biases of deer kills by tigers. Karanth and Sunquist's (1995) study in Nagarhole, India, showed some striking patterns of selectivity for sex classes. Tigers appeared to select adult male spotted deer, sambar and wild boar, and preferred adult males next only to young gaur.

The male-biased predation hypothesis is explained by the relatively more solitary nature of males (Taylor 1976), spacing behaviour of males in the herd (Fitzgibbon 1990), wide roaming in rutting season (Karanth and Sunquist 1995), weakened condition after rut (Hornocker 1970), more conspicuous as a target (Karanth and Sunquist 1995, this study), less agile to escape when with antlers (Karanth and Sunquist 1995), and from intra-specific aggression-related injuries (Estes and Goddard 1967, Kruuk 1972, Schaller 1972, Karanth and Sunquist 1995). Based on my field observations it seemed most likely that the larger size of the male makes it more attractive and conspicuous to the tiger, which might be the main reason of male biases in tiger kills.

I could not study the sex of the kills, because in most cases partly fed kills were found. Tigers start feeding from the caudal portion of the kill, so the genital organ was rarely observed, but, based on the presence of antlers or antler bases, it appeared that most of the spotted deer kills were adult males.

4.5 SUMMARY

- This study was conducted to determine prey selection by tigers in the Sundarbans East Wildlife Sanctuary of Bangladesh. A total of 145 scats were analysed and 78 kills were studied.

- The frequency of occurrence of different prey species in scats and kills were significantly different. On average, the spotted deer was the most frequent prey in scats and kills (78%).

- The frequencies of occurrence in scats were converted to the relative numbers of kills. Results showed that the spotted deer was still the most frequently occurring prey in the tiger diet, but the percentage decreases to 29.9% by this method.

- When the relative numbers were converted to relative biomass, the spotted deer was found to form 80.1% of the prey biomass consumed by tigers. This was because the spotted deer is the commonest and largest prey in the Sundarbans.

- Other than the spotted deer, tigers also preyed on wild boar, rhesus macaque, lesser adjutant, etc.

- Soil and sungrass were found in scats as non-food items. Scats with high (more than 50% of the volume) soil contents were more available in winter than in summer.

- In general, the trend of prey selection appeared to follow prey size and abundance, but wild boar and lesser adjutant were two most high-ranking prey species because their selectivities were higher in comparison to their abundance.

- Most spotted deer kills were adult animals both on the basis of kills (56.5%) and eruption of teeth (76.5%), and most were in good condition before they were killed (78.8%).

CHAPTER 5 RELATIVE HABITAT USE

5.1 INTRODUCTION

To maintain viable populations, large carnivores need large areas with adequate prey densities and are therefore threatened by habitat loss and fragmentation (Woodroffe and Ginsberg 1998, Terborgh 1999). According to Sunquist and Sunquist (2002), the tiger's main requirements are a sufficient supply of large prey, enough cover for stalking and access to water. Tigers are not tied to a particular habitat type or temperature regime and they have few ecological constraints that relate to specific habitat requirements (Miquelle *et al.* 1996). It is important to know, however, how they use different habitat types for their different activities in a particular ecosystem, so that any management programme can consider the use of diversified habitat types by the tiger. According to Smith *et al.* (1998), good quality habitat is important for the tiger's existence: when the good quality habitat drops below about 50%, tigers no longer breed successfully; when it drops below 30%, tigers no longer occur in an area.

According to Garshelis (2000), the word *habitat* has two distinct usages. The true dictionary definition is the type of area where an animal normally lives or, more specifically, the collection of resources and conditions necessary for its occupancy. A second definition is a set of specific environmental features, which for terrestrial animals are often equated to a plant community, vegetative association, or cover type. According to the Botanical Survey of India (1984), a habitat may be defined as an area possessing uniformity of physiography, vegetation, climate and any other parameter that the investigator considers is important in a particular context. Two other terms, habitat *selection* and *preference*, are often used interchangeably to describe differential use of habitat types, but they have subtly different meanings. Johnson (1980) defined *selection* as the process of choosing resources and *preference* as the likelihood of a resource being chosen if available on an equal basis with others. In the wild, however, preferences must be inferred from patterns of observed use of environments with disparate, patchy, and often varying resources (Garshelis 2000).

The tiger is found in a variety of habitats: from the tropical evergreen and deciduous forests of southern Asia to the coniferous, scrub oak, and birch woodlands of Siberia (Nowell and Jackson 1996). While tigers survive in a variety of habitat types, they live at higher densities in areas with high prey biomass (Sunquist and Sunquist 2002). The greatest ungulate biomass in southern Asia is found in areas where grassland and forest form a mosaic of vegetation types that support a rich ungulate community (Schaller 1967, Eisenberg and Seidensticker 1976, McDougal 1977, Sunquist 1981, Smith *et al.* 1987a, Karanth 1987, Karanth and Sunquist 1992, Sunquist *et al.* 1999).

Habitat loss and fragmentation are two of the main challenges in the conservation and management of large carnivores in the world (Peyton *et al.* 1999). Habitat fragmentation can result in small and isolated populations that become vulnerable to extinction (Diamond 1986, Wilcove 1987). Thus, examining relative habitat use by tigers is important to identify the priority issues of habitat management for long-term conservation of the tiger, its prey and the quality of the Sundarbans.

The ability to detect and analyse animal signs in the wild through non-invasive techniques is becoming an integral part of wildlife research and management, particularly with carnivores that are generally secretive and costly to capture and study (Leslie 2001). There are various uses of mammal signs in the scientific study of less visible species. For example, mammal tracks may provide clues about behaviour, age, social status, mode of locomotion and foraging behaviour, as well as the identity of the animal (Wemmer *et al.* 1996), and even used as indices of abundance (Tyson 1959, van Dyke *et al.* 1986, Nichols and Conroy 1996). Tiger signs are not only used to study their relative habitat use, but also to know how they mark their territories. Tigers usually lead a solitary life and the intra-sexual territories are maintained by advertisements – both olfactory as well as visual (Kotwal and Mishra 1995). Calls, scent markings, claw markings, and defaecation are common ways of maintaining the territory. There are few reports on tiger olfaction (scent marks, pheromones, etc.) (Brahmachary and Dutta 1979, Chaudhury 1979, Smith *et al.* 1989, Brahmachary *et al.* 1991, Asa 1993, Sunquist and Sunquist 2002) and scratches or claw marks (Kotwal and Mishra 1995).

The general objective in this Chapter is to *assess the relative use of four different habitat types by tigers for their different activities in the Sundarbans*. The specific questions are –

1) Is there any habitat preference for tigers for their different activities?
2) Is there any similarity in the habitat preference for some of the activities?
3) Which habitat type is most commonly used?
4) Which trees are commonly used for scratches?

5.2 METHODS

The primary hypothesis of interest was that each of the habitat types is used in proportion to its availability in the study area (Neu *et al.* 1974, Alldredge and Ratti 1986, Otis 1997). Deviations from expected proportional use are interpreted as evidence of selection, depending on the sampling design. According to Garshelis (2000), habitat use is generally considered to be selective if the animal makes choices rather than wandering haphazardly through its environment. Typically, the disproportionate use of a habitat compared to its availability is taken as *prima facie* evidence of selection, i.e. a habitat that is used more than its availability is considered to be selected for. Conversely, a habitat that is used less than its availability is often referred to as being selected against, or even avoided. This was the primary assumption to compare the relative density of different types of tiger signs in four different habitat types in the Sundarbans East Wildlife Sanctuary (WS).

This study was based mainly on the differences of the relative density of tiger signs in four habitat types. These differences could be a result of the differential accessibility for tigers, differential density or territorial borders of tigers, compression effects among tigers or even some habitat bias due to differential longevity of the signs and amongst the observers' sign visibility. If these had little effects on the results, the relative density of tiger signs in different habitat types might be an indication of the differential use, i.e. the habitat preference of the tiger. Results based on signs can rarely be fully accurate, because the animals are not directly observed, but in case of many threatened species, signs are the only easily available source of information.

Line-transect sampling (Eberhardt 1978, Burnham *et al.* 1980, Drummer and McDonald 1987, Buckland *et al.* 1993, Lancia *et al.* 1994, Buckland *et al.* 2001, Thomas and Karanth 2002) was conducted in order to record the relative abundance of tiger signs in four major habitat types (mangrove woodlands, grasslands, sea beaches and transitional zones) available in the Sundarbans East WS. Sign surveys via transects have been executed successfully by many specialists (Gibson and Hamilton 1983, Garshelis *et al.* 1999, Cuesta *et al.* 2002, Augeri 2004 in prep.), but to be reliable as an indicator of the presence and activities of a given species, signs must have been previously validated, i.e. that species must have been identified in the act of producing the sign (Wemmer *et al.* 1996). Similar methods were used to study habitat use by jaguar (*Panthera onca*) (Lopez Gonzalez and Brown 2002) and ocelot (*Leopardus pardalis*) (Lopez Gonzalez *et al.* 2003) in the Americas. Since the tiger is the only large carnivore in the Sundarbans, there was virtually no question of confusing tiger signs with the signs of other animals. Joslin (1973) pointed out that relative density of tigers between localities or years could be estimated using suitably-designed indices like number of tracks/scats/sightings each km of roads traversed. Line-transect sampling is widely used to estimate the density of wild animals or their signs.

Sample bias is an obvious potential problem in measuring habitat use based on signs (Garshelis 2000). Interpretations of habitat use from visual observations of animals or their signs can vary among observations (Schooley and McLaughlin 1992) and sightability can vary among types of habitats (e.g. because of differing vegetation density; Neu *et al.* 1974), both of which can introduce biases in the data. In order to avoid these potential biases, large sample sizes were derived and three local assistants (mainly the same persons throughout the study period) continuously accompanied me in order to avoid the biases of visual observations. Since the widths of the transects were only five metres, there was virtually no bias due to the observers' different visibilities in different habitat types, but this was still prone to biases of the differential longevity or distinctiveness of signs in different habitat types.

I covered a total of 360.2 km distance by 276 line-transects in 18 months (September 2001-February 2003), i.e. the average length of a transect was 1.3 km (range 0.5-3.6 km) and the monthly average distance covered by transects was 20 km; the transect width was always five metres. Most of these transects were the same transects conducted to record prey density (see Chapter 3), because in most cases a transect was conducted simultaneously for prey and tiger signs. In areas where both prey and tiger signs were very common, it was difficult to pay attention to both prey and tiger signs at the same time, so some transects were conducted separately. A Garmin 12XL GPS (accuracy: ±15 m) was used to calculate the length of each transect (in km). GPS readings were always taken in relatively open areas in order to get more satellite connections, hence more accurate readings. Since the Sundarbans is generally a flat land, the aerial distance was a close representation of the actual distance covered in line-transects. The sampling effort was uniform for different seasons of the year. Since many parts of this mangrove forest were very dense and there were many rivers and creeks, it was not possible to make very long transects at a time.

Stratified random sampling (Buckland *et. al.* 1993) was designed, i.e. the four habitat types in the entire Sanctuary were demarcated (based on vegetation maps prepared by Sundarbans Biodiversity Conservation Project, Bangladesh Forest Department, and my preliminary survey), and the transect lines were placed randomly in each of the habitat types. This was done by putting some random points on the map to start the transects, but the directions of transects were chosen from the starting points on the basis of accessibility. A few areas were very unsuitable for making transects due to inaccessibility and presence of large rivers, and only those areas had to be avoided. At least 4.5 km transects were conducted in every month in each of the four habitat types. The four habitat types were defined as –

1) Mangrove woodlands – areas dominated by mangrove trees like *Heritiera fomes*, *Excoecaria agallocha* and *Sonneratia apetala*, covering about 70% of the land area of the Sanctuary, and includes narrow creeks because these are intertwined with mangrove woodlands; the woodland floor was relatively clear in many areas.
2) Grasslands – open meadows with *Imperata cylindrica*, *Acrostichum aureum*, *Myriostachya wightiana*, etc., covering about 10% of the land area of the Sanctuary; there were some bare areas and sand dunes in the grasslands.
3) Sea beaches – relatively open but narrow sandy strips along the sea, with sparse reeds and other stunted vegetation, covering about 6% of the land area of the Sanctuary.
4) Transitional zones – areas that fell in none of the above-mentioned three categories, such as areas between mangrove woodlands and grasslands, characterised by having few trees and sometimes sungrass and reeds, which covers about 14% of the land area of the Sanctuary.

With three assistants I walked along transects at a uniform speed of about 1.3 km/h and recorded all types of tiger signs in 5 m width, i.e. 2.5 m on each side of the basal line. A compass and a GPS were used to make sure that the walk was straight. The different types of signs recorded were of movement, feeding, resting, defaecation, interaction [with mate/cub(s)], scratch-scent-urinal, and 'others' (hunting, drinking, etc.). Aggregation of the same types of signs produced at the same time were counted as one observation, e.g. many pugmarks along the transect were considered as one movement sign, or many scratches on a tree were considered as one scratch sign. The soft muddy ground in most of the Sundarbans was very suitable to record tiger signs. In general, signs could be easily identified in most of the soil and vegetation types, but since the longevity of signs in four different habitat types was not uniform (mainly due to differences in soil types), signs that were more than about 10 days old were discarded. Normally most of the sign types last at least 10 days in any habitat type in the Sundarbans (M.M.H. Khan pers. obs.). The ages of signs were determined rather arbitrarily, but the rate of decay of newly-produced tiger signs (known to us) and our own footprints in different soil types were useful.

Since the lengths of transects were variable, the data, i.e. the absolute frequencies of signs for each of transects, were then standardised by dividing the frequencies by the respective transect length. This gave relative frequencies (or densities) of signs adjusted for a 1-km transect in all cases. Then the means of total relative frequencies of all sign types across four different habitat types, and the means of each of the different sign types across four different habitat types, were tested statistically (non-parametric Kruskal-Wallis H) to examine whether the mean frequencies in different habitat types were significantly different or not. The total frequencies of each of different sign types irrespective of habitat types, and in each of the four different habitat types, were tested statistically (non-parametric χ^2 test) to examine whether the frequencies of different sign types were significantly different or not.

Tiger scratches on trees were especially recorded to know what types of trees they prefer to use for this activity. Following Kotwal and Mishra (1995), notes were taken on the species of trees used, together with the bark type and heights of claw marks from the ground.

5.3 RESULTS

5.3.1 Relative Habitat Use

The mean density of tiger signs (total of all types of signs) in mangrove woodlands, grasslands, sea beaches, and transitional zones show that they were not significantly different across four different habitat types (Kruskal-Wallis H = 3.48, df = 3, p = 0.323). It indicates that, in general, habitat use by tigers was similar, i.e. there is no indication of habitat preference among these four habitat types.

The mean number of signs per unit area (total of all types of signs) in four different habitat types were not much variable (Figure 5.1), which shows that tigers widely use all the four habitat types available in the Sundarbans East WS, but the sign density was highest in mangrove woodlands (966.9/km^2) and lowest on the sea beaches (533.9/km^2).

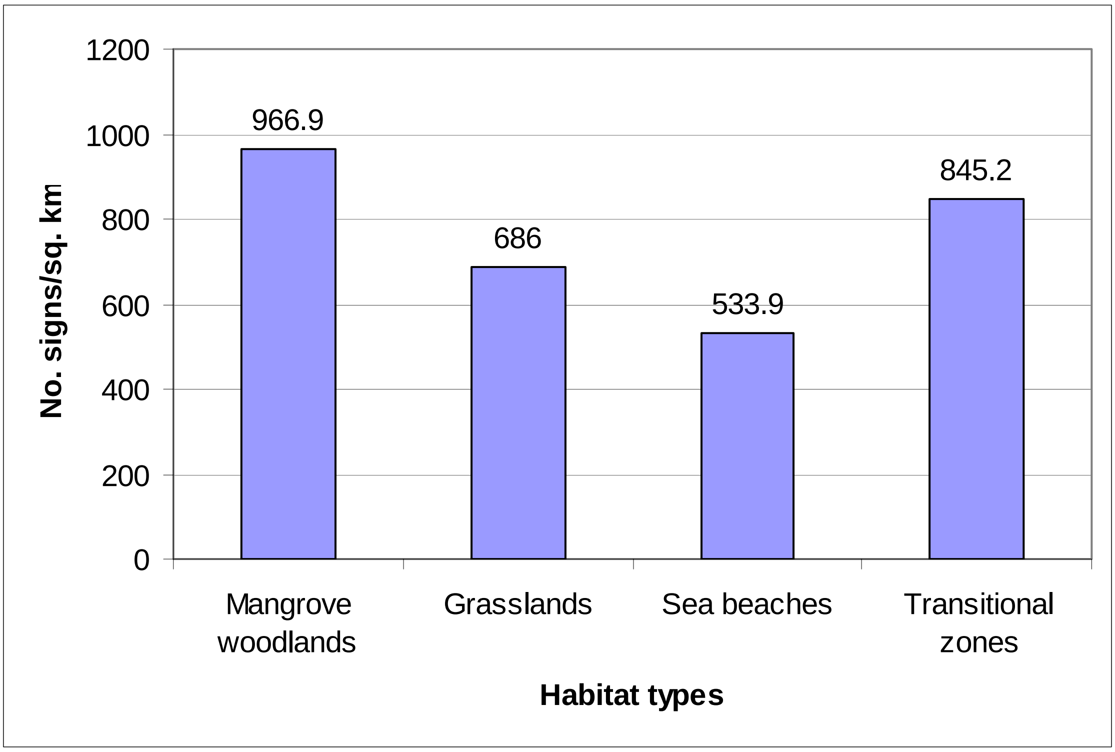


Figure 5.1 Mean density (no./km^2) of tiger signs in four different habitat types in the Sundarbans East Wildlife Sanctuary.

Table 5.1 Total number and density (no./km^2) of different types of tiger signs in the land area of the Sundarbans East Wildlife Sanctuary. Here MA = mangrove woodlands, GR = grasslands, BE = sea beaches, and TR = transitional zones

Habitat type	**Total transect length (km)**	**Tran-sect width (m)**	**Total signs per habitat type**		**Sign types**													
					Movement		**Feeding**		**Resting**		**Defaecation**		**Interaction [with mate/ cub(s)]**		**Scratch-scent-urinal**		**'Others' (hunting, drinking, etc.)**	
			no.	**no./km^2**	**no.**	**no./km^2**	**no.**	**no./km^2**	**no.**	**no./km^2**	**no.**	**no./km^2**	**no.**	**no./km^2**	**no.**	**no./km^2**	**no.**	**no./km^2**
MA	103.2	5	499	966.9	367	711.2	38	73.6	6	11.6	43	83.3	28	54.3	9	17.4	8	15.5
GR	89.8	5	308	686.0	175	389.8	8	17.8	17	37.9	74	164.8	20	44.5	8	17.8	6	13.4
BE	81.3	5	217	533.9	158	388.7	2	4.9	2	4.9	18	44.3	36	88.6	1	2.5	0	0
TR	85.9	5	363	845.2	259	603.0	29	67.5	14	32.6	30	69.8	16	37.3	6	14.0	9	21.0
Total/ Overall	**360.2**	**5**	**1,387**	**770.1**	**959**	**532.5**	**77**	**42.8**	**39**	**21.7**	**165**	**91.6**	**100**	**55.5**	**24**	**13.3**	**23**	**12.8**

Results varied for the mean densities of different types of tiger signs in different habitat types (Figure 5.2). In case of feeding, resting, defaecation and interaction signs the means for four different habitat types were significantly different, which indicates that tigers probably have habitat preference for these activities. In case of movement, scratch-scent-urinal, and ‘others’ signs, however, the means for four different habitat types did not differ significantly, i.e. tigers probably have no significant preference for any habitat type for these activities (Tables 5.1 and 5.2).

Table 5.2 Kruskal-Wallis tests for different types of tiger signs in four different habitat types

Sign type	**Kruskal-Wallis test for means of frequencies**		
	H value	**df**	***p***
Movement	6.72	3	0.081
Feeding	11.41	3	0.010
Resting	8.66	3	0.034
Defaecation	17.45	3	0.001
Interaction [with mate/cub(s)]	28.09	3	<0.001
Scratch-scent-urinal	0.79	3	0.852
‘Others’ (hunting, drinking, etc.)	3.57	3	0.312

The density of the movement signs and feeding signs were highest in mangrove woodlands and transitional zones. The density of the resting signs was highest in grasslands and transitional zones, and defaecation signs in grasslands. Tigers preferred defaecating in small dry sand dunes and besides footpaths. Similar patterns were found in the densities of movement and feeding signs, as well as of resting and defaecation signs across four different habitat types (first two pairs of diagrams in Figure 5.2). The density of the interaction signs was highest on the sea beaches, and scratch-scent-urinal signs in grasslands and mangrove woodlands. Since tigers prefer to urinate close to the place where they defaecate, most of the urinal signs were found in grasslands, but scratch and scent marks were mainly found on the trees in mangrove woodlands and transitional zones. The density of ‘others’ signs was highest in the transitional zones.

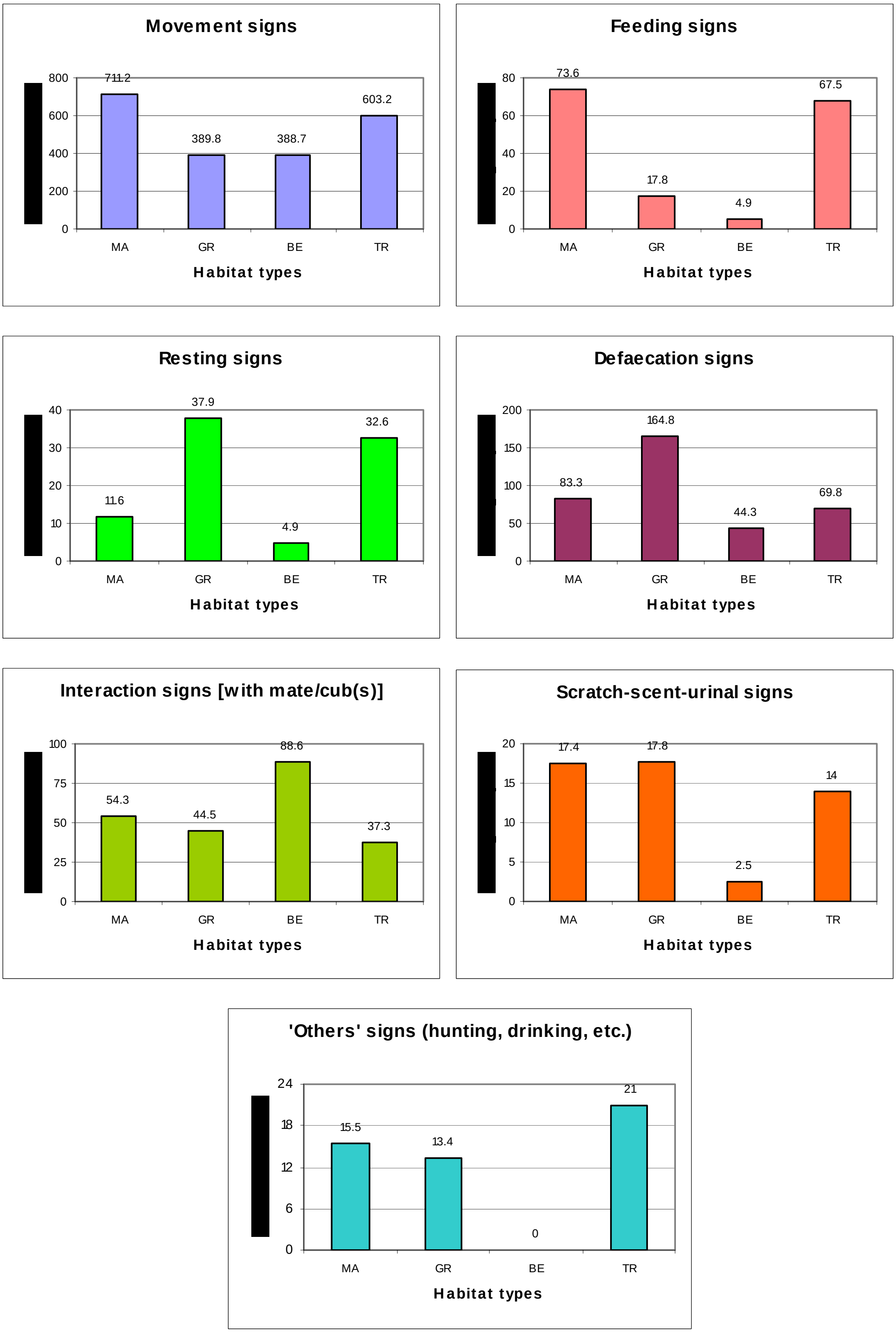


Figure 5.2 Mean density of different types of tiger signs in four different habitat types in the Sundarbans East Wildlife Sanctuary. Here MA = mangrove woodlands, GR = grasslands, BE = sea beaches, and TR = transitional zones.

The frequencies of different types of tiger signs, irrespective of habitat types, were significantly different (χ^2 = 3,485.55, df = 6, p < 0.001). The maximum percentage of signs was for movement (69.1%). Three other common sign types were defaecation (11.9%), interaction (7.2%) and feeding (5.6%) (Figure 5.3). The relative abundance of signs of different activities indicates that movement is probably the principal activity of tigers.

The frequencies of different types of tiger signs in each of the four different habitat types were significantly different (Table 5.3). The movement signs were the commonest sign type in all of the habitat types (varied from 56.8 to 73.6%). Defaecation (8.6%) and feeding (7.6%) were the second commonest sign in mangrove woodlands, defaecation (24.0%) in grasslands, interaction (16.6%) in sea beaches, and defaecation (8.3%) and feeding (8.0%) in transitional zones (Figure 5.4).

Table 5.3 Chi-square tests for the frequencies of different types of tiger signs in four different habitat types

Habitat type	**χ^2 test for frequencies**		
	χ^2 value	**df**	***p***
Mangrove woodlands	1,450.16	6	<0.001
Grasslands	531.86	6	<0.001
Sea beaches	518.29	5	<0.001
Transitional zones	975.12	6	<0.001

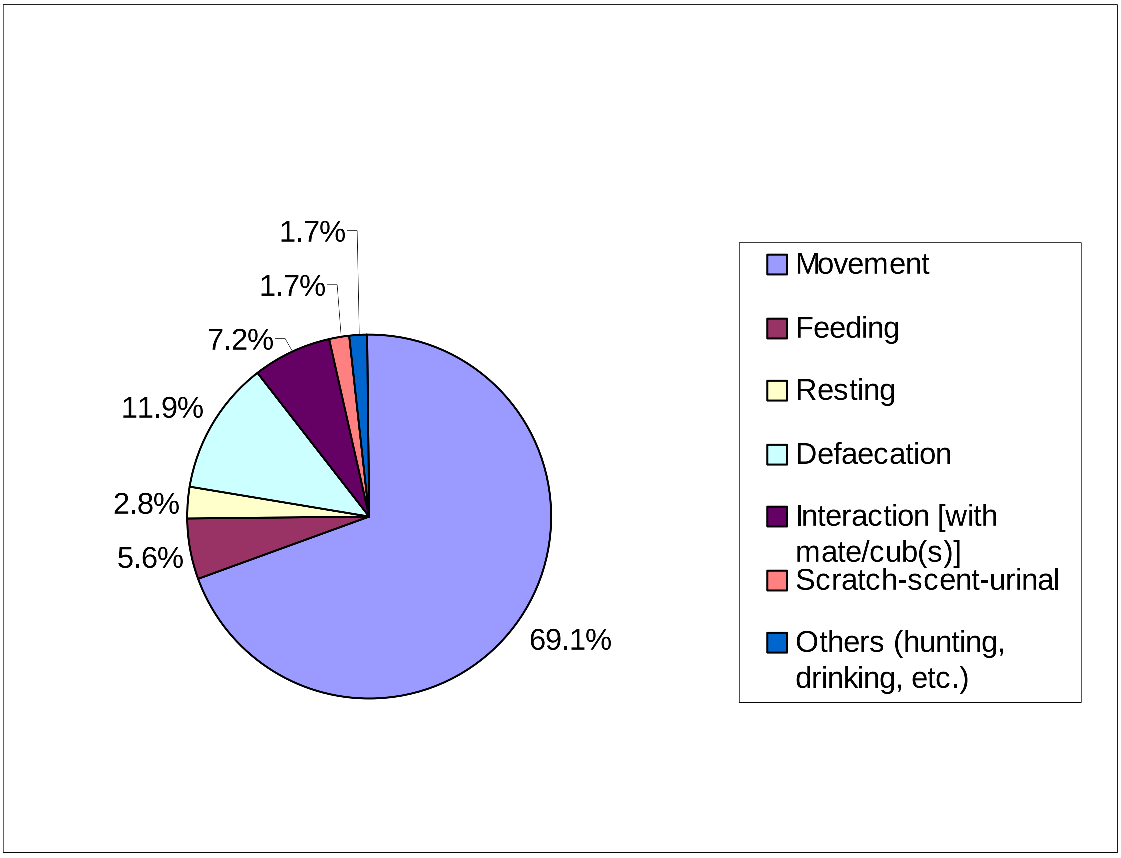


Figure 5.3 Proportions of different types of tiger signs (% of density or no./km^2) in the Sundarbans East Wildlife Sanctuary.

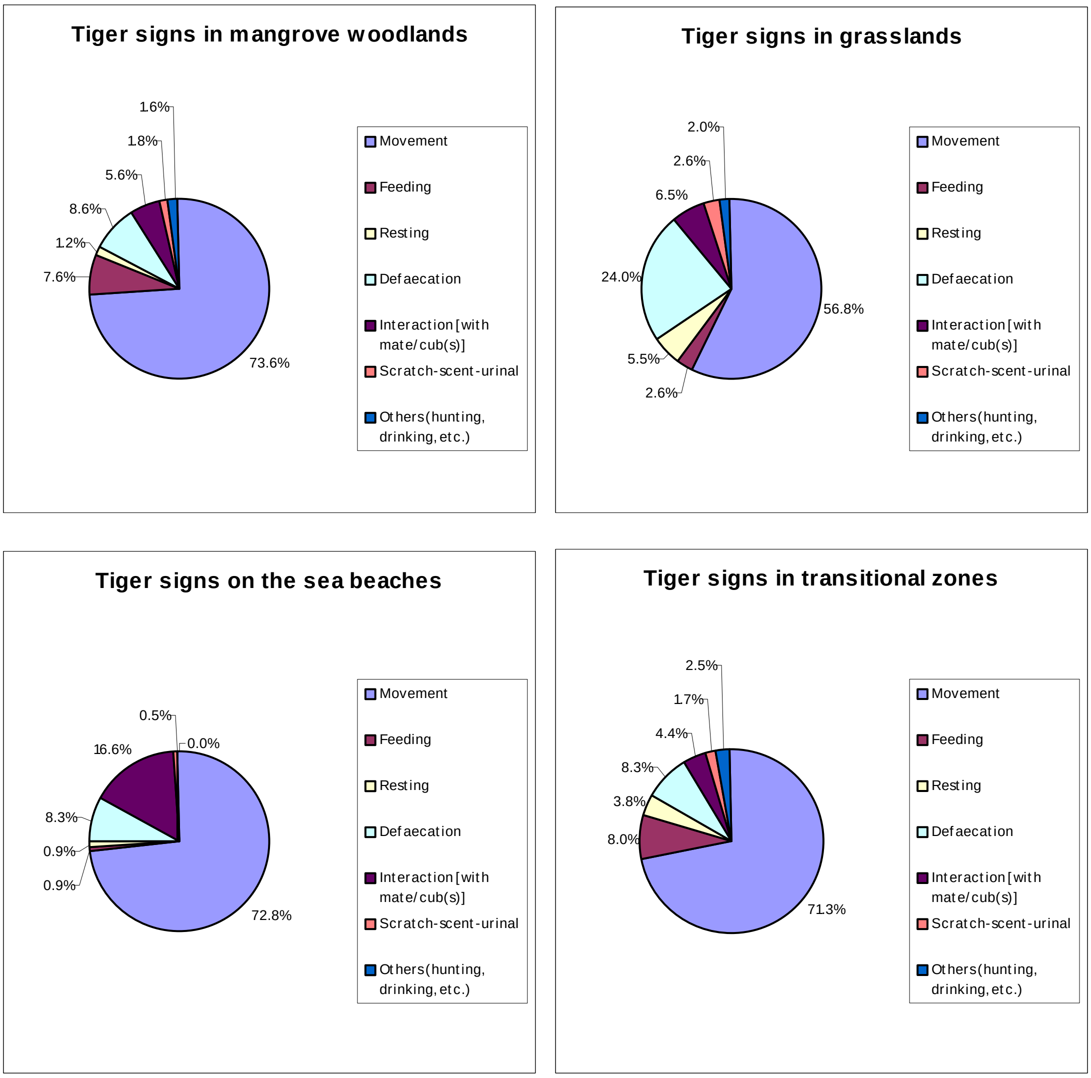


Figure 5.4 Proportions of different types of tiger signs (% of density or no./km^2) in four different habitat types in the Sundarbans East Wildlife Sanctuary.

During the sign survey fresh signs were found mainly in the mornings, but not in the afternoons, but, in undisturbed season (summer – when the natural resource harvest and tourism were minimum), new signs were also found in the afternoons. It indicates that tigers were probably more active at night (since there was no survey at night, signs were found in the next morning). During the undisturbed season, tigers were also active during the day (though less active than night time).

5.3.2 Scratches on Different Tree Species

The records of tiger scratches or claw marks on different tree species in the Sundarbans East WS shows that tigers prefer to use soft-barked trees. The scratches were found on three tree species (*Syzygium* sp., *Lannea coromandelica* and *Zizyphus* sp.) and two of them (*Syzygium* sp. and *Lannea coromandelica*) were relatively soft-barked; 13 out of 16 scratches were found on these two tree species (Table 5.4). It should be noted here that relatively hard-barked trees were more available in the Sundarbans (e.g. *Heritiera fomes*, *Sonneratia apetala*, etc.). The heights of scratches from the ground level varied between 0-2 m, but commonly between 0.3-1.5 m. The tiger often repeated its scratches at the same tree at different times. All of the scratches were on tree trunks of sizable girths, ca. 100 cm. The trees were located 0.5 to 7 km away from each other.

Table 5.4 Tiger scratches on different tree species in the Sundarbans East Wildlife Sanctuary

Tree species	Local name	Family	Bark type	No. trees used	Height of scratches from ground level (m)
Syzygium sp.	Bon jam	Myrtaceae	Medium soft	7	0.3-2.0
Lannea coromandelica	Kocha, ziga	Anacardiaceae	Very soft	6	0-2.0
Zizyphus sp.	Bon boroi	Rhamnaceae	Hard	3	0-1.5

5.4 DISCUSSION

5.4.1 Relative Habitat Use

There are very few studies on habitat use by tigers based on signs, because signs are difficult to find in most of the tiger ranges. In the Sundarbans, however, tiger signs are relatively easy to find because the ground is soft (Khan 2004c). During this study the density of the movement and feeding signs were highest in mangrove woodlands and transitional zones, probably because the better cover offered by these two habitat types were useful for movement and feeding of tigers. Grasslands and sea beaches were more open compared to mangrove woodlands and transitional zones. The fact that most of the tiger kills were found away from open areas is supported by Karanth and Sunquist's (2000) findings. Based on tiger signs, Karanth and Sunquist (2000) found that most of the tiger attacks (55%) on its prey took place in moist-deciduous habitat type in Nagarhole, India.

In the Sundarbans East WS the reason for the tiger's preference of grasslands and transitional zones for resting was probably due to the combination of the drier ground, presence of air flow and less disturbance from humans (although there are drier grounds and air flow in the sea beaches, but human disturbance is much higher there). The density of the defaecation signs was highest in grasslands because tigers preferred defaecating in small dry sand dunes and besides footpaths, both of which were available in grasslands.

The habitat preference for movement and feeding showed similar pattern probably because tigers prefer cover for both of these activities. On the other hand, the habitat preference for resting and defaecation were very similar, because tigers often defaecate where they rest. After feeding they take a long rest and then defaecate and leave that area. The interaction signs (based on pugmarks) were relatively more obvious on the sea beaches, which is an indication that tigers probably like to interact there at night (human disturbance existed during daytime). Such pugmarks would have been equally observable in mangrove woodlands.

Most of the tiger signs (69.1%) were of movements. It makes sense because tigers do need to move a lot for hunting and patrolling the territory. In general, the highest percentage of tiger signs (31.9%) were in mangrove woodlands, which agrees with

Chundawat's (2001) statement: on average tigers use the densely-forested areas more than other habitats.

Based on the number of tracks found, Reza *et al.* (2001b) reported the habitat preference of the tiger for waterholes, sea beaches, forest edges, forests, grasslands and riverbanks in Katka-Kochikhali area (20 km^2) in the Sundarbans East WS. Since they did not consider the availability (i.e. total areas available) of different habitat types, only the abundance of signs, there is no strong basis to conclude anything on habitat preference. The results are very different from the results of my study. Reza *et al.* (2001b) found the highest percentage of tracks at waterholes (42%) and lowest percentage on riverbanks (5%). They found only 6% of tracks in forests, but in my study, the highest density of tracks (i.e. 'movement signs' in my study) was found in forests (i.e. 'mangrove woodlands' in my study).

Among a few sign studies elsewhere, Sankhala (1978b) reported the distribution and habitat preferences of tigers in India. Based on the distribution patterns of tigers in different habitat types he concluded that moist deciduous forests support over 40% and dry deciduous forests support 30% of the tiger population in India. This means that over 70% of the tiger population is held by these two ecosystems, which extend over 60% of the tiger habitat of India. The remaining 40% of habitats are composed of wet evergreen forests, semi-evergreen forests, freshwater swamps, thorn forests, littoral swamps and sub-montane hills. The preference of the tiger is for the habitat type that not only supports wide prey range and good prey populations, but also ensures freedom from competitive co-predators. Although the prey range and prey population in the Sundarbans are not as rich as some tiger habitats in the Indian sub-continent, unlike most other habitats, there is no co-predator of tigers in the Sundarbans.

Johnsingh (1983) worked on the differential use of habitat by tiger, leopard (*Panthera pardus*) and Asiatic wild dog (*Cuon alpinus*) in Bandipur, India. Out of a total of 219 quadrats, he found predator signs in 138 quadrats. Of the 138, indications of all three predators were seen in 31 (23%) of the quadrats and only tigers were seen in 7 (5%) quadrats. Based on the signs and clues of tiger and leopard, a possible 'intolerance' was suggested between these two species. In 56 quadrats in each of the two habitat types (thin vegetation and dense vegetation), tiger signs were found in only two quadrats in thin vegetation area, whereas tiger signs were found in 28 quadrats in dense vegetation area. This indicates the preference of tigers for dense vegetation. My study weakly supports this conclusion, because the density of tiger signs was higher in mangrove woodlands and transitional zones than in grasslands and sea beaches, but there was no significant difference of tiger sign density in these four habitat types. The latter two habitat types were much more open than the former two. Johnsingh (1983) also reported that all 19 tiger kills were found in scrubby areas. My study does not support this, because the highest density of feeding signs (i.e. kill remains) was in mangrove woodlands and transitional zones, but transitional zones had bushes, which were somewhat similar to scrubs in Bandipur.

In Kerinci Seblat, Indonesia, Linkie *et al.* (2003) recorded the occurrence of tiger signs (pugmarks, scats and sightings). Of 141 locations surveyed, tiger signs were found in 126, 43 of which were outside of the National Park. Tiger signs were found in seven out of nine logging concessions surveyed. Tigers were recorded at altitudes of 50-2,440 m, and across all the major habitat types. In the Sundarbans, I also found a wide distribution of tiger signs in all the major habitat types. It indicates that the tiger's adaptability in different habitat types is very high.

According to Schaller (1967), Sunquist (1981), and Johnsingh (1983) tigers do not normally kill prey in open habitats including short grass. The results of my study fully support this. There were no hunting signs on the sea beaches, probably because it is almost entirely open, or because the prey density was very low in comparison to other three habitat types (see Chapter 3). Although there were hunting signs on grasslands (probably because the *Imperata* grasses in the Sundarbans were long enough to provide stalking cover for tigers), the density was lower than in transitional zones and mangrove woodlands. The prey densities were similar in these three habitat types (see Chapter 3).

5.4.2 Scratches on Different Tree Species

Although hard-barked trees were more available in the Sundarbans, tigers preferred soft-barked trees for scratching, because it was probably more comfortable and more effective to use soft-barked trees to mark the territory and sharpen the claws. This emphasises the importance of conserving the entire landscape for the conservation of the tiger. A soft-barked tree is a minor requirement of the tiger; we are yet to know other minor requirements. Both male and female tigers use scratching to mark their territories (Smith *et al.* 1989). This action perhaps also sharpens the claws by peeling off any thin, loose or desquamated strips of laminae from the surface that are ready to flake off, either on the top of the claw or along the sides and thickened margins (Wyne-Edwards 1962, Kotwal and Mishra 1995).

The conclusion of this study regarding tiger scratches is matched by the conclusion of Kotwal and Mishra (1995) that trees with soft bark having a good amount of sap were more frequently scratched than those having rough bark, though the latter were more abundant. In Kanha, India, Kotwal and Mishra (1995) found that the girth of marked trees varied between 37-324 cm. The height of scratches from the ground level varied between 0.7-2.7 m, which was higher than the height recorded in this study. This was probably because tigers of the Sundarbans are smaller than tigers elsewhere in the Indian sub-continent (Sankhala 1978b; M.M.H. Khan pers. obs., see Appendix V). Moreover, whether trees were standing straight or not, also caused a variation in the heights of scratches from the ground.

In Huai Kha Khaeng, Thailand, Rabinowitz (1989) recorded more than 350 scrapes from large cats (leopards and tigers) and, based on these, he concluded that scrapes are found throughout the year, most frequently during the rainy season. The largest proportion of recorded scrapes (44%) was in the area where the ranges of all resident large cats overlapped. Most scrapes were found along roads and trails either in grass, if present, or in dirt near the edge of the road. In comparison to these findings, I could not present the seasonal pattern of scratching on trees, because my sample size was small, but most of the trees scratched were along roads and trails.

5.5 SUMMARY

- The study was conducted to determine the relative habitat use by tigers for their different activities [movement, feeding, resting, defaecation, interaction (with mate/cubs), scratch-scent-urinal and ‘others’ (hunting, drinking, etc.)] in four habitat types (mangrove woodlands, grasslands, sea beaches and transitional zones) in the Sundarbans East Wildlife Sanctuary.

- Line-transect sampling method was used in order to count tiger signs. The width of each transect was 5 m.

- The mean density of tiger signs (total of all types of signs) in mangrove woodlands, grasslands, sea beaches and transitional zones show that the mean densities were not significantly different across four habitat types.

- The mean density of signs of feeding, resting, defaecation and interaction were significantly different across four different habitat types, which indicate that tigers have habitat preference for at least some activities. The mean density of signs of movement, scratch-scent-urinal and 'others' were not significantly different.

- The density of the movement signs and feeding signs were highest in mangrove woodlands and transitional zones, resting signs in grasslands and transitional zones, defaecation signs in grasslands, interaction signs on the sea beaches, scratch-scent-urinal signs in grasslands and mangrove woodlands, and 'others' signs in transitional zones.

- Similar patterns were found in the densities of movement and feeding signs, as well as of resting and defaecation signs, in four different habitat types.

- The frequencies of different types of tiger signs in all habitat types, as well as in each of the four different habitat types, were significantly different, but movement signs were the commonest sign type in all habitat types (varied from 56.8 to 73.6%).

- Tigers were found to use soft-barked trees for scratching more often than other types. Thirteen out of 16 scratching were in soft-barked trees (*Syzygium* sp. and *Lannea coromandelica*). The heights of scratches normally varied between 0.3-1.5 m from the ground.

CHAPTER 6 BREEDING AND LITTER SIZE

6.1 INTRODUCTION

Understanding the breeding parameters of the tiger is critical for developing sound conservation strategies (Kerley *et al.* 2003). The breeding parameters and litter size of tigers might vary from place to place throughout its global range, and in some areas there might not be any breeding peak at all. Most of the information about the breeding of the tiger comes from captive animals (e.g. Kleiman 1974, Sadlier 1966, Seal *et al.* 1987). Although there is some information on the breeding and litter size available for wild tiger populations in India (other than in the Indian Sundarbans) (Singh 1959, Schaller 1967; Sankhala 1967, 1978a), Nepal (McDougal 1977, Sunquist 1981, Smith and McDougal 1991, Smith 1993), Russian Far East (Salmin 1940; Abramov 1965, 1977; Kucherenko 1972, 1985; Smirnov 1986, Bragin 1989, Heptner and Sludskii 1992, Smirnov and Miquelle 1999, Kerley *et al.* 2003) and Manchuria (eastern Asia) (Baikov 1925, 1936; Ognev 1935), there is no scientific report on breeding and litter size of tigers in the Sundarbans of Bangladesh and India. Since the tiger is a widely-distributed species, breeding parameters may vary between the five extant sub-species in response to different climates, habitats, prey densities, and other environmental parameters (Kerley *et al.* 2003). For the same reason it might vary even between different populations of the same sub-species living in different habitat conditions. Since the Sundarbans is the only mangrove habitat of the tiger, it is assumed that the breeding parameters and litter size might differ from other habitats. Information on how reproductive parameters vary between different areas and sub-species is essential for range-wide conservation planning (Kerley *et al.* 2003).

The general objective in this Chapter is to *determine the possible breeding pattern and litter size of tigers in the Sundarbans*. The specific questions are –

1. When is the breeding peak of tigers in the Sundarbans (if any)?
2. What is the litter size of tigers in the Sundarbans?
3. Is the birth rate of spotted deer fawns (young) and tiger cubs correlated?

6.2 METHODS

A two-way approach was taken to collect the data: a) record signs in the field, and b) interviews with local people. Signs (e.g. pugmarks or tracks) of putative male-female interactions and mother-cub(s) interactions were recorded during January-December 2002 (12 months) in the Sundarbans East wildlife Sanctuary (WS) of Bangladesh. The reproductive parameters of Amur tigers were extensively studied, based on snow tracking alone (Baikov 1925, Abramov 1962, Abramov 1977, Matyushkin 1984, Smirnov 1986, Yudakov and Nikolaev 1987, Bragin 1989, Salkina 1994, Matyushkin *et al.* 1999, Smirnov and Miquelle 1999), or in combination with ground tracking, live capture, and telemetry (Kerley *et al.* 2003). Tigers are usually solitary animals, except for females with cubs (Nowell and Jackson 1996, Kerley *et al.* 2003), and when males associate with females for breeding (Schaller 1967, McDougal 1977, Sankhala 1978a, Sunquist 1981; Thapar 1986, 1989; Sunquist and Sunquist 2002). Assuming that adult male and female tigers interact only for mating, their interaction signs (Wemmer *et al.* 1996) were recorded in different months from January to December 2002. The sexes were identified on the basis of the shape and size of pugmarks; details of the method is described elsewhere (Panwar 1979, Das and Sanyal 1995, Singh 1999, Smirnov and Miquelle 1999, Matyushkin *et al.* 1999, Nath 2000, Sharma *et al.* 2003). Briefly, the pugmarks of males are bigger than that of females and if four straight lines are drawn touching the front, back, left and right sides of the hind pugmark, it resembles a square in males and a rectangle in females (Figure 6.1). Identification of sex on the basis of pugmarks, however, was sometimes prone to bias in differential soil types. The pugmarks of female with cubs(s) were easily identified on the basis of measurements (Nikolaev and Yudin 1993, Smirnov and Miquelle 1999, Matyushkin *et al.* 1999). The cubs were defined as very small animals accompanied by the mother.

Monthly observations were added to the data collected from the local people through interviews. Since the variation of the raw data was very low, there was no problem of mixing data which were collected from two sources. The local people were asked if they ever saw male-female tigers together and/or mother-cub(s) together in the Sundarbans. If they saw any of these interactions then the sighting-months and locations were recorded. These sightings were not necessarily recent (sightings in the last 30 years) and could be anywhere in the Sundarbans, so long as the interviewee could remember accurately the sighting-month and location. The reliability of the information provided by the interviewed persons was always tested before taking the formal interview. This was done by asking some basic questions, of which the answers were known to me, e.g. the length of the tiger, what tigers eat, etc. The sightings of tiger male-female, however, are prone to biases of the sightings of the mother with a grown offspring. Hence, their behaviour (as observed by the interviewee) was also recorded in order to distinguish male-female sightings and mother-grown-offspring sightings as much as possible. People of different professions in different areas were interviewed in order to avoid seasonal biases (different professional groups prefer to work in the Sundarbans in different seasons of the year) and possible biases of sightings of the same tigers by different interviewees. See Appendix X for the interviewing sheet. Although interviewing is not a good method of collecting scientific data, best use of any information from any source was required to fulfil the lack of information on tiger breeding parameters in the Sundarbans.

Similarly, mother-cub(s) interaction signs were recorded in the field during January-December 2002. Tiger cubs continue to live with their mothers until 2-3 years of age (Nowak 1991, Nowell and Jackson 1996). Only a mother with small cub(s) (newborn) was recorded in this study. Small cubs do not normally wander alone (Nowak 1991, Nowell and Jackson 1996). Then the sight records by the local people of the tigress with small cubs were added with the monthly records of mother-cub(s) interaction signs.

In general, observers note that tigers call (roar) more often during the peak mating period than any other time (Smith and McDougal 1991, Sunquist and Sunquist 2002). This is also evident in captivity, where oestrus in tigers is usually signaled by an increase in the frequency of calling (Kleiman 1974). Moreover, local people in the Sundarbans believe that the tiger normally calls in the mating season in order to contact the mate. Based on this the number of calls in each month, heard during January-December 2002, were recorded to compare with the data on male-female interactions. Repeated calls by the same tiger (i.e. similar calls from the same area) with few minute's gaps were counted as one observation.

While recording mother-cub(s) interaction signs in the field, during January-December 2002, the number of small cubs accompanied by the mother were also recorded. The data from interviewing local people were then added with my observations in order to estimate the possible litter size of tigers in the Sundarbans.

(**Figure 6.1** The pugmark of a male tiger is larger and can fit into a square box rather than a rectangle box in case of a female → import from Maps and Illustrations folder.)

The people were asked how many small cubs they saw in each observation, but records were discarded when the interviewee was not sure about the total number of cubs. This result, however, does not represent the actual litter size at the time of birth.

Tiger male-female observations and mother-cub(s) observations were tested statistically (non-parametric χ^2 test) across months in order to examine whether the frequencies were significantly different or not. Similarly, the frequencies of tiger cubs across different litter size classes were tested statistically. The frequencies of monthly sightings of spotted deer fawns (see Chapter 3) and tiger cubs were compared to examine whether there is any correlation (Perarson correlation, r) between their birth rates.

6.3 RESULTS

Based on the records of breeding parameters it is inferred that, in the Sundarbans, tigers probably breed throughout the year, but the peak is the winter (October-March), because the putative male-female interactions and mother-cub(s) interactions were higher in winter (Figure 6.2). Most of the male-female observations (total of signs and observations by people) were during October-March (74.7%), with the highest in November (17.2%). Male-female observations were significantly different across months ($\chi^2 = 28.45$, df = 11, $p = 0.003$). On the other hand, most of the mother-cub(s) observations were during October-April (84.6%), with the highest in December (21.5%). The mother-cub(s) observations were also significantly different across months ($\chi^2 = 34.51$, df = 11, $p < 0.001$). Most of the calls were heard during the probable mating season (August-October: 60.7%). Because of small sample size, no statistical test could be conducted to prove that the number of calls was significantly different across months. The total number of observations for male-female, mother-cub(s) and call was 87, 65 and 28, respectively.

The records based on signs and observations by local people on the litter size of tigers reveal that litter size 1 is probably the commonest (60.7%), followed by 2 (33.9%) and 3 (5.4%) (Figure 6.3). The number of observations in these three litter sizes was significantly different ($\chi^2 = 25.75$, df = 2, $p < 0.001$). The mean litter size was 1.4 (range = 1-3, n = 56, sd = 0.6). Since this result is based on observations of the small cub(s) with mother, this does not represent the actual litter size at the time of birth.

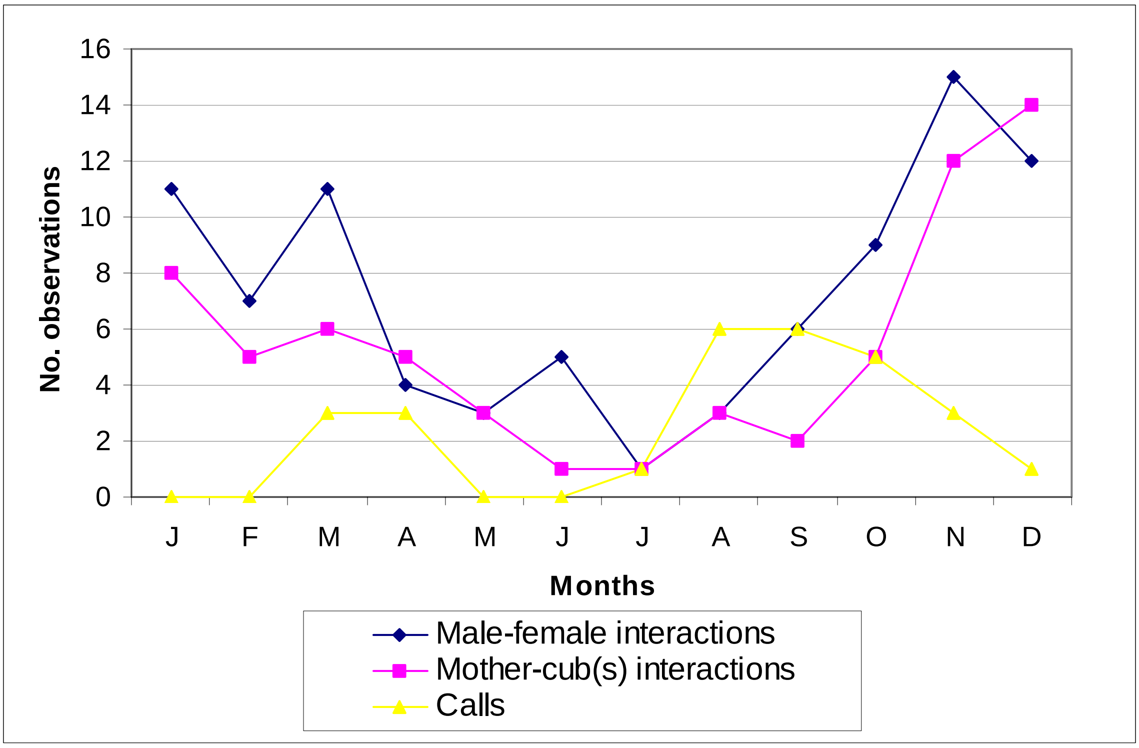


Figure 6.2 Breeding parameters of tigers in the Sundarbans.

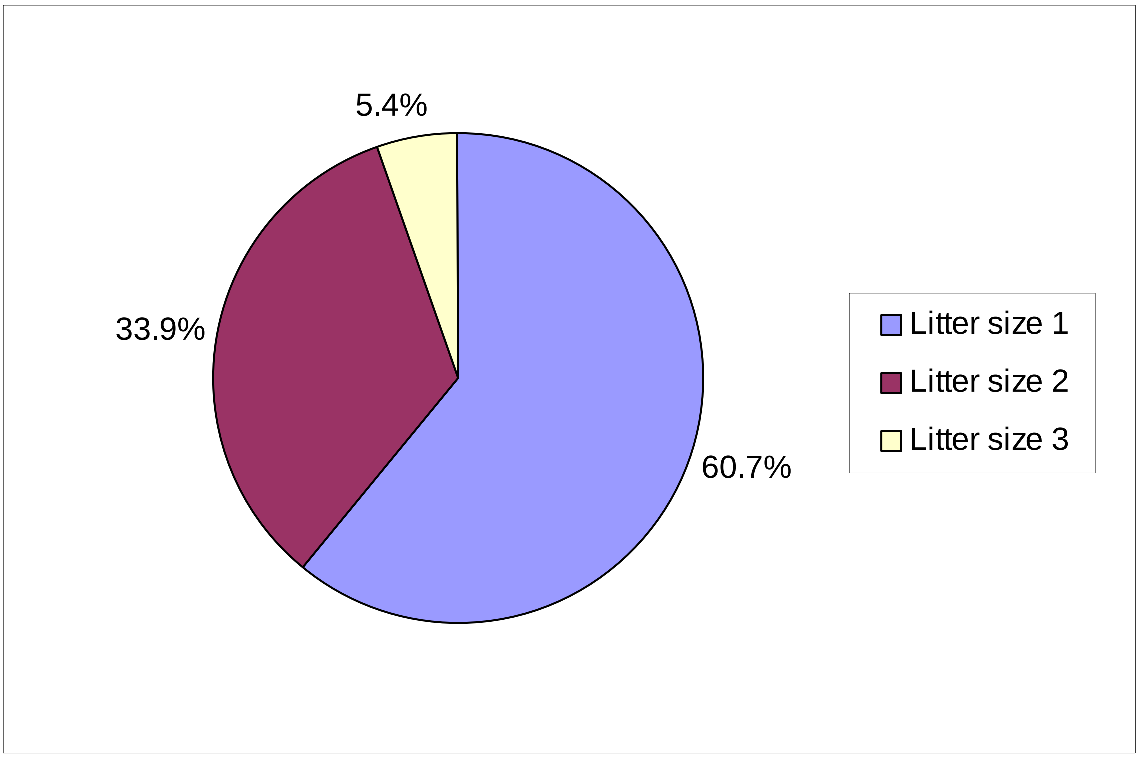


Figure 6.3 Proportions of different litter sizes of tigers in the Sundarbans.

The frequencies of monthly sightings of spotted deer fawns and tiger cubs were compared to examine whether there is any correlation between their birth rates. The statistical analysis shows that they have insignificant negative correlation ($r = -0.285$, $p = 0.370$) and thus the birth rate of spotted deer fawns and tiger cubs are not correlated, but the latter probably follows the former about six months later (Figure 6.4). For fawns, only the sightings during January-December 2002 was used (see Chapter 3), so that the January-to-December data on observation of tiger cubs (which is based on signs and on sightings by local people) could be properly compared.

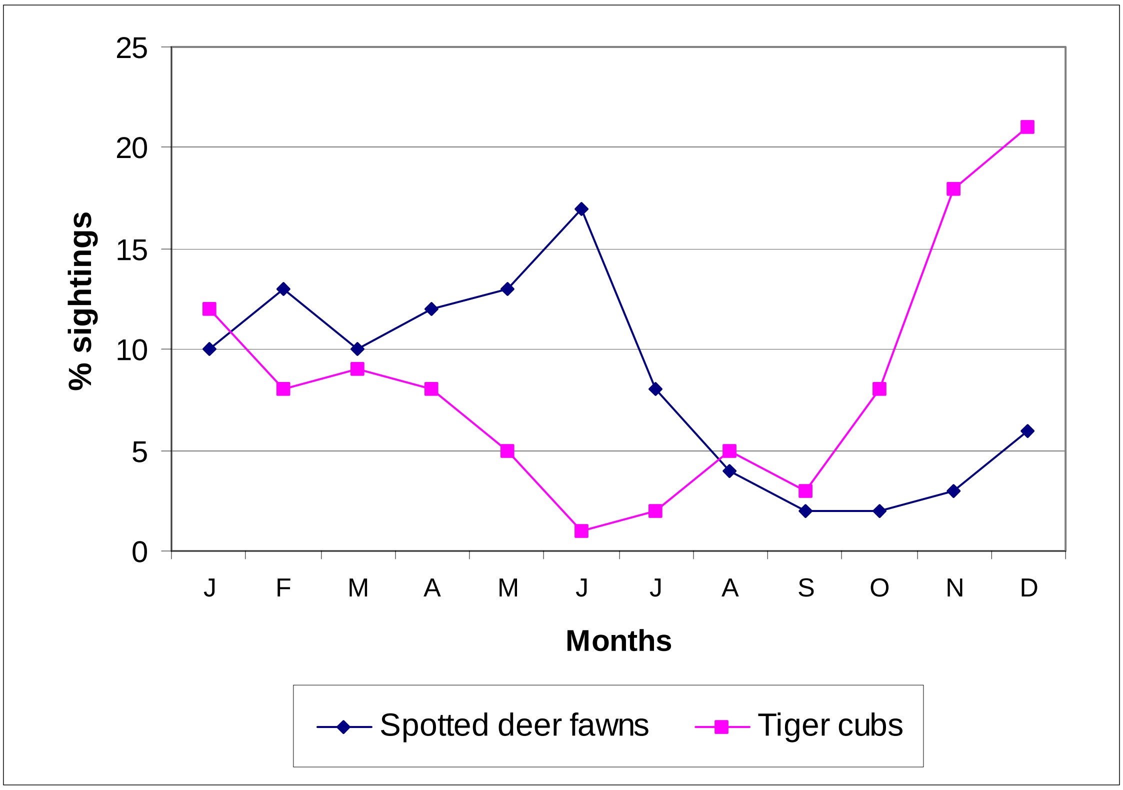


Figure 6.4 A comparison between monthly observations of spotted deer fawns (young) and tiger cubs in the Sundarbans.

6.4 DISCUSSION

The breeding peak of the tiger is rather controversial. According to Mazak (1981), tigers' mating takes place year-round, but most frequently from the end of November to early April. Singh (1959), Schaller (1967) and Sankhala (1967, 1978a) mentioned that it is November-April in India. According to Sanyal (1987), the mating season of tigers in the Indian Sundarbans is late monsoon, which is spring in the peninsula. In Chitwan, Nepal, young are born throughout the year, with a birth peak from May to July (Smith and McDougal 1991, Smith 1993). Sunquist and Sunquist (2002) mentioned that in South and South-east Asia, cubs may be born at any time of the year, but zoo data from India revealed that there could be a birth peak during March-June and another smaller peak during August-October (Sankhala 1978a). Karanth (2001) believes that there is no birth peak in wild tigers in India, but Amur tigers in the Russian Far East have a more definite birth peak. Kucherenko (1972, 1985), and Dunishenko and Kulikov (1999) mentioned that the breeding peak of tigers in the Russian Far East is the winter (January-March), but Kerley *et al.* (2003) found that tigers give birth almost all through the year, most frequently in late summer (August-October: over 50%), which indicates that the conceptions are most frequent during March-May. According to Salmin (1940), tigers breed year round in the Russian Far East. In Manchuria young are born during December-February (Ognev 1935; Baikov 1925, 1936). Data on 530 litters born in zoos in the northern hemisphere show that most cubs of Amur tigers are born between April-June (Seal *et al.* 1987). Based on interviewing local people, Reza *et al.* (2002b) mentioned that the monsoon (45%) and winter (31%) are the breeding seasons for the tiger in the Bangladesh Sundarbans.

The results of this study show that there is probably a breeding peak in the Sundarbans, which is in winter (October-March), probably because the winter is less wet and muddy, and less stormy (storms and coastal cyclones are common in summer), which probably reduces the cub mortality. My conclusion agrees with Ognev (1935), Baikov (1936), Singh (1959), Schaller (1967), Sankhala (1967, 1978a) and Mazak (1981), but not with others. However, because of the seasonal characteristics and seasonal prey abundance, the breeding peak is likely to vary in different parts of the tiger's global range.

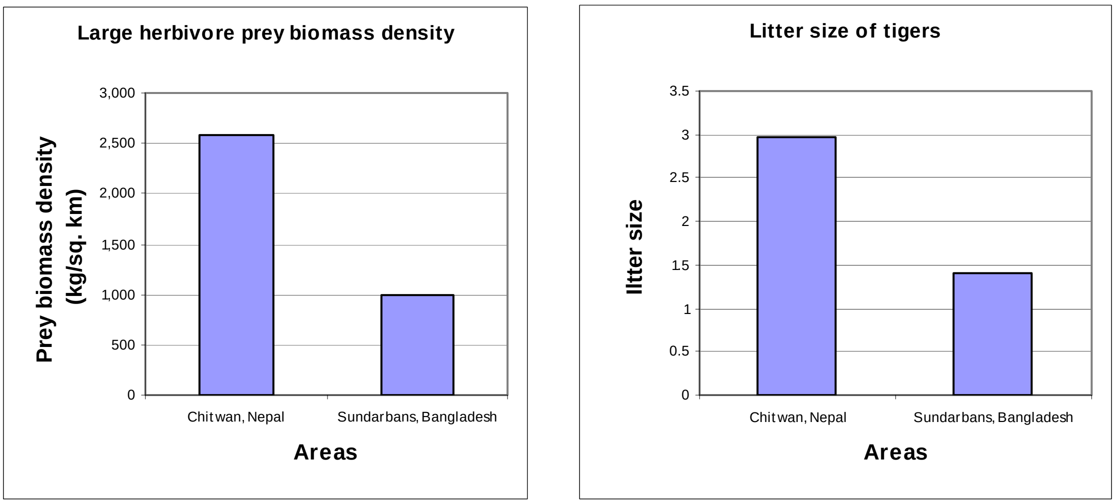
Since the gestation period of a tigress is 98-112 days (Crandall 1964, Perry 1964, Sankhala 1978a, Kitchener 1991; Sunquist and Sunquist 1991, 2002), the mother-cub(s) observation curve should follow the male-female observation curve about three months later, but in Figure 6.2 it follows only about one month (or even less) later. This could probably because: a) the continuation of male-female interactions (not necessarily matings) after a successful mating, or b) individuals frequently mated later in the season while at the same time the first-mated tigers successfully produced cubs. Notably, the findings of this study were based on different individuals. There is no relevant literature to explain this short gap between the male-female observations and mother-cub(s) observations.

A tigress may give birth to one to seven young, although a tigress in the wild is rarely accompanied by more than two or three cubs (Brander 1923, Tamang 1993, Sunquist and Sunquist 2002). In Bangladesh, a tigress gave birth to 4 cubs in Dhaka Zoo, but tigress with 2 cubs is normally seen in the Sundarbans (Moudud 1998). The mean litter size is 3.0 (range 2-5, n = 49) in Nepal's Royal Chitwan National Park (Smith and McDougal 1991), though according to Tamang (1993) the mean litter size in Nepal is 2.5, and in Indian zoos it is 2.9 (range 1-6, n = 49) (Sankhala 1978a). In the Russian Far East, Kerley *et al.* (2003) found that the mean litter size is 2.4 ± 0.6 (range = 1-4, n = 16), but it decreased to 1.3 ± 0.5 by the time litters are 12 months old. Others reported the litter size of 1.5-2.5 in the Russian Far East (Abramov 1962, Abramov 1977; Kucherenko 1972, 1985; Smirnov 1986, Bragin 1989, Smirnov and Miquelle 1999).

Based on the records (pugmarks and sightings by people) of small cubs with mother in the Sundarbans, the mean litter size is suggested to be 1.4 in the Sundarbans, which is much lower than the mean litter size in Chitwan, in Indian zoos, and in the Russian Far East (many reports, though not all). This might be either because: a) cub mortality at early life stages is probably much higher in the Sundarbans or b) the tough habitat (since this is the only mangrove habitat of the tiger) and limited prey probably force the tiger population to produce smaller litters. Although tigers are prolific breeders, mortality among pre-dispersal offspring is as high as 50%, as found in Chitwan, Nepal (Sunquist 1981, McDougal 1985). Kerley *et al.* (2002, 2003) found 41-47% cub mortality in the Russian Far East due to anthropogenic and other factors. Even in captivity, mortality rates of nearly 40% have been reported during the first two months of life (Christie and Walter 2000). All the wild tigers I saw (n = 15; see Appendix V) during this study were quite thin, which might be another cause of the smaller litter size. Although there is no study on large cats to support this assumption, changes in body weight of female snowshoe hares (*Lepus americanus*) during winter are positively correlated with litter size and pregnancy rates in summer (Keith and Windberg 1978, Cary and Keith 1979). In general, ovulation in mammals is regulated indirectly by female energy reserves (Bronson and Manning 1991). Based on the above-mentioned discussion, I agree with Kerley *et al.* (2003) that the assumption of the rapid growth and recovery of tiger populations (Sunquist *et al.* 1999, Karanth 2001) from substantial losses may be overly optimistic.

The birth rate of tiger cubs probably follows the birth rate of spotted deer fawns about six months later. This was probably because the fawns grow up in six months and enrich the prey population when tiger cubs are born. Tigresses need more food when they have cubs (Karanth 2001).

The herbivore prey biomass density and the mean litter size of tigers were compared between Chitwan, Nepal (Tamang 1982), and Sundarbans, Bangladesh (this study) (Figure 6.5). It is evident that the available prey biomass density and the litter size of tigers show very similar pattern in both areas. In other words, even if the actual litter size (at the time of birth) of tigers in the Sundarbans is the same as in Chitwan, the reduced prey biomass might cause reduced cub survival. Note that the litter size in the Sundarbans was not based on the litter size at the time of birth, but on the number of small cubs accompanied by mother. There are no scientific estimates of both litter size of tigers and prey biomass density in other tiger ranges, and so they could not be compared herein.



(a) (b)

Figure 6.5 Comparison of available large herbivore prey biomass density (kg/km^2) (a) and tigers' litter size (b) in Chitwan, Nepal (data source: Tamang 1982) and Sundarbans, Bangladesh (data source: this study).

6.5 SUMMARY

- The study was conducted to provide information on the breeding and litter size of tigers in the Sundarbans.

- In order to collect data, signs (e.g. pugmarks) of putative male-female interactions and mother-cub(s) interactions were recorded in the field and local people were interviewed about the sightings of tiger male-female and mother-cub(s).

- In the Sundarbans, tigers probably breed all through the year, but the peak is the winter (October-March). Both male-female interactions and mother-cub(s) interactions were significantly different across months.

- Tiger litter size 1 is probably the commonest (60.7%), but litter sizes 2 and 3 were also recorded, giving a mean litter size of 1.4, which is lower than in other tiger ranges.

- The birth rates of spotted deer fawns and tiger cubs are not correlated, but the latter probably follows the former after about six months.

CHAPTER 7 TIGER-HUMAN INTERACTIONS

7.1 INTRODUCTION

Large carnivores are generally unpopular with the people that share their range as they are blamed for loss of life and livestock (Schaller and Crawshaw 1980). Carnivores' protein-rich diet and large home ranges draw them into recurrent competition with humans, who have somewhat similar needs (Treves and Karanth 2003). In communities with a subsistence economy, even small losses can be of economic importance and can generate negative attitudes towards wildlife and conservation (Mishra 1982b, Upreti 1986). Public attitudes toward carnivores affect conservation efforts (Kellert *et al.* 1996) and increased aggressive encounters may weaken public support for tiger conservation (Kerley *et al.* 2002). Conflicts with people and their livestock are significant sources of mortality for large carnivores. Tiger-human conflicts have already contributed to the decline and extinction of two sub-species of the tiger [Bali tiger (*P. t. balica*) and Javan tiger (*P. t. sondaica*)] (Hoogerwerf 1970, Seidensticker 1987b) and there is an urgent need to characterise and develop measures to reduce these conflicts (Nowell and Jackson 1996, Woodroffe and Ginsberg 1998, Linnell *et al.* 1999). Increased conflict with people, together with poaching for financial gain (Nowell 2000), has lead to many large carnivore mortalities that further reducing their population densities (Ginsberg and Macdonald 1990, Nowell and Jackson 1996).

In the past four centuries, tigers are thought to have killed 1,000,000 Asians, or about 2,500 people annually, or 25 people/1,000 tigers (Matthiessen 2000). Unlike other tiger populations, the Sundarbans tigers are believed to be responsible for a considerable number of human deaths annually (Montgomery 1995, Karanth 2001). Man-eating is one of the most important issues facing the conservation of tigers in the Sundarbans (Sunquist and Sunquist 2002). The Sundarbans tigers have had a reputation as man-eaters, but elsewhere man-eating is usually the result of a tiger's incapacity, through age or injury, to catch normal prey (Mountfort 1969, Nowell and Jackson

1996). The Sundarbans 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 Sundarbans. 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 Sundarbans since at least the 17th century (Bernier 1670[1], 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 Sundarbans (Bangladesh and Indian Sundarbans). Many people and few tigers die every year from these conflicts. Some tigers start killing cattle, or even attack people in the adjacent areas of the Sundarbans, and are eventually killed by people. Moreover, some tigers are poached each year for their lucrative hides and other body parts. The removal of a few individual tigers from a healthy population may not necessarily affect population growth, because transient tigers may fill any vacant territories (McDougal 1977), but if the population is decreasing and is not very healthy, the poaching of a few individuals may dramatically increase the probability of extinction (Kenney *et al.* 1994, Seal *et al.* 1994).

In the Sundarbans severe poaching and consumption of the tiger's prey species [mainly the spotted deer (*Cervus axis*)] by local people existed. Subsistence hunting of tiger prey by local people and competition by livestock for land are now powerful forces driving the tiger's decline over large parts of its range (Karanth and Stith 1999, Nowell and Jackson 1996). Seidensticker (1986) attributed the extirpation of tigers in Bali and Java to extensive habitat fragmentation and widespread loss of critical ungulate prey through disease and over-hunting by humans. Rabinowitz (1986) noted an unexpected low abundance of tigers combined with a reduced number of banteng (*Bos benteng*), gaur (*Bos frontalis*) and sambar (*Cervus unicolor*) in Huai Kha Khaeng, Thailand. Heptner and Sludskii (1972) reported the emaciation of Amur tigers in winter because they are naturally vulnerable to sharp declines in ungulate prey populations during severe winters, which cause the tiger to starve. Although the decline of the prey population due to poaching is the single most severe threat to the tiger in the

[1] Francois Bernier (1670) was a French jeweller who travelled in the Sundarbans in 1665/1666, writes '… among these islands, it is in many places dangerous to land, and great care must be had that the boat, which during the night is fastened to a tree, be kept at some distance from the shore, for it constantly happens that some persons or another falls prey to tigers. These ferocious animals are very apt, it is said, to enter into the boat itself, while the people are asleep, and to carry away some victim, who, if we are to believe the boatmen of the country, generally happens to be the stoutest and fattest of the party.'

Sundarbans (Khan 2004c), measuring poaching levels is extremely difficult, because the poaching and marketing of the poached meat is secretive. Although there is no permanent settlement inside the Bangladesh Sundarbans, the poached meat is largely consumed in the villages adjacent to the Sundarbans.

The general objective in this Chapter is to *provide clear picture of tiger-human interactions and their intensity, together with the consumption of tiger prey by local people, in and around the Sundarbans.* The specific questions are –

1. What is the rate of tiger mortality, and which age and sex classes of tigers are the main victims?
2. What is the rate of human mortality and injury, and which age and professional classes of people are the main victims?
3. What types of protection measures do people take when they work in the Sundarbans?
4. Where do people see the tiger?
5. What were the conditions of wild tigers that people have seen?
6. What is the level of public knowledge of Bangladesh Wildlife (Preservation) (Amendment) Act 1974?
7. What is the belief of the local people on the medicinal use of tiger parts?
8. What is the opinion of the local people on tiger conservation?
9. What is the consumption rate of tiger prey by local people and what proportion of the animal protein comes from tiger prey?

7.2 METHODS

7.2.1 Interviewing Local People, Newspaper Reports and Forest Department Records

Information was mainly collected by interviewing local people, but relevant newspaper reports (during the study period) and Forest Department records (from 1993 up to the end of this study) were also used to enrich the data. Interview surveys have been used extensively for biological survey work, especially for species in situations where direct observation is difficult, such as with bears or tigers (Herrera *et al.* 1994, Hokkaido Institute of Environmental Sciences 1995). Interviewing and collecting reports from different sources are widely-used methods in studying interactions between big cats and humans (Beier 1991, Oli *et al.* 1994, Saberwal *et al.* 1994, Baogang *et al.* 1999, Hean 2000, Hussain 2003, Nyhus and Tilson 2004).

The interviewing was conducted either in the Sundarbans or in the local villages. A standard interviewing sheet was used to ask common questions about the interviewee's sightings of killed and injured tigers (covering date, location, age and sex of the tiger, reason of killing/injury, etc.) and humans (covering date, location; age, sex and profession of the victim; group size, dragging distance of the kill, type of attack, etc.), whether he had seen paired tigers or tigress with small cub(s) in the Sundarbans, what does he do to protect himself from the tiger while in the Sundarbans, whether he has seen a tiger anywhere, what were the conditions of sighted wild tigers in the Sundarbans, what is his level of knowledge on Bangladesh Wildlife Act 1974, what is his belief on the medicinal use of tiger parts, whether he wants to conserve the tiger or not, etc. The answers were recorded with each question. These types of data provide a valuable index of the degree of tiger-human conflict (McDougal 1987). A sample interview sheet is given in Appendix X.

The age and sex of killed tigers were identified on the basis of physical characteristics described by the interviewees. Tiger attacks across months were tested statistically (non-parametric χ^2 test) in order to examine whether the frequencies were significantly different or not. In the cases when the companions of the human victims rescued the kill immediately, the records of dragging distance were not recorded. Only men were interviewed because women do not work in the Sundarbans and even if they do, they are restricted to the fringe areas.

A total of 123 individuals were interviewed during this study. More emphasis was given to experienced senior people, like group leaders. In the Sundarbans, people mainly work in groups. Special emphasis was given to the knowledge and experience of those who had experienced a tiger attack or who himself had seen tiger attack(s) on other people. The reliability of the information provided by the interviewed persons was always tested before taking the formal interview. This was done by asking some basic questions, of which the answers are known to me, e.g. the length of the tiger, what tigers eat, etc. Individuals having a tendency of providing exaggerated information were excluded from interviewing, but I think most people were honest about providing correct information, since in most of the cases the information matched known knowledge.

Other than interviewing local people, the relevant newspaper reports and Forest Department records were collected for comparison and enrichment of the data derived from interviews. The reports were collected from both Bengali and English newspapers and all prominent newspapers were checked for any news of tiger and human deaths in and around the Sundarbans. Recorded information on tiger and human deaths were collected from the local and divisional offices of the Forest Department. After gathering all of the information, the data were analysed and, if required/possible, statistically tested in order to draw conclusions.

While in the field, some sampling was conducted to know the proportions of available people in different age and professional classes, so that they could be compared with the proportions of tiger attacks in the respective classes. A total of 623 men from different groups were sampled who were arranged according to the age and professional classes. Since some people did not know their exact age, and it was sometimes embarrassing to ask ages of different people, I considered only three age classes (age less than 30, 30-50, more than 50), so that I could segregate them in different age classes without even asking their ages.

7.2.2 Consumption of Tiger Prey by Local People

It is locally well-known that the bulk of poached meat is consumed by people living in the vicinity of the Sundarbans. Hence, the daily protein intake of 50 randomly-selected local families was recorded to determine the rate of consumption of tiger prey, as well as the proportion of protein that comes from the prey in relation to the total animal protein consumed. The families were selected from ten different villages in the same area (for convenience of daily visits) along the northern boundary of the Bangladesh Sundarbans, all were located in Mongla Upazilla (sub-district) of Bagerhat district. Geographically the villages are located between 22º20′-22º30′ N latitudes and 89º30′-89º40′ E longitudes. The names of the villages are Colabari, Gaabbunia, Joymoni, Bouddamari, Burburia, West Chila, South Chila, Goalbunia, Gilar Khalkul and South Haldibunia.

It was very tricky to attain the actual information on the consumption of poached meat, because people know that this is illegal and hence they are careful not to disclose it to outsiders. Moreover, it was impossible for me to work in the forest and in the local villages at the same time. Taking these into account, two local schoolteachers were employed who were fully acceptable to local villagers. Traditionally, people respect teachers and medical doctors in Bangladesh, especially in the villages. The schoolteachers visited each of the 50 randomly-selected families every morning and recorded the quantity and market price of all types of animal proteins that each of the families consumed in the previous day.

Out of these 50 families, 31 were Muslims and the rest were Hindus; the proportion of Hindu families was relatively high in the study area compared to the national average. The total number of people in all the 50 families was 289. The family size ranged between 2 and 12 (mean = 5.8, sd = 1.7). There were 77 adult male, 69 adult female, 48 adolescent male, 40 adolescent female, 28 children male and 27 children female. Based on the profession of the family heads, there were five main professional classes, i.e. day labour (8%), fisherman (22%), farmer (16%), businessman (38%) and serviceman (16%). Based on the level of monthly income of the families, I divided them into seven groups starting from Tk (i.e. Bangladeshi currency: Taka) 2000 up to Tk 5000, but the highest percentage of families were in Tk 4000 (26%) and Tk 3000 (24%) levels. At the time of the survey US $ 1 = Tk 57.

7.3 RESULTS

7.3.1 Interviewing Local People, Newspaper Reports and Forest Department Records

7.3.1.1 Tigers Killed by People

During the 18 months (September 2001-February 2003) of my fieldwork in the Bangladesh Sundarbans and the adjacent areas, people killed a total of seven tigers, but the official figure was four. Since the official number of tigers killed by people is very different from the actual number, only the data of interviewing were used for the following results.

The information derived from interviewing local people about some tiger killing in the last 30 years (n = 30 tigers, which was not complete for all tigers killed, but only those cited by the interviewees) shows that the percentage of tigers killed by people was much higher in winter (November-February: 77%) (Figure 7.1). However, due to small sample size, no statistical test was conducted to examine whether the numbers of killed tigers in different months were significantly different or not. Among the killed tigers, most were middle-aged (68%) males (73%) (Figures 7.2 and 7.3). Here 'middle-aged' tigers are those which are sexually mature and are neither young nor obviously old. Most of the tigers (68%) were killed in the villages around the Sundarbans and the rest were in the Sundarbans. There were different reasons for tiger-killing by people, but the main reason (47%) was the attack on humans. The attack on humans and cattle together were the primary motives (in 76% cases) for tiger-killing by people; poaching also was a significant reason (19%) (Figure 7.4). Poachers kill tigers commonly by poisoning the half-eaten kill of the tiger, but they also use firearms directly or set it on the tiger trail which is triggered by the tiger itself (see Figure 7.5 for the setup, as demonstrated by a poacher). Based on the official (Forest Department) records, a total of 30 (annual mean = 3, range = 0-5) tigers were killed in a 10-year period (1993-2002).

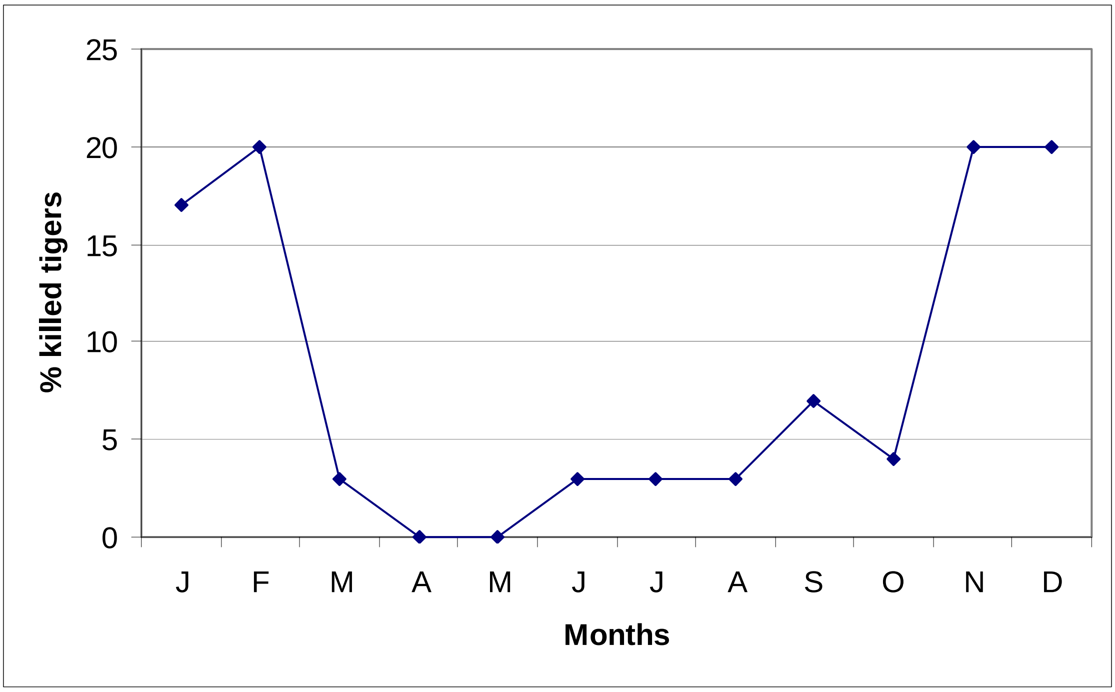


Figure 7.1 Tigers killed by people in different months in and around the Bangladesh Sundarbans (n = 30 tigers, only those cited by the interviewees over the last 30 years).

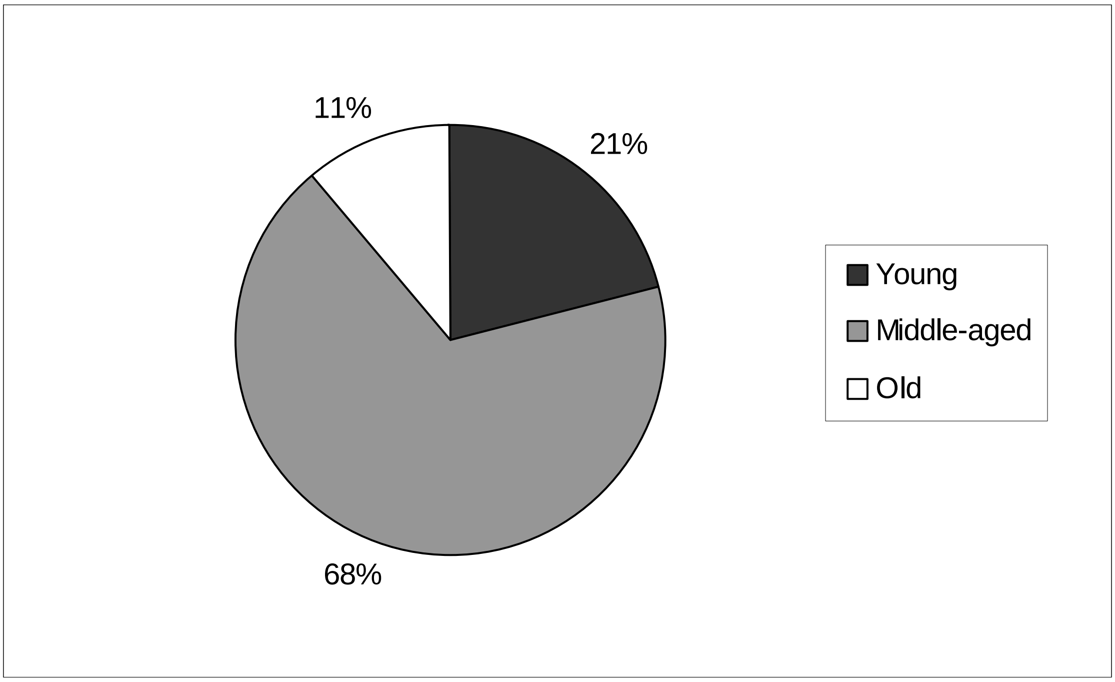


Figure 7.2 Proportions of different age classes of killed tigers in and around the Bangladesh Sundarbans (n = 30 tigers, only those cited by the interviewees over the last 30 years).

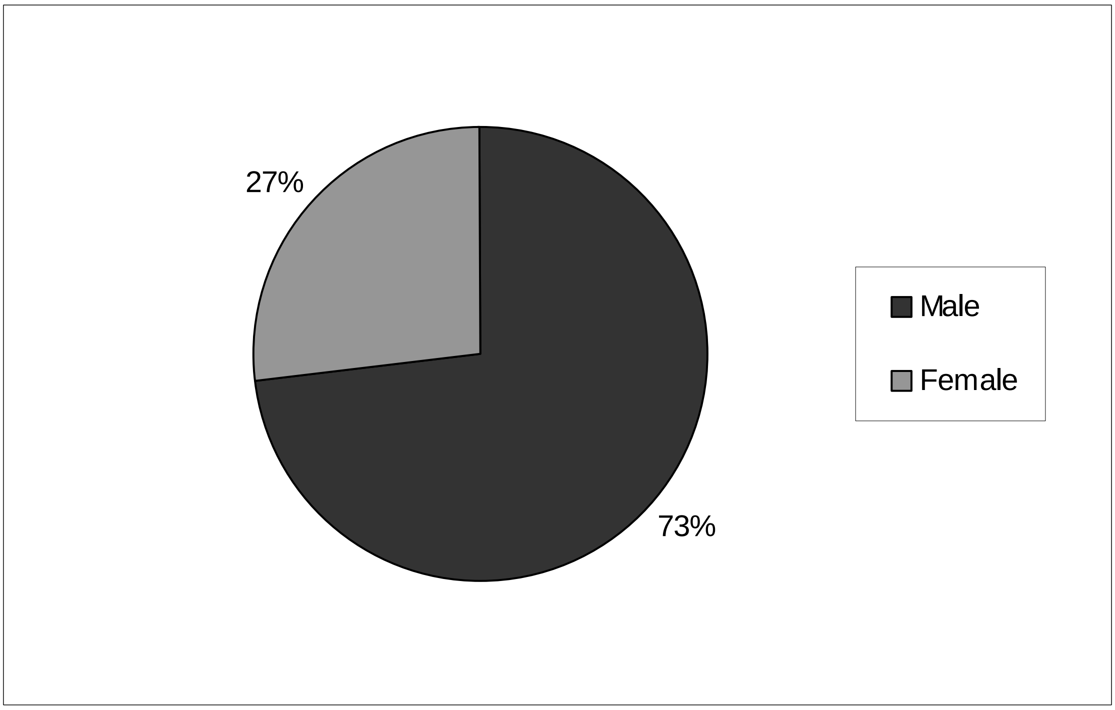


Figure 7.3 Proportions of male and female among killed tigers in and around the Bangladesh Sundarbans (n = 30 tigers, only those cited by the interviewees over the last 30 years).

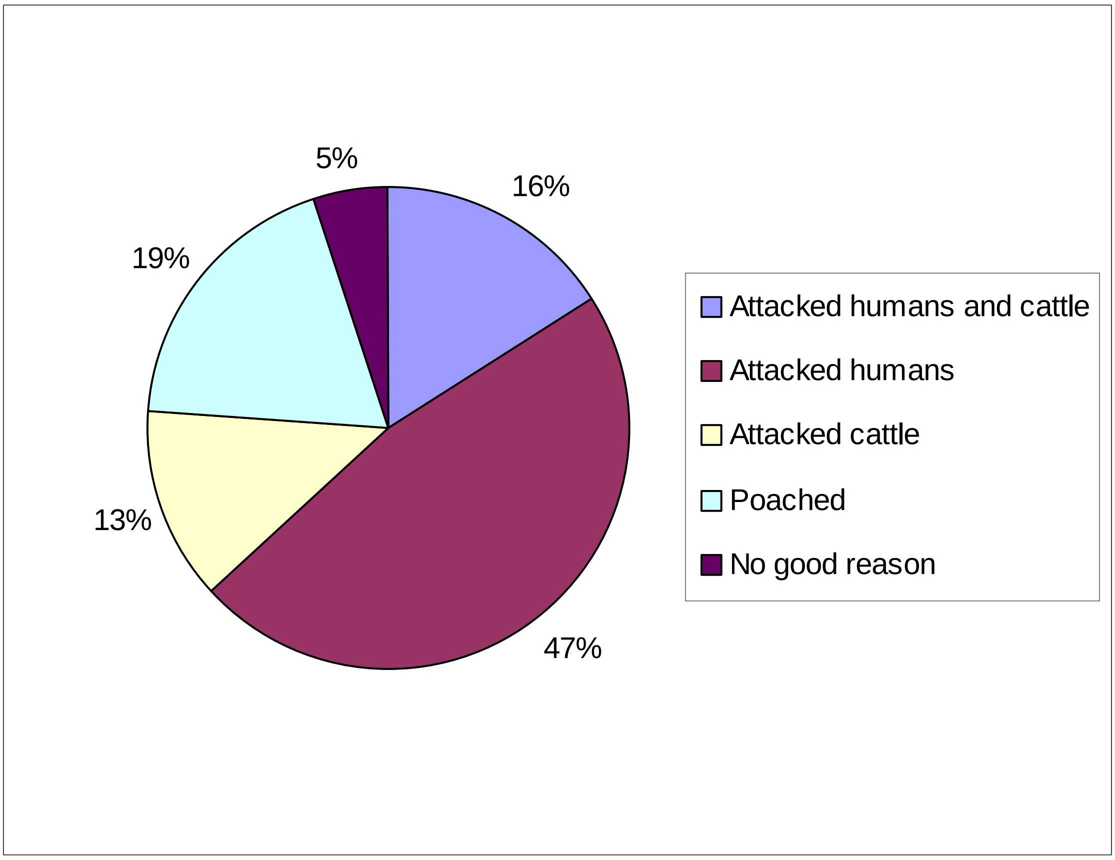


Figure 7.4 Proportions of different reasons for killing tigers in and around the Bangladesh Sundarbans (n = 30 tigers, only those cited by the interviewees over the last 30 years).

(**Figure 7.5** Diagram of firearm setting by tiger poachers to kill the tiger → import from Maps and Illustrators folder.)

7.3.1.2 People Killed or Injured by Tigers

During the 18 months (September 2001-February 2003) of my fieldwork, tigers killed a total of 41 people, but officially this figure turned out to be only five. Since the official number of casualties is very different from the actual number, only the data of interviewing and observations were used for the following results.

The tiger-attacks on humans (killed/injured) in different months were significantly different ($\chi^2 = 26.20$, df = 11, $p = 0.006$). The attacks were slightly higher towards the winter (October-April: 80%) (n = 104), with the highest peak in April (16%), which probably corresponds to the high influx of honey gatherers (Figure 7.6). Most of the people (95%) 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.

The percentage of available humans (sample n = 623) and attacked (killed/injured) humans (n = 123; those known to the interviewees over the last 30 years) in different age and professional classes were compared to examine whether the man-eating tiger has any preference for humans of any age and professional class. The comparison revealed that middle-aged people (age 30-50) were most commonly attacked (73%), but at the same time, people of this age class were found to be the most available (45%), i.e. people of this age classes most frequently entered the forest. However, in comparison to other two age classes, tiger-attack was relatively high in 30-50 age class (Figure 7.7). The range of ages of people killed by tigers was 13-85 (n = 123, mean = 38.1, sd = 13) and the range of group sizes of people when tigers attacked most of the above-mentioned victims was 1-30 (n = 102, mean = 6.1, sd = 4.8). The attacks on different professional classes were compared with the availability of people in those professional classes and was found that most of the attacks were on fishermen (45%) and 'Bawalis' (woodcutters and other plant product harvesters) (37%), which mainly followed the availability. However, in comparison to the availability, attacks were slightly higher in honey gatherers and much lower in 'others' (mainly tourists) (Figure 7.8).

Out of four forest ranges (Sarankhola, Chandpai, Khulna and Satkhira) in the Bangladesh Sundarbans, the human casualties were highest (40%) in Satkhira range, which is located at the western end of the Bangladesh Sundarbans along the Bangladesh-India border. Based on the records of killed (n = 98) and injured (n = 25) humans, 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 (Figure 7.9). It probably indicates that neck-head bite from the back is the primary hunting tactic of the tiger. There is little chance for any human to survive from a neck-head bite by a tiger. Human kills were found to have been dragged a mean distance of 1,364 m (n = 48, range = 15-8,000 m, sd = 2,084) from the initial spot of attack. Based on the official records, a total of 173 humans were killed in a 10-year period (1993-2002) (annual mean = 17.3, range = 0-42).

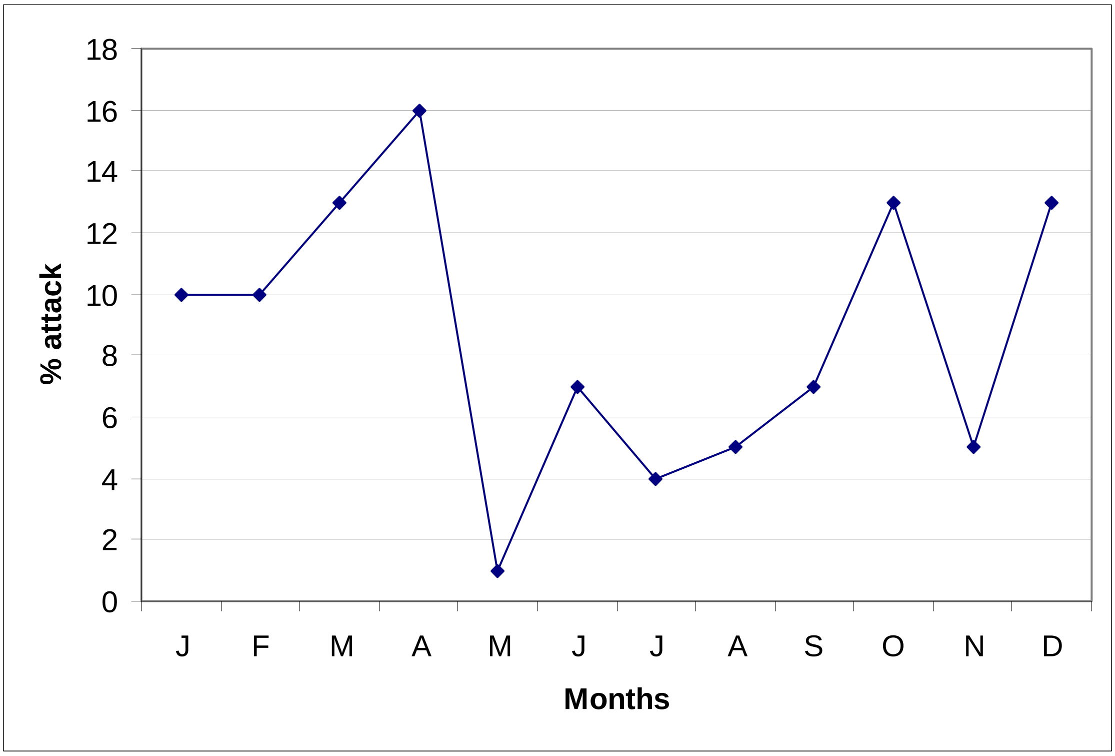


Figure 7.6 Tiger-attacks on local people in different months in and around the Bangladesh Sundarbans (n = 123 humans, those known to the interviewees over the last 30 years).

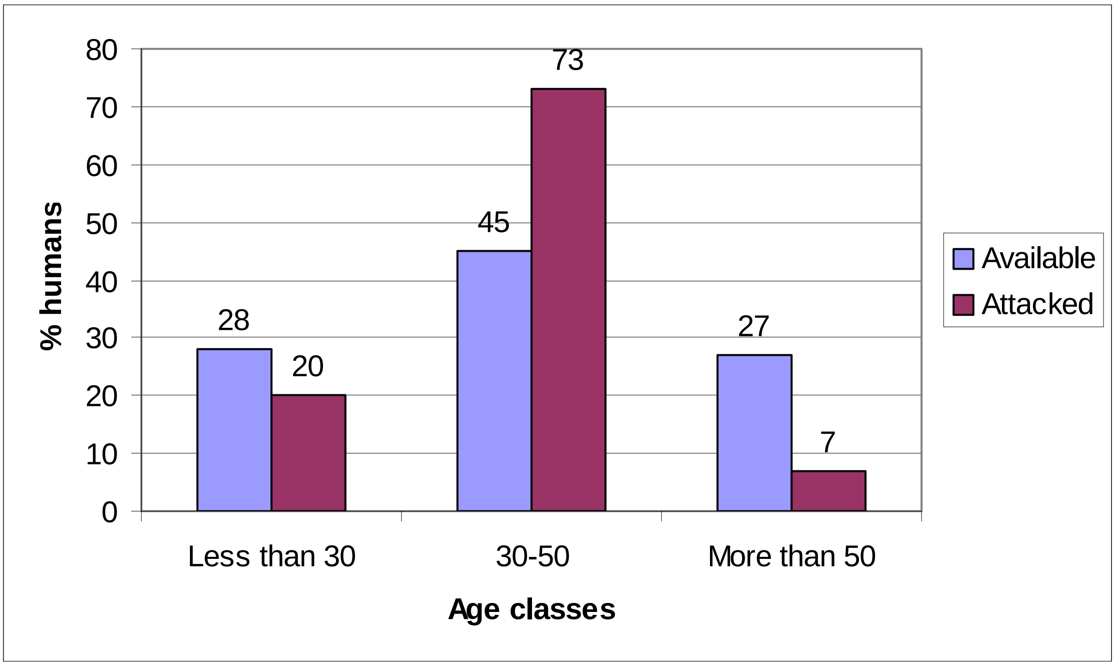


Figure 7.7 Available humans and attacked humans in different age classes in and around the Bangladesh Sundarbans (available: sample n = 623 humans; attacked: n = 123 humans, those known to the interviewees over the last 30 years).

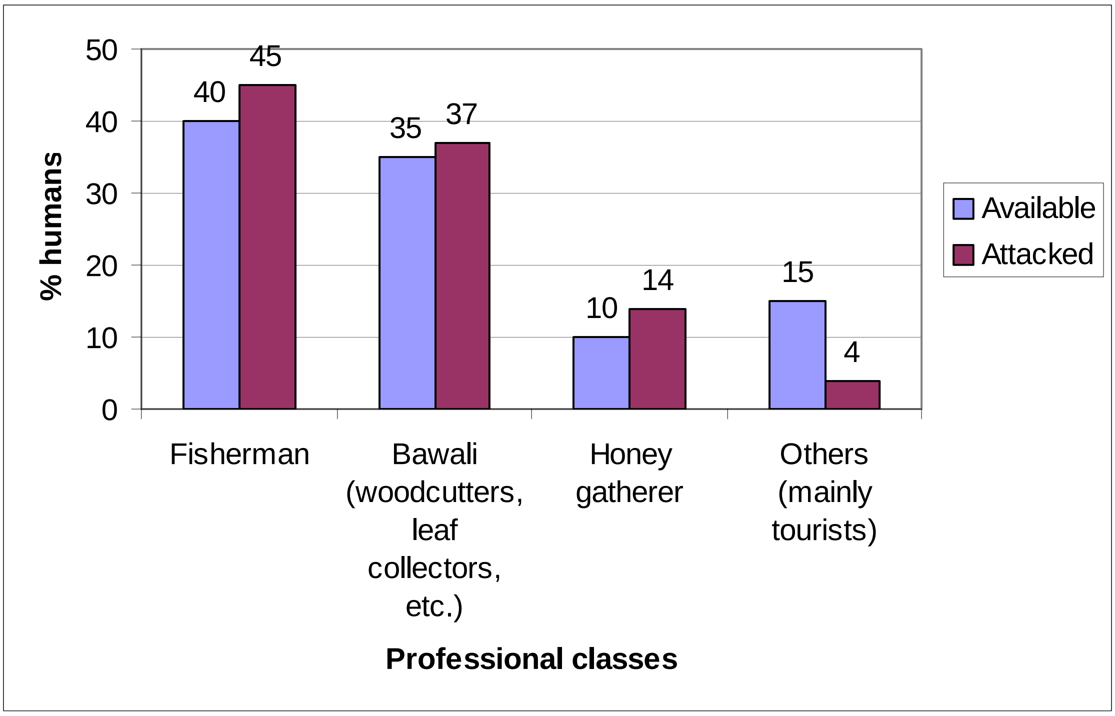


Figure 7.8 Available humans and attacked humans in different professional classes in and around the Bangladesh Sundarbans (available: sample n = 623 humans; attacked: n = 123 humans, those known to the interviewees over the last 30 years).

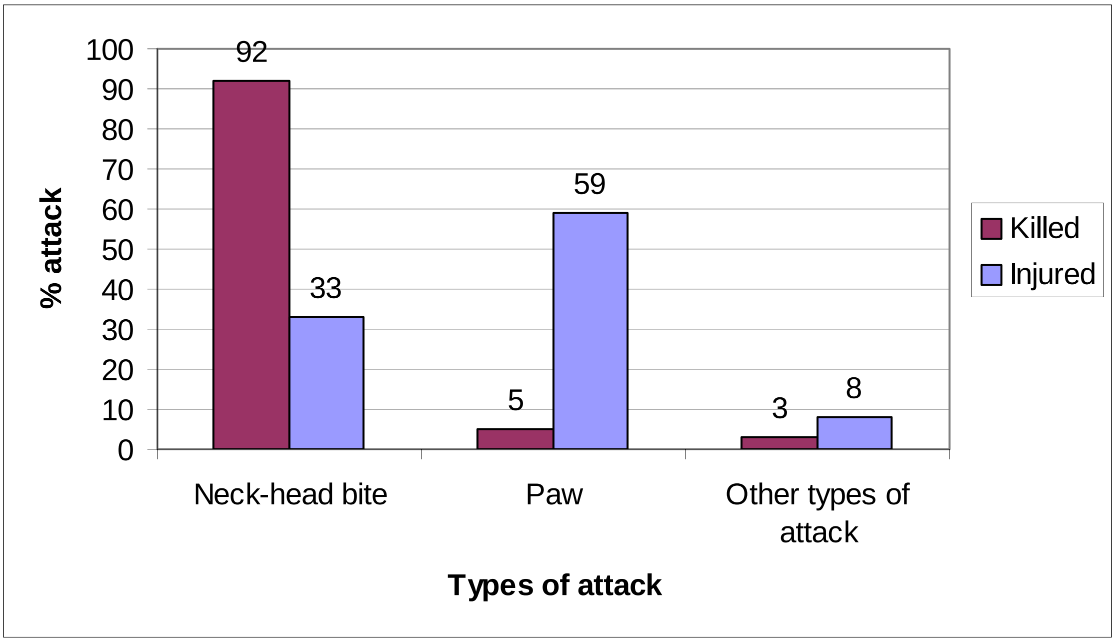


Figure 7.9 Types of initial tiger attack in killed and injured humans in and around the Bangladesh Sundarbans (available: sample n = 623 humans; attacked: n = 123 humans, those known to the interviewees over the last 30 years).

7.3.1.3 Protection From the Tiger

The majority of the interviewed local people (53%) relied only on spiritual measures to protect themselves from the tiger (Figure 7.10). These measures have no practical use, so most of the people are potentially easy prey for a man-eating tiger.

Human culture and religion in and around the Sundarbans are closely connected to its plants and animals, especially the tiger. There are a number of folk deities worshipped in the region in the belief that they will save people from danger, especially from tiger attacks. The three principal folk deities are Banbibi, Dakshin Rai and Gazi Saheb. ‘Banbibi’ means ‘the lady of the forest’ and she is the supreme deity. According to the legend entitled ‘Banbibir Jahura Nama’, Banbibi fought against Dakshin Rai, a cruel king, to save the life of a destitute honey gatherer named Dukhey. The people of the Sundarbans worship Banbibi and believe that she will save them if they are in danger, as she once saved Dukhey. Local people ask Banbibi for permission before entering the forest. Dakshin Rai is also worshipped because he is considered to be the ‘God of the Tigers’. People believe that all tigers in the Sundarbans are under the control of Dakshin Rai. Gazi Saheb was believed to be a great Muslim leader of the region, and the tiger and other wildlife of the Sundarbans obeyed him.

Every year people release live goats and chicken in the forest (which ultimately get killed and eaten by the wildlife of the Sundarbans) in order to please the spirit of the Sundarbans. Some people of the Muslim community believe that the tiger was born from the menstrual blood of the great mother ‘Fatema’, which is why the tiger has a strong odour. Some people believe that the man-eating tiger is not actually a tiger. It is an evil spirit named ‘Ufari’ (literally means something that comes from above). The Ufari comes from the sky and sits at the top of a tree. Due to the weight of the Ufari, the tree starts bending. Once the top of the tree touches the ground, the Ufari takes the form of a tiger that kills people. Since it is an evil spirit, people think that there is little they can do to stop it.

Whenever people talk about the tiger, they address it very respectfully. People carry sacred beads and threads given to them by spiritual leaders (locally known as ‘Hujur’ or ‘Peer’) in the belief that these will protect them from man-eating tigers. People also put sacred red flags, treated by a spiritual leader in the area they work so that the tiger cannot approach the area. Furthermore, people do not usually go to work in the Sundarbans without a companion of the ‘same blood’, i.e. a close relative like brother or son. They do this because they believe that if a man-eating tiger attacks someone in their group, everyone other than close relatives will run away to save himself. People always try to work in groups and many groups have a professional spiritual man, locally known as ‘Gunin’ or ‘Guni’, who is believed to have the spiritual power to lock the jaws of the tiger and move it away so that people can work freely. The Gunin carries a big stick and carefully watches the surroundings while others work. The verses used by the Gunin to deter the tiger are considered top secret, and they normally do not reveal these to anyone. Three of the verses, translated, are: ‘Sunken on the blood, the soul from the blood (tiger), if you look towards my people, (you will have to) tear out your own penis and eat’, ‘In the name of Ali, in the name of Fatema, hey bastard (tiger) get lost’ and ‘Mother Fatema, (I have) come to your forest, please keep me in mind’. Out of thousands of workers in the Bangladesh Sundarbans, only some of them always work cautiously and always carry either a big stick or a hand-axe. These are the only practical protection measures people ever take.

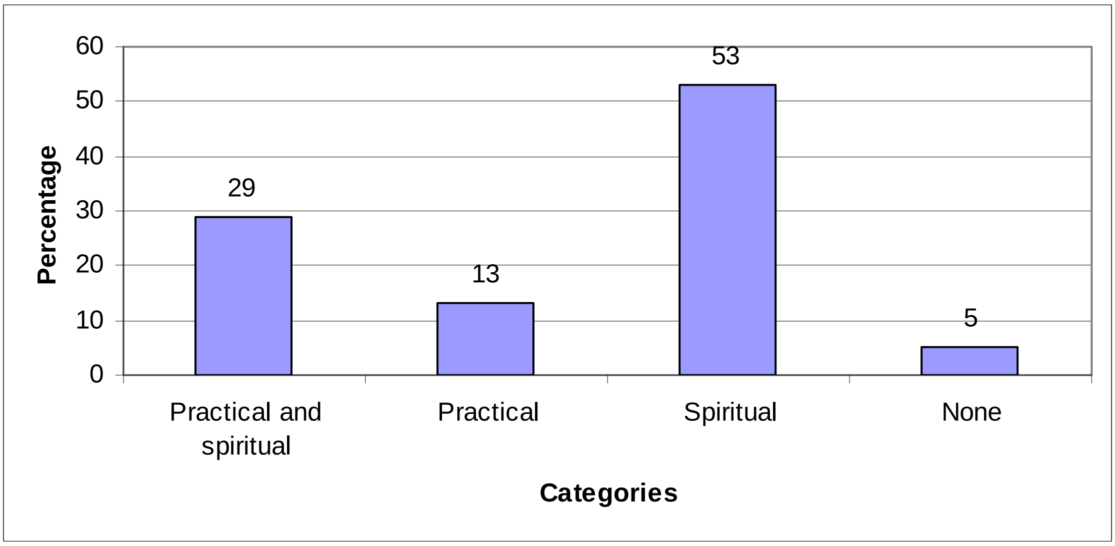


Figure 7.10 Protection measures from tigers taken by local people in the Bangladesh Sundarbans.

7.3.1.4 Where Do People See the Tiger?

Among the interviewed local people who have ever seen live tiger(s) (n = 81), 47% of them had seen tigers in the wilderness of the Sundarbans (Figure 7.11). This means that the local people still familiarise with the tiger in the Sundarbans rather than in the adjacent villages (tigers coming from the Sundarbans), zoos or circus. Familiarity with a species is important in terms of conservation, because if people never or rarely see the animal, they may not care for it.

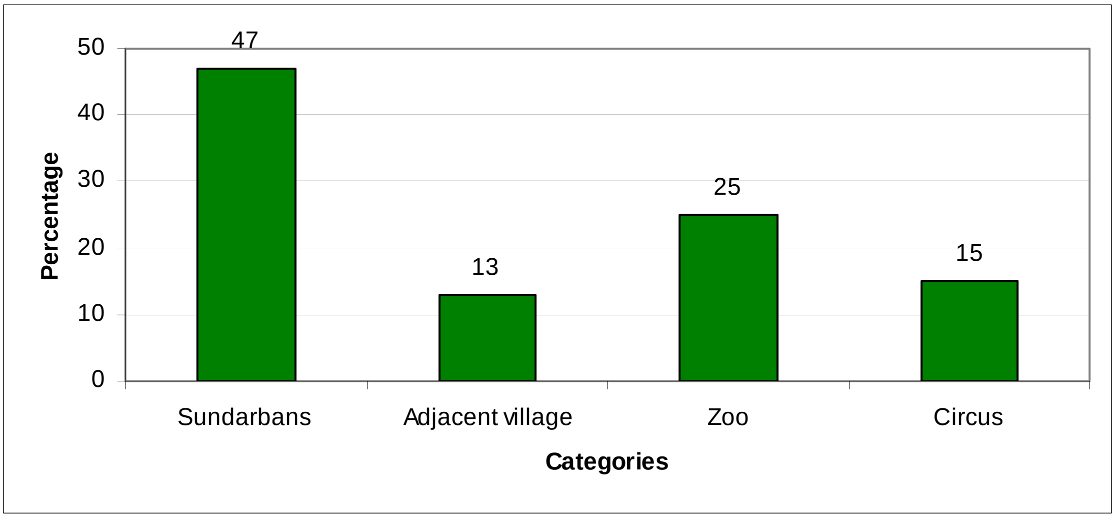


Figure 7.11 Tiger sightings by local people in the Sundarbans, adjacent villages, zoos and circus.

7.3.1.5 Condition of Sighted Wild Tigers

Among the wild tigers seen by interviewed local people (n = 70), 23% sightings were killed tigers (Figure 7.12). It indicates that perhaps local people often kill tigers, but 56% sightings were of normal live tigers.

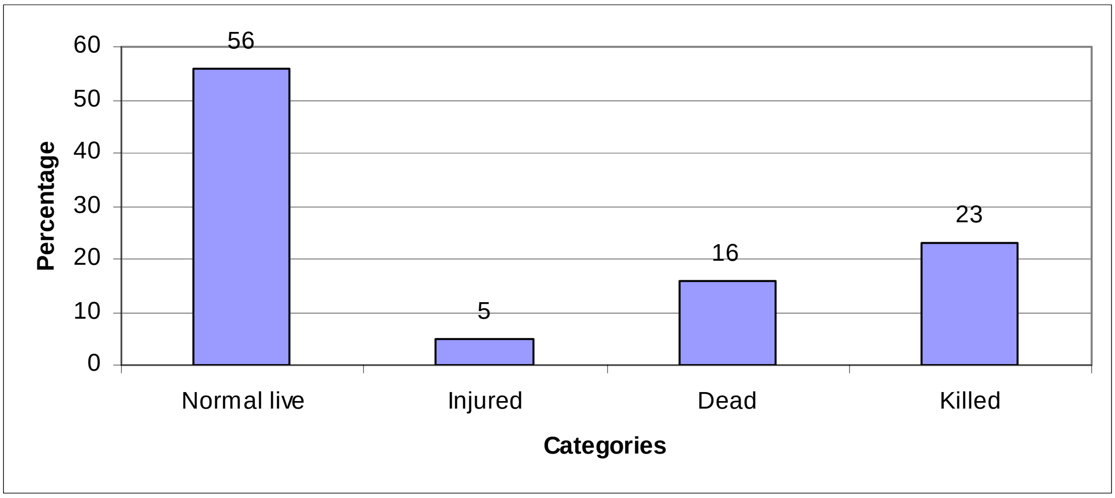


Figure 7.12 Conditions of the sighted wild tigers in and around the Bangladesh Sundarbans.

7.3.1.6 Public Knowledge on Bangladesh Wildlife Act 1974

The interviewing reveals that only 5% of the interviewed local people properly knew (i.e. knew the basic features) about the existence of Bangladesh Wildlife Act 1974. Among the rest of the local people, 62% weakly knew (i.e. only knew the existence of the Act, but did not know the basic features) and 33% did not even know the existence of the Act (Figure 7.13).

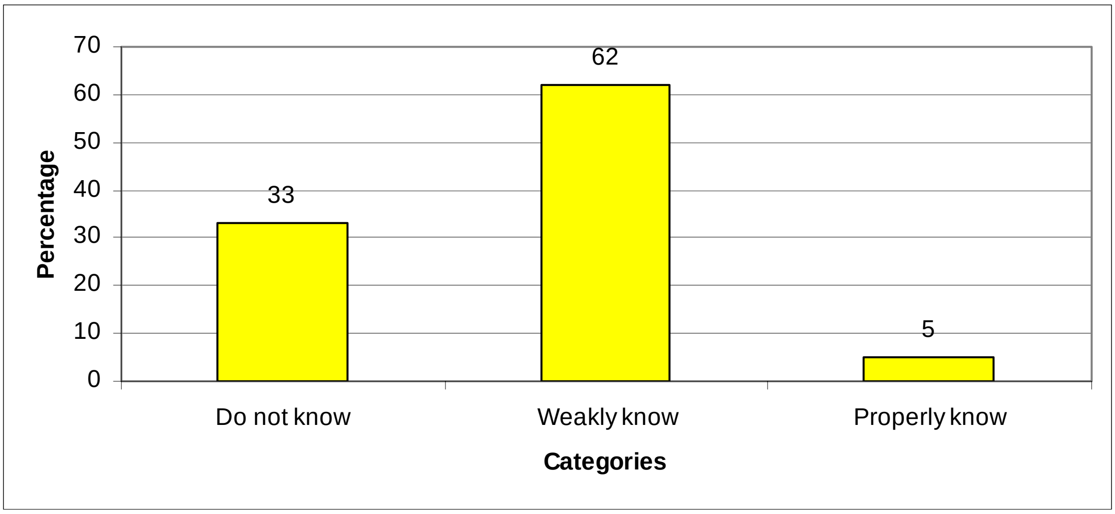


Figure 7.13 Public knowledge on the existence of Bangladesh Wildlife Act 1974.

7.3.1.7 Public Belief on the Medicinal Use of Tiger Parts

Forty-two percent of the interviewed local people believed that there are medicinal uses for tiger parts, i.e. the fat works as a pain killer when used as an ointment, the tooth (mainly the canine tooth) increases the strength and vigour when used as a locket, the genital organ is useful to cure sexual weakness or sexual diseases of both male and female humans, etc. The findings indicate that there is a significant demand for tiger parts in the locality, since nearly half of the local people believed on the medicinal use of tiger parts. Only 15% of the interviewed local people did not believe on any medicinal use of tiger parts (Figure 7.14). The use of tiger parts as medicines were seen during this study.

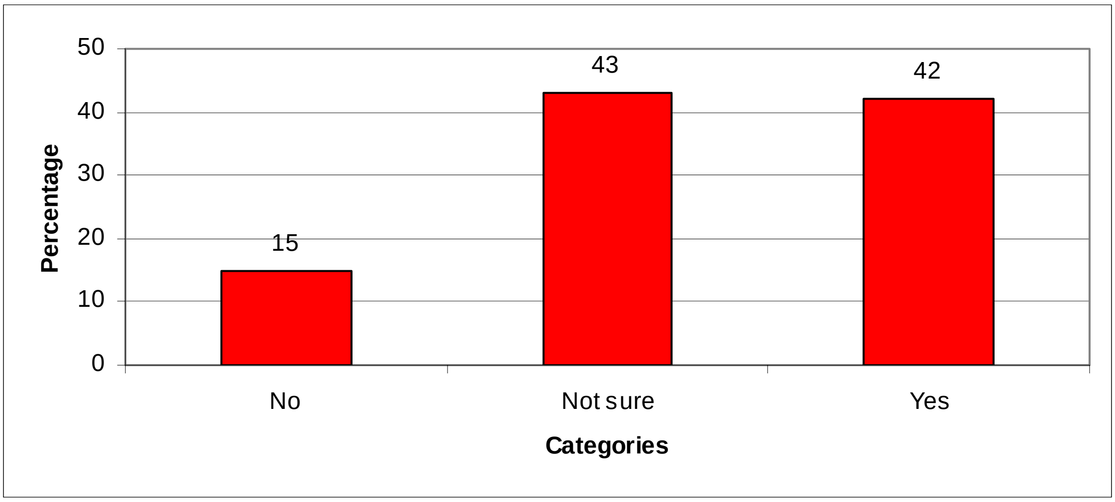


Figure 7.14 Public belief on the medicinal use of tiger parts.

7.3.1.8 Public Opinion on Tiger Conservation

Interestingly, despite all of the fatal encounters with tigers, 75% of the interviewed local people wanted the tiger to remain in the Sundarbans (Figure 7.15). They believe that without the tiger, illegal loggers and poachers would have nothing to fear, and would destroy the Sundarbans by cutting down trees and killing wild animals. As a consequence, the local people would lose their livelihood, but 22% of the interviewed local people said that they do not want the tiger in the Sundarbans, so that they could work without any fear. It was noticed that in the area where the rate of human casualty is relatively high (e.g. Burigoalini area besides Satkhira range of the western Sundarbans), people are less interested to conserve the tiger than people of the eastern Sundarbans where the rate of human casualty is relatively low.

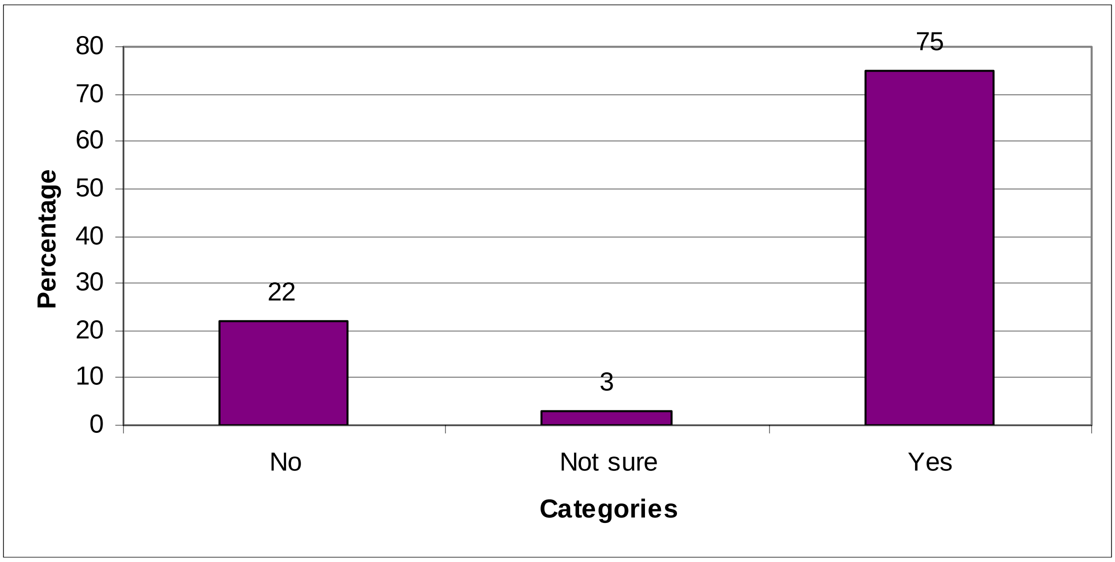
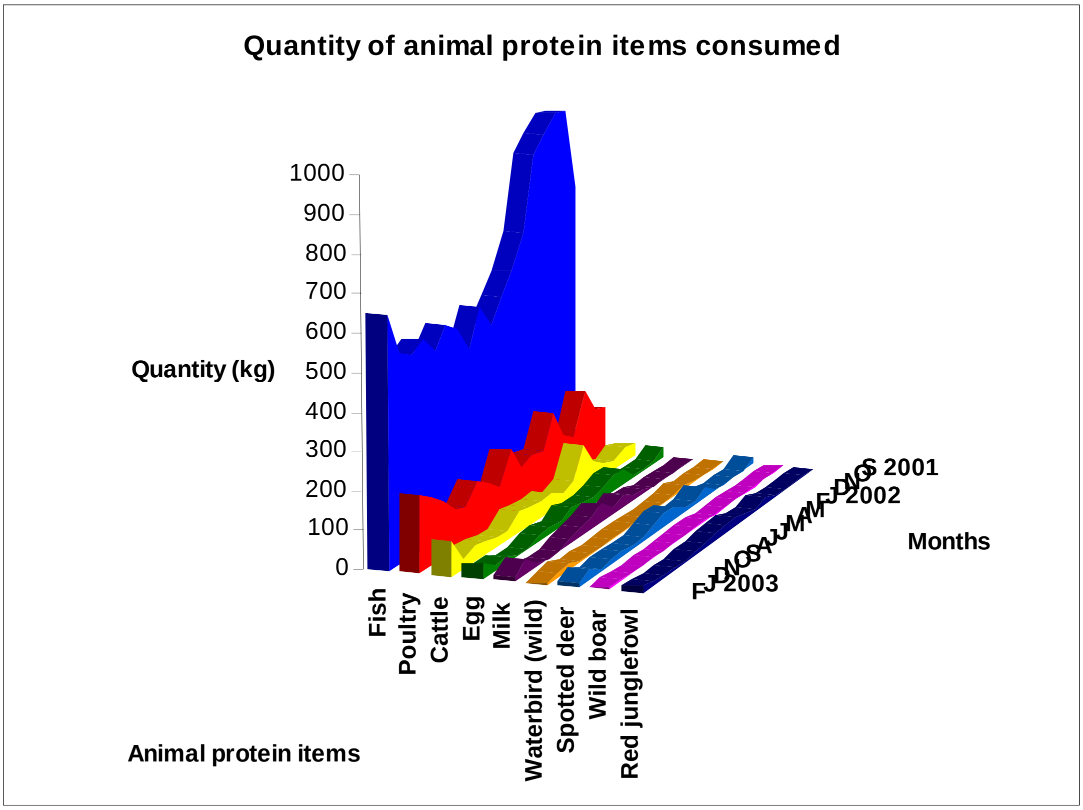


Figure 7.15 Public opinion on tiger conservation.

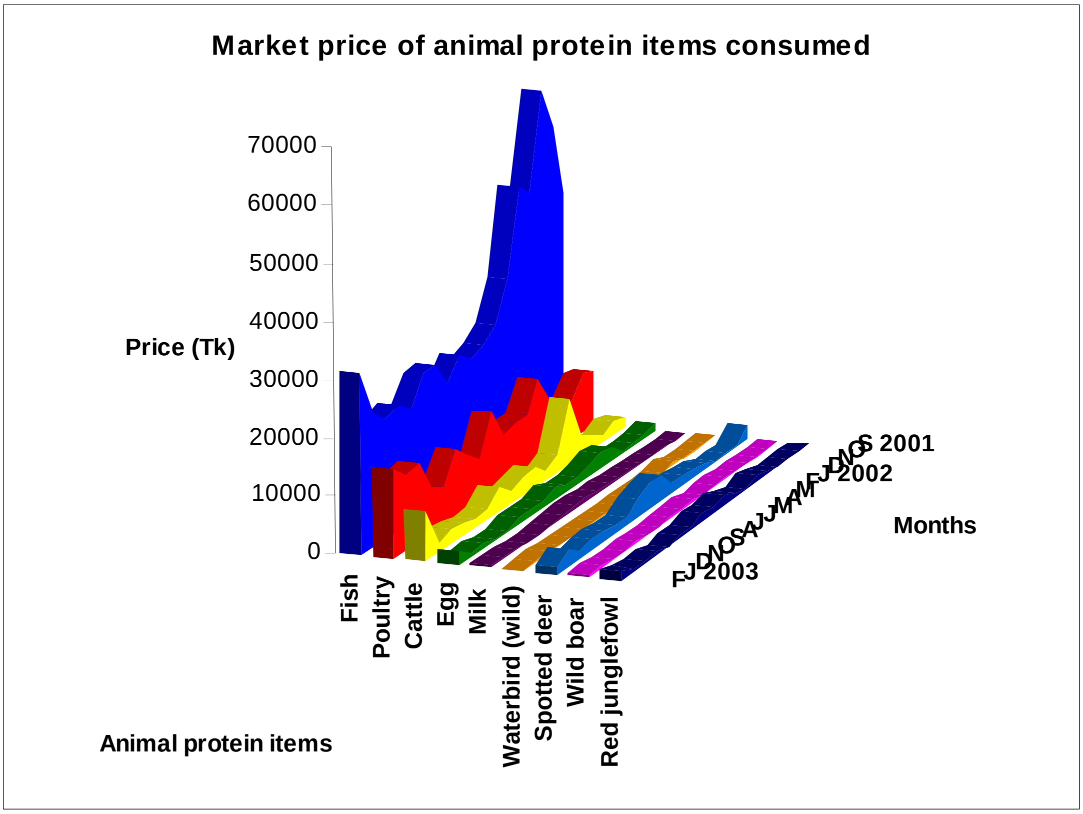
7.3.2 Consumption of Tiger Prey by Local People

The data on 18 months (September 2001-February 2003) of animal protein intake by 50 local families reveals that the percentage of non-prey (fish, poultry, cattle, etc.) and wild prey [spotted deer, wild boar (*Sus scrofa*) and red junglefowl (*Gallus gallus*)] proteins were 97.2% (15,258 kg) and 2.8% (442 kg, of which the spotted deer meat was 260 kg, i.e. 1.7%), respectively. In terms of market price, the percentages were 94.9% (Tk 857,279 = US $ 15,040) and 5.1% (Tk 46,250 = US $ 811), respectively. According to local poachers, a spotted deer produces an average of 32 kg of salable meat. This means that the above-mentioned 50 families together consumed the deer meat that is equivalent to about eight spotted deer in 18 months. In relation to the total animal protein consumed by local people, the percentage of protein from tiger prey is insignificant, but if the figure is extrapolated against thousands of similar families living around the Sundarbans, it will be evident that local villagers consume hundreds of prey every year. Since there is no estimate of people living in few-km-wide buffer zone of the Sundarbans, I could not extrapolate the prey consumption.

It is clearly evident that fish is the main source of protein. The total quantity of fish protein consumed, followed by the total price, is much higher than other types of proteins. Among the tiger prey items, spotted deer forms the highest proportion, both in terms of quantity and market price (Figure 7.16).



(a)



(b)

Figure 7.16 Quantity (a) and market price (b) of monthly consumed animal protein items during September 2001-February 2003 by 50 families in the vicinity of the Sundarbans. N.B. 1 US $ = Tk 57.

Prey protein was more expensive [mean = Tk 111 (US $ 1.95)/kg, sd = 19.9] than non-prey protein [mean = Tk 55.4 (US $ 0.97)/kg, sd = 4.8], and especially the deer meat was rather a delicacy in the locality. The prey protein consumption fluctuated significantly in different months because the supply of poached products was not continuous (Figure 7.17). No major difference was found in the monthly-consumed quantity of protein in different professional (Table 7.1 and Figure 7.18) or income families (Table 7.2 and Figure 7.19). In 'serviceman' families, however, the percentage of total animal protein consumption was slightly higher, probably because they were more educated and hence were more health conscious.

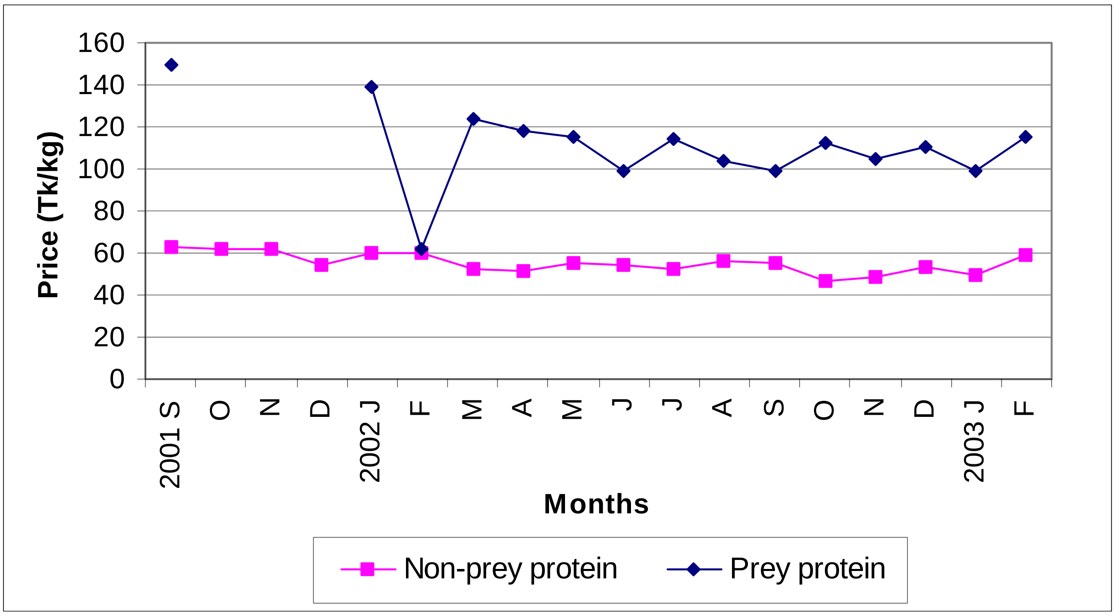


Figure 7.17 Market price of non-prey and prey protein items during September 2001-February 2003 in the vicinity of the Sundarbans. (There was no consumption of prey protein during October-December 2001, probably because the prey protein was not available in the market.) N.B. 1 US $ = Tk 57.

Table 7.1 Non-prey and prey protein consumption/family/month (with standard deviation) in different professional families in the vicinity of the Sundarbans. Here n = number of families

Businessman (n = 19)		Day labour (n = 4)		Farmer (n = 8)		Fisherman (n = 11)		Serviceman (n = 8)	
Non-prey (kg)	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**
19.4 (±1.0)	0.5 (±0.2)	20.7 (±1.1)	0.6 (±0.3)	17.6 (±0.9)	0.7 (±0.3)	14.2 (±0.7)	0.5 (±0.3)	23.4 (±1.3)	0.5 (±0.2)

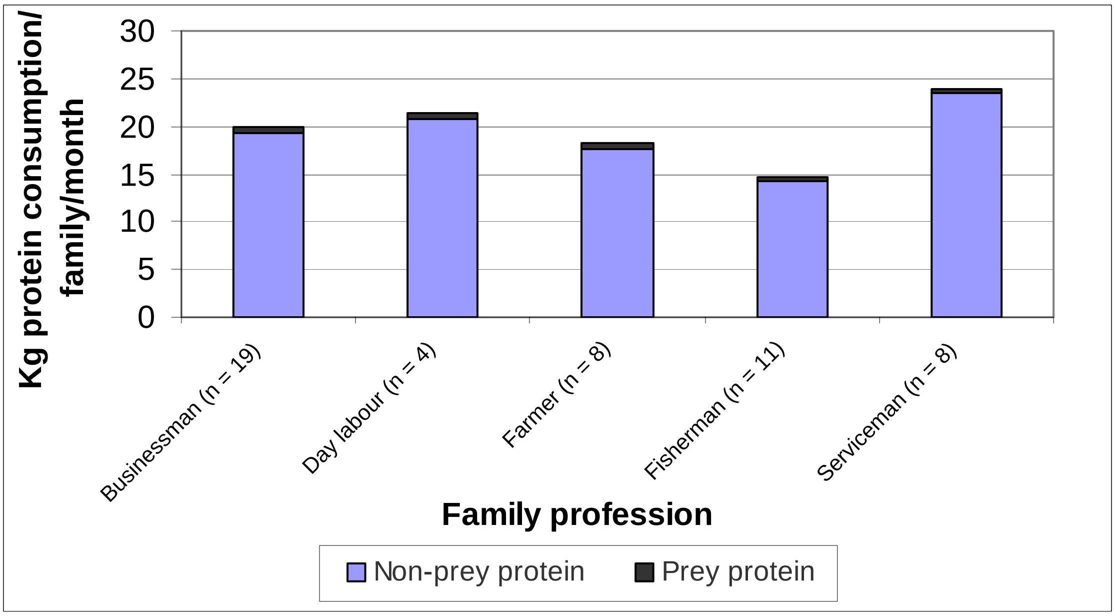


Figure 7.18 Non-prey and prey protein consumption/family/month in different professional families in the vicinity of the Sundarbans.

Table 7.2 Non-prey and prey protein consumption/family/month (with standard deviation) in different income families. Here n = number of families

Tk 2,000 (n = 7)		Tk 2,500 (n = 7)		Tk 3,000 (n = 12)		Tk 3,500 (n = 2)		Tk 4,000 (n = 13)		Tk 4,500 (n = 4)		Tk 5,000 (n = 5)	
Non-prey (kg)	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**	**Non-prey (kg)**	**Prey (kg)**
20.6 (±1.1)	0.4 (±0.2)	17.5 (±0.9)	0.5 (±0.2)	20.1 (±1.1)	1.0 (±0.4)	14.8 (±0.7)	0.5 (±0.2)	21.1 (±1.2)	0.4 (±0.2)	16.5 (±0.8)	0.5 (±2)	18.4 (±0.9)	0.8 (±0.3)

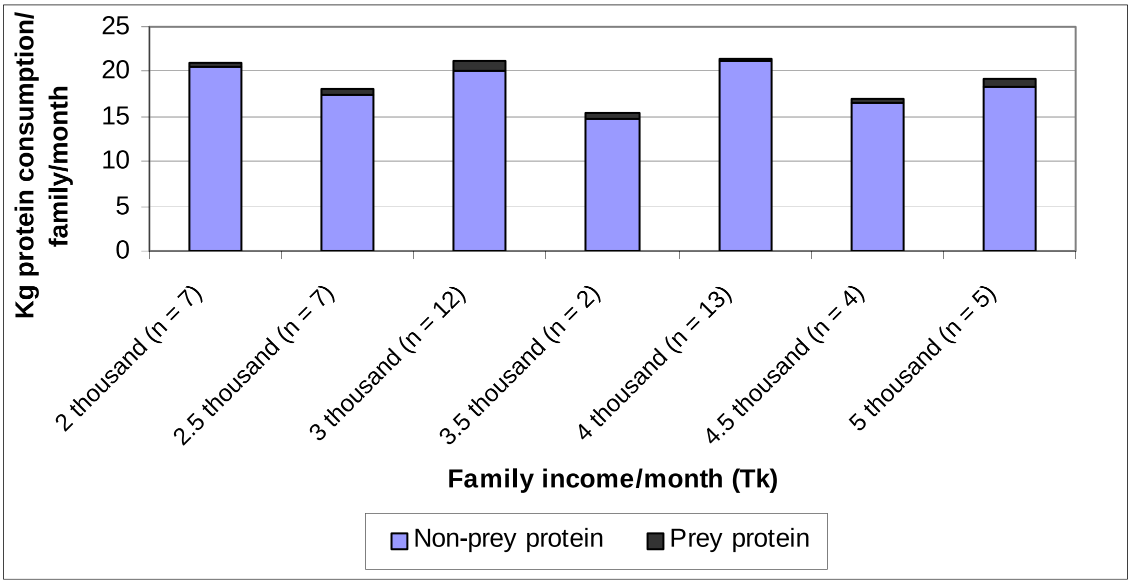


Figure 7.19 Non-prey and prey protein consumption/family/month in different income families in the vicinity of the Sundarbans.

It is almost impossible to know the actual rate of poaching, because poachers take great precautions to avoid detection. Only when they are arrested, or their traps or trapped deer are found, does it become known to all. During my 18 months fieldwork (September 2001-February 2003) I came to know about five attempts at deer poaching (one attempt at both deer and tiger poaching) from the Sundarbans East WS, which is only 5% of the entire area of the Bangladesh Sundarbans. These attempts were in Katka, Egg Island, Kochikhali, Badamtala and Bhulurdia in the above-mentioned Sanctuary. A total of only two poachers (from a group of four) were arrested on 14 March 2002 by the Forest Department officials. This group of poachers set 162 deer traps, locally known as 'dowa' (snare traps), which were set in the evening and checked the next morning. The trapped deer are slaughtered and taken to the nearest market (Patharghata) where they sell the meat for at least Tk 100/kg. This group also had a big bottle of liquid poison in order to poison the tiger kill, so that the tiger would be poisoned and killed. A tiger skin is locally sold for about Tk 30,000 (US $ 500), but the price rises to a few times when it is sold in Dhaka.

Other than the above-mentioned group of poachers, a total of 15 slaughtered deer were seized in two attempts (13 in one and 2 in another) in the Sundarbans East WS. Moreover, a few hundred deer traps were seized from the forest in a total of five raids by the Forest Department officials. This is just a part of the scenario of the alarming situation of deer poaching in the Sundarbans.

7.4 DISCUSSION

7.4.1 Tigers Killed by People

The actual number of tigers killed every year is almost double that officially recorded by the Forest Department. Siddiqui and Choudhury (1987), Helalsiddiqui (1998), Ahmed (2002a, 2002b, 2002c), Jagrata Juba Sangha (JJS; a local NGO) (2002), Reza *et al.* (2002b) and Gani (2002) reported tiger death rates and some other aspects of tiger-human interactions in the Bangladesh Sundarbans, but all of these reports were mainly based on the same official (Forest Department) records, which do not represent the actual figures, and there is very little or no primary information.

Helalsiddiqui (1998) mentioned that, although officially a maximum of five tigers are poached every year, the actual figure could be 7-11 tigers. Both Helalsiddiqui (1998) and Ahmed (2002a, 2002b) mentioned that the deaths of tigers due to unnatural causes are gradually increasing. Poachers killed a total of 33 tigers during 1981-1999 (Bangladesh Forest Department 2000a). Based on official records Reza *et al.* (2002b) reported that, on average, about three tigers were killed each year during 1984-2000, and Gani (2002) mentioned the death of 23 tigers (52% by local people and 44% by poachers) during 1996-2000. The above-mentioned results are similar to my result which was based on the Forest Department records, but the actual figures of casualties, as mentioned in my results, are very different from the official figures. I found that 68% of the tiger deaths occurred in the villages around the Sundarbans and the rest in the Sundarbans which is similar to Gani's (2002) result (65% tiger deaths in the village).

The percentage of tigers killed by people in different months was much higher in winter (November-February: 77%). This was probably because the breeding peak of tigers is in winter that caused more extreme territorial conflicts among male tigers. As a result, some of the tigers were probably forced away from the forest. These tigers started killing cattle, or even people, in the local villages and eventually were killed by the villagers. Probably for the same reason most (73%) of the killed tigers were males. This is supported by the findings of Hendrichs (1975) who reported that of the ca. 200 tigers shot (it was not illegal to shoot/kill tigers until 1973) in a 19-year period (1950-1974), 58.5% were males. Even for females, winter is the period when they need more food to raise cubs, causing more competition. Based on small sample size (n = 11), Nyhus and Tilson (2004) have reported that, in Sumatra, Indonesia, 73% of the killed and trapped man-eating tigers were males and 27% females. This is strikingly similar to the male-female ratio I found among the killed man-eating tigers in the Sundarbans.

Most of the killed tigers (68%) were middle-aged and in good condition, which indicates that, at least in the Sundarbans, a tiger can become a man-eater for a reason that falls in none of the popularly-believed three main reasons (Corbett 1954, Rabinowitz 1986, Sunquist and Sunquist 1988, Hoogesteijn *et al.* 1993, Linnell *et al.* 1999): 1) wounds and infirmity, 2) old age, and 3) loss of home ranges to other tigers. However, these causes rarely turn some big cats like tigers (Corbett 1954, Hendrichs 1975, McDougal 1987, McNeely and Wachtel 1988, Sunquist and Sunquist 1988, Chakrabarti 1992, Montgomery 1995), lions (*Panthera leo*) (Guggisberg 1961, Schaller

1972, Alderton 1993, Chellam and Johnsingh 1993, Saberwal *et al.* 1994, Thomas 1994, Yamazaki and Bwalya 1999), leopards (*Panthera pardus*) (Corbett 1948, Turnbull-Kemp 1967), jaguars (*Panthera onca*) (Nowell and Jackson 1996) and pumas (*Puma concolor*) (Young and Goldman 1946, Beier 1991, Seidensticker and Lumpkin 1991, Foreman 1992, Hansen 1993) into man-eaters in different parts of the world.

A number of studies of big-cat-human interactions reported that most of the big cats that attack humans or cattle were sub-adult individuals displaced from their former home ranges. Examples are man-eating tigers in India (Seidensticker *et al.* 1976), Nepal (McDougal 1987), and Sumatra (Nyhus and Tilson 2004); livestock-raiding lions in Africa (Schaller 1972, Bertram 1973, Rudnai 1979, Hanby and Bygott 1987, Stander 1990) and India (Saberwal *et al.* 1994); and human-attacking pumas in the USA and Canada (Beier 1991). My results showed no indication that sub-adult tigers were more likely to attack humans and cattle, and it appears that people are more vulnerable while working away from the group, or alone, as mentioned by some of the above-mentioned authors.

Poaching is a serious threat to the existence of tigers. As side-effects, this also causes injuries to many tigers that are not killed and causes territorial disharmonies in the wild population. There is a high demand for tiger parts in east Asian countries, but a significant demand in the local villages around the Sundarbans also exists. There are few data on tiger poaching in the Sundarbans. Tiger hides are sometimes seized in Zia International Airport, Dhaka, as well as in some other border check-posts of Bangladesh. In 1998 two forest guards of Bogi Forest Station, Sundarbans, were arrested in connection with killing a tiger by poisoning and selling the skin (Tigerlink 1999). In May 2001, the Bangladesh Rifles (BDR) officials seized 12 hides of tiger from poachers in Kaliganj, near the Sundarbans (The Daily Ittefaq, Dhaka, 7 May 2001). During 1999-2000, one poached tiger and six tiger skins were seized in and around the Indian Sundarbans (Government of West Bengal 2001).

According to Thapar (1996), at least 2,000 tigers were killed throughout its global range in only a five-year period (1989-1993). By August 1993, the biggest-ever haul of big-cat derivatives in India's history took place with nearly 400 kg of tiger bones, eight tiger skins and over 60 leopard skins being seized in Delhi. In known poaching incidents in 1995, about 115 tigers were killed in India (WWF 2001). In the early 1990s, between 60 and 70 tigers were killed every year in Russia (WWF 2001). In

China alone, it is estimated that about 3,000 tigers were killed during a 30-year period (1950s-1970s) (Lu and Sheng 1986). In Sumatra, poachers kill an average of 33 tigers each year, which might lead Sumatran tigers to extinction by 2014 (Associated Press Worldstream, 18 September 2003). In Cambodia, about 50 tigers are killed each year for the wildlife trade (Hean 2000).

The remaining tiger populations are located in small, relatively-isolated populations, which makes them more susceptible to random demographic and genetic events, as well as to external threats, such as poaching (Smith *et al.* 1987a, Kenney *et al.* 1994, Seal *et al* 1994). Using a tiger population simulation model, Kenney *et al.* (1995) found that when poaching continued over time, the probability of population extinction increased sigmoidally, i.e. in manifold. According to them, about 95% of the remaining tiger populations throughout the world are composed of less than 120 tigers. For these populations, three additional years of low-level poaching (5 tigers/year) leads to an extinction probability of less than 5%, but if poaching continues to be moderate (10 tigers/year), the probability of extinction is over 95%. This illustrates dramatically how a small increase in poaching can lead to a much greater probability of extinction. In the Bangladesh Sundarbans, the rate of tiger killing is probably about 5 tigers/year (since I found that 7 tigers were killed in 18 months). Because the Sundarbans tiger population is larger than 120 animals, the probability of the tiger's extinction due to poaching may be less than 5%.

7.4.2 People Killed or Injured by Tigers

As with the tiger, the actual number of humans killed every year is always much higher than the officially recorded figures. This was because, if the victim was an illegal intruder, the death is not officially recorded, which was also pointed out by Montgomery (1995).

The neck-head bite from the back is the primary human-hunting tactic of the tiger, but according to Karanth and Sunquist (2000) tigers kill their prey most often using throat bites; biting the nape alone or together with the throat are less common and used only on relatively small prey. Karanth (2001) has observed kill dragging distance up to 350 m in Nagarhole, India, although the average was around 50 m. In the Sundarbans I have recorded a much higher drag distance for human kills (mean = 1,364 m). This was probably because the man-eating tigers wanted to move human kills sufficiently far away so that the companions of the victim could not disturb while feeding.

Hendrichs (1975), Siddiqui and Choudhury (1987), Helalsiddiqui (1998), Ahmed (2002a, 2002b, 2002c), JJS (2002) and Reza *et al.* (2002b) reported the human casualties and some other aspects of tiger-human interactions in the Bangladesh Sundarbans. Since most of these reports were based on the same official (Forest Department) records, the figures are much lower than the actual figures. None of these reports compared the attacks on people of different age or professional classes with the availability.

Regarding human casualties, Helalsiddiqui (1998) assumed that the actual figure of people killed by tigers each year could be 100-150. According to Ahmed (2002a), tigers in the Bangladesh Sundarbans are blamed for about 1,000 human deaths over the last 50 years. According to JJS (2002), there was a total of 196 tiger attacks on humans during 1999-2002, of which 71 humans were eaten, 76 killed (dead body recovered before eating) and 49 injured. Ahmed (2002a, 2002b) mentioned that officially the average annual death is 23, but the actual number of deaths might be 30% higher. Reza *et al.* (2002b) reported that, on average, about 24 people were killed each year during 1984-2000. In comparison to the above-mentioned findings, my findings from the Forest Department records generally agree with the rate of human casualties, because all of these were based mainly on the same source, although at different times, but the actual number of human casualties that I have recorded was quite different from the speculated figures reported by the above-mentioned authors.

Based on official records of human casualties in the Sundarbans, Hendrichs (1975) found that most of the human deaths occurred in winter (November-February: 45.3%). I have also found higher percentage of tiger attacks towards the winter (October-April: 80%).

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. These figures indicate that the rate of human casualties due to tiger attack is higher in the Indian Sundarbans than in the Bangladesh 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.

Apart from the Sundarbans, a limited number of tiger attacks on people have been reported. Since 1978, over 200 people have been killed around India's Dudhwa National Park, near south-western Nepal (Nowell and Jackson 1996). Although prey is plentiful and tigers are unprovoked, about two people are killed each year in Chitwan, Nepal (Matthiessen 2000). In Kerinci Seblat, Sumatra, Linkie *et al.* (2003) reported 34 incidents in the 1990s, comprising both attacks on humans and livestock depredation. In Way Kambas, Sumatra, at least eight people were killed in 1996-1997 alone (Matthiessen 2000). For the entire island of Sumatra, Nyhus and Tilson (2004) reported that tigers killed 146 people (annual average of 16 during 1978-1982 and 2 during 1988-1992) and injured 30, and killed at least 870 livestock during 1978-1997. The conflict was commoner in the intermediate areas between forests and farmlands. According to a report of Associated Press Worldstream (18 September 2003), in Sumatra, tigers killed seven people in one year (August 2002-July 2003). In Cambodia, 20% of Hean's (2000) interviewees reported tiger attacks on livestock or humans in 1998. In comparison to the above-mentioned results, the problem is much more severe in the Sundarbans, with a higher rate of human casualties.

More tiger attacks in certain seasons might be the effect of more available people in those seasons, but I could not compare the findings with availability because there is no authentic record of the actual number of people available in different seasons. In comparison to the total number of people working in the Sundarbans every year, the percentage of casualties is very low (probably less than 0.05%) (Salter 1984). Seidensticker and Hai (1978) argued that, even in the Sundarbans, there is less risk from being killed by a tiger than from driving a car in most 'developed' countries.

According to JJS (2002), the month January was identified as the highest attack-prone season in the Bangladesh Sundarbans. In the entire Sundarbans, according to Chaudhuri and Chakrabarti (1972), Chakrabarti (1984) and Siddiqui and Choudhury (1987) the maximum fatalities of people by tigers occur in April, which may correspond to the high influx of honey gatherers. A further peak in fatalities is recorded in January, which may correspond to the fact that the number of permit holders in the forest increases slightly during the winter months. My results partially support this, because I found that 80% of the casualties were during October-April, with the highest peak (16%) in April, although the overall conflict was higher in winter.

Siddiqui and Choudhury (1987) found that most of the victims were nipa-leaf (*Nypa fruticans*) collectors (31.2%) and honey gatherers (30.0%), but there were also firewood collectors, fishermen and collectors of *Ceriops decandra* and the leaves of *Phoenix paludosa*. Reza *et al.* (2002b) mentioned that among eight occupational groups, fishermen (44%), woodcutters (36%) and honey gatherers (18%) comprised the bulk of tiger victims. In the Indian part of the Sundarbans, Chaudhuri and Chakrabarti (1972), reported that among the four major groups of forest workers, honey gatherers (58.3%) are the most vulnerable group to tiger attacks, but others mentioned that, although fishermen constitute 70% of human entry, 82.2% of the total casualties are fishermen (Sanyal 1987, Chowdhury and Sanyal 1985a). According to my findings the percentages of tiger attacks in different professional classes are: 45% fishermen, 37% 'Bawalis', 14% honey gatherers, and 4% 'others', which are more or less similar to some of the above mentioned findings (Chowdhury and Sanyal 1985a, Sanyal 1987, Reza *et al.* 2002b). However, when my findings were compared with availability, the attacks on honey gatherers were relatively high.

According to Ahmed (2002a) most of the human victims were in 26-35 (37%) and 36-45 (29%) age classes in the Bangladesh Sundarbans, and Reza *et al.* (2002b) mentioned that among seven age classes, the 26-35 age class (38%) and 36-45 age class (30%) were the most vulnerable to tiger attacks. In the Indian part of the Sundarbans, Chaudhuri and Chakrabarti (1972), and Chakrabarti (1984), reported that among four age classes, the maximum fatalities (about 80%) occurred among the 36-45 age class, which suggests that the healthy, middle-aged people represent the most threatened group. According to Nyhus and Tilson (2004), the 'typical' tiger victim in Sumatra was a middle-aged male working during the daytime in his field near the forest edge. The age of the victims ranged between 6-70, with a mean age of 37. Regarding the percentages of human casualties in different age classes, my findings are similar to the above-mentioned findings. When I compared the results with the availability, casualty rate is relatively high in people of the 30-50 age class, that most of the victims were middle-aged with a mean age of 38.7, which is very similar to Nyhus and Tilson's (2004) findings.

According to Ahmed (2002a, 2002b), most tiger attacks on local people were at the time when the victim was going to the working site, i.e. during 0600-1000 h (36%), and at the time when the victim was returning to the camp in the afternoon, i.e. 1400-1700 h (31%). Referring to interviews, he also mentioned that man-eating tigers sometimes attack people sleeping on boats in the river or creek, but this type of attack takes place at midnight. In the Indian part of the Sundarbans, Chaudhuri and Chakrabarti (1972) mentioned that the commonest times for labourers to be attacked by tigers was between 0700-0900 and 1430-1630 h, with a few attacks taking place at night, around 2300 h. Nyhus and Tilson (2004) mentioned that four times as many tiger attacks reportedly occurred during daylight than at night in Sumatra. In my study most people (95%) were attacked during daytime when working in the forest or in a narrow creek.

Among four forest ranges in the Bangladesh Sundarbans, Ahmed (2002b) and JJS (2002) mentioned that human casualties are highest in Satkhira range, but according to Reza *et al.* (2002b), most people were killed in Satkhira (45%) and Sarankhola (24%) ranges. My result is similar to theirs, i.e. human casualties are highest (40%) in Satkhira range.

In the Indian part of the Sundarbans, Sanyal (1987) worked on tiger-human interactions. He mentioned fatal attacks by tigers in all cases is on the right nape of humans. My results partially agree with this, because I found that the fatal attack is mainly on the neck-head region (92% of the killed humans had neck-head bites).

According to Hendrichs (1975), only about 3% of the Sundarbans tigers were man-eaters. In the Indian part of the Sundarbans, Chaudhuri and Chakrabarti (1972) thought that 25% of the tigers might be incipient or actual man-eaters, whereas Sanyal (1987) reported that only 5% of tigers were man-eaters. Based on the rate and locations of human casualties, and the inferred total population of the tiger, I assume that about 5% of the tigers might be man-eaters in the Bangladesh Sundarbans.

Different authors put forward different theories about tigers turning into man-eaters. Some experts (Chaudhuri and Chakrabarti 1972, Hendrichs 1975, Sanyal 1987, Siddiqui and Choudhury 1987) suggested that water salinity might be the cause of tigers becoming man-eaters in the Sundarbans. According to them, greater salinity causes more incidences of man-eating by tigers. Siddiqi and Choudhury (1987) showed a correlation ($r = 0.61$) between seasonal salinity variations and human casualties, but the work conducted by Chowdhury and Sanyal (1985a) does not support this theory.

Analysis of their data showed that soil and water salinity increases in a southward direction. The locations of human fatalities from tiger attacks do not follow a similar pattern. Salter (1984) suggested a direct correlation between the man-eating habit of tigers with the availability of easy prey, i.e. the human, but others (Chowdhury and Sanyal 1985a, Sanyal 1987) concluded that man-eating frequency is not correlated with the human availability. Nowell and Jackson (1996) believe that a man-eating tigress may introduce her cubs to human prey, but deaths and injuries caused by surprised tigers, or a tigress defending her cubs from intrusion, do not usually lead to man-eating. Chowdhury and Sanyal (1985a) firmly believe that the assumption that tigers of the Sundarbans are hereditary man-eaters is groundless. According to them, if this hypothesis is correct, there would have been a large number of human deaths a year. Sankhala (1978a) believes that human casualties by tigers in the Sundarbans are primarily the effect of disturbance to tiger territory and carelessness, especially by the honey gatherers. Matthiessen (2000) mentioned that John Seidensticker thinks it much more likely that the Sundarbans tigers are not accustomed to human company and that their hunting instinct may be triggered by the solitary gatherers, who are frequently bent over in rough semblance of four-legged prey. I do not agree with this, because if this was the case then there would be a positive correlation between the rate of human casualty and human availability in different parts of the Sundarbans.

Since none of the above-mentioned hypotheses has any concrete evidence, I think the man-eating habit of Sundarbans tigers is simply a behavioural character, but it is exacerbated by more humans and scarcity of natural prey. I am not sure how the man-eating became a behavioural character in some tigers, but I assume that, in the remote past, tigers of the western Sundarbans encountered a large number of human carcasses (probably as a result of a catastrophic cyclone or epidemic disease). When they tasted it they realised that humans were ‘edible’. The trend then transferred and spread from generation to generation. Corbett (1944) mentioned the possibility of big cats turning into man-eaters from the availability of human carcass during the spread of epidemic diseases. It is very likely that, if the mother is a man-eater, the cubs will learn to consider humans as part of their normal menu. The records of four incidences in Sumatra support this, when a tigress accompanied by cubs attacked people (Nyhus and Tilson 2004).

In the Sundarbans, the deaths of many people every year due to tiger attack raise the question: why people so courageous as to work there? The courage actually comes from different types of spiritual beliefs. The local people surrender to the forest Goddess who, they think, is their sole protector (Chaudhuri and Chakrabarti 1972). Moreover, many forest communities have accepted the loss caused by the tiger. As Thapar (1996) noted: 'The tiger was the protector, the guardian, the intermediary between heaven and earth. It was the symbol of fertility and regeneration. What is remarkable is that this belief prevailed, despite the fact that tigers sometimes killed people'.

Tigers, which are not man-eaters, are generally good tempered. Schaller (1967) agrees with the view of Corbett (1957): 'Tigers, except when wounded or man-eaters, are on the whole very good tempered. If warnings (growls, rushes, and roars) are disregarded, the blame for any injury inflicted rests entirely with the intruder'.

7.4.3 Public Knowledge and Belief

My interviewing reveals that only 5% of the interviewed local people knew properly about Bangladesh Wildlife Act 1974, which emphasises that public awareness must be raised. Reza (2000) found that 10% of interviewed local people knew properly about Bangladesh Wildlife Act 1974, which is slightly different from my result. Driven by hunger, most of the local people have no choice but to depend on the natural resources of the Sundarbans. If people have very little or no idea about the Act, it is very likely that they will break the rules. The scenario is very similar in many human communities living with big cats in different parts of the world. Oli (1991) worked in Annapurna Conservation Area of Nepal and found that only about 1% of local people were aware of the legally-protected status of the snow leopard (*Uncia uncia*). The local people find it difficult to understand why they should not kill snow leopards that damage their property. In Cambodia, however, Hean (2000) found that 76% of the hunters understand conservation policy and regulation, but, because of their economic dependence, they cannot stop hunting tigers.

I found that a high percentage (42%) of the interviewed local people believed on the medicinal use of tiger parts, which is an indication of a significant demand for tiger parts in the locality. If there is a significant demand, then some people will certainly be lured to poach the tiger. Reza *et al.* (2002b) also reported a similar percentage (55%) of interviewees believed that tiger body parts might have some medicinal use.

Although tigers kill some people every year, my study as well as Reza *et al.*'s (2002b) study reveals that people are not very hostile towards the tiger (75% interviewees wanted the tiger to remain in the Sundarbans). Globally, the local people are generally hostile towards their big cat neighbours. The main reason for this is that the big cats often turn into cattle-predators, and sometimes even attack people. The study conducted by Ahearn *et al.* (2001) shows that tiger populations are sustainable at a low density of domestic prey, but not sustainable if domestic prey density increases to three or more/km^2. When levels of domestic prey were greater than or equal to 3/km^2, poisoning of kills by people increased to levels where tiger populations were no longer sustainable. This phenomenon held even when wild prey populations were increased well above normally sustainable levels (e.g. 3-6 wild prey/km^2). The change in behaviour and attitudes of villagers towards tigers, such as increased guarding of livestock and higher tolerance of domestic prey kills, will significantly reduce tiger mortality caused by poisoning. Oli (1991) and Oli *et al.* (1994) reported that in Annapurna, Nepal, the predation losses by snow leopards were high and their impact on the local subsistence economy is substantial. As a result, the local people (95% of the interviewees) had a negative attitude towards snow leopards. In the Gir forest, India, Saberwal *et al.* (1994) worked on the lion-human conflict. A majority of villagers (61%) interviewed expressed hostile attitudes toward lions owing to the threat of personal injury and economic hardship (mainly livestock damage) posed by lions.

7.4.4 Consumption of Tiger Prey by Local People

The monthly consumption of fish, which is the main source of animal protein to the local people, varied in quantity because the fish are mainly caught from the open water (rivers, estuaries and sea) and, hence, the consumption depended mainly on the fish catch. Although there are some prawn and fish farms in the region, the prawns are mainly exported to the towns and abroad.

In all seasons, deer meat is much more expensive than any other protein types. Since deer meat is considered a delicacy and is not always available in the market, when it is available, everybody wants to buy it.

The percentage of protein (both non-prey and prey protein) consumed by different professional or income families were not very different. This was probably because of the wide availability and relatively cheap price of non-prey protein food items, especially fish.

According to JJS (2002), the different buyers of deer meat are local households (41%), local markets (30%), outsiders and others (24%), and officials (5%). Based on interviews with the local poachers, JJS found that most (roughly 90%) of the poachers could not supply deer meat to meet the demand. For the sake of secrecy, the poached deer meat is mainly consumed in the poacher's own village. Only a small proportion of deer meat goes elsewhere, either in the form of gift or to meet an order from a reliable buyer. The total number of wildlife hunters in the local villages was estimated at 131, of whom 79 were professional and 52 semi-professional. The amateur hunters were mainly from places far from the nearby villages. The percentages of deer killing by professional, semi-professional and amateur hunters were 77, 52 and 31%, respectively. The yearly average numbers of killed spotted deer, wild boar, rhesus macaque and red junglefowl were 15,880, 40, 40 and 103, respectively. My findings confirm that the local people mainly consume the poached meat and there is not enough meat to satisfy the demand. According to my result, 50 local families together consumed the deer meat that is equivalent to eight spotted deer in 18 months. Based on this the estimate of total annual consumption of 15,880 deer (JJS 2002) by the local people appears to be an over-estimate.

Poaching of tiger prey not only takes place in the Sundarbans, but in other tiger ranges as well. According to Linkie *et al.* (2003), in Kerinci Seblat, Indonesia, the staff of two Tiger Protection and Conservation Units found and disabled 172 snare traps, during 184 patrol days, in and around the National Park. The poaching pressure was greatest for barking deer (*Muntiacus muntjak*) and lowest for serow (*Naemorhedus sumatrensis*) and mouse deer (*Tragulus napu* and *T. javanicus*). In an area of forest of only 1 km^2, they once dismantled a total of 51 snare traps, mainly set for the barking deer. Since the people living around the National Park are predominantly Muslims, the wild boar is not hunted for meat (Blouch 1984), but hunted for sport and trapped by farmers trying to protect their crops. Any concentration of prey species, such as at the farmland-forest edge, attracts tigers, which are also vulnerable to the traps set for the crop pests. Four tigers were reported to have died as a result of being accidentally snared in wild boar and sambar (*Cervus unicolor*) traps (Hartana and Martyr 2001), but more serious threat comes from direct poaching of tigers, the incentive for which is great. The current price paid for a tiger skin in villages around the National Park is US $ 400-500, and US $ 600-700 in provincial capitals, which are similar to the price in Bangladesh. A monitoring programme operated by a local NGO with Fauna and Flora International and WWF indicates that at least 14 tigers were poached from the National Park during 1998-1999.

In the Neotropical forests, the competition of jaguar (*Panthera onca*) and puma (*Puma concolor*) with subsistence hunter people has been reported by Jorgenson and Redford (1993). According to them, pumas, jaguars and humans took prey from at least three taxonomic classes of animals (i.e. mammals, birds and reptiles/'other'). Mammals were the most frequently-taken items, comprising 95.0% of puma, 81.9% of jaguar and 52.4% of human diets by item. Birds comprised 38.5% of human, 3.7% of jaguar and 0.8% of puma diets. Reptiles/'other' comprised 14.4% of jaguar, 9.0% of human and 4.2% of puma diets. Humans took about four times as many mammalian prey taxa as pumas and about twice as many as jaguars. Puma and jaguar food habits overlap almost entirely with those of human hunting for subsistence. Consequently, if humans are allowed to hunt in these multiple-use areas, the local populations of big cats may decline. Since there is no subsistence hunter in the Sundarbans region (poachers poach animals on an *ad hoc* basis), the competition between tigers and people for mammalian prey is less intense than in Neotropical forests.

7.5 SUMMARY

- The study was conducted to produce a clear picture of tiger-human interactions and their intensity, together with the rate of consumption of tiger prey by local people, in and around the Bangladesh Sundarbans.

- A total of 123 local people were interviewed, and relevant newspaper reports and Forest Department records were collected in order to obtain the raw data.

- During 18 months of fieldwork (September 2001-February 2003) humans killed a total of seven tigers and tigers killed 41 humans, but officially these two figures are only four and five, respectively.

- Most of the killed tigers were middle-aged (68%) males (73%). The main reasons for tiger-killing by people were attacks on human beings and cattle (76%), but poaching was also a significant reason (19%). Tiger-killing by people was much higher in winter (November-February: 77%) than in summer.

- The middle-aged people (age 30-50) were most commonly attacked (73%), but these people were most available (45%). Among four professional classes, most of the attacks were on the fishermen (45%) and 'Bawalis' (woodcutters, leaf collectors, etc.) (37%), but the pattern mainly follows the availability. Tiger attacks on humans in different months were significantly different, and more attacks occurred towards winter (October-April: 80%). Most of the killed humans (92%) had neck-head bites and most of the injured (67%) did not have neck-head bites.

- The majority of the local people interviewed (53%) relied only on the spiritual measures to protect themselves from the tiger. Among the interviewees who have ever seen live tiger(s), 47% saw them in the wilderness of the Sundarbans. Among the wild tigers seen by interviewees, 23% sightings were killed tigers. Only 5% of the interviewees properly knew (i.e. knew the basic features) about the existence of Bangladesh Wildlife Act 1974. Forty-two percent of the interviewees believed that there are medicinal uses for tiger parts. Interestingly, despite all of the fatal encounters, 75% of interviewees wanted the tiger to remain in the Sundarbans, so that the area is protected from illegal loggers and poachers.

- The data on 18 months animal protein intake by 50 local families reveals that the percentage of non-prey (fish, poultry, cattle, etc.) and prey (spotted deer, wild boar and red junglefowl) proteins were 97.2% and 2.8%, respectively. The prey protein was more expensive (mean = US S 1.95/kg) than the non-prey protein (mean = US $ 0.97/kg).

CHAPTER 8 CONCLUDING DISCUSSION

8.1 INTRODUCTION

The overall goal in this research project was to provide baseline information on tiger ecology and other aspects relevant to tiger conservation in the Sundarbans mangrove forest of Bangladesh. The specific objectives were to determine the prey population structure and density, prey selection by tigers, relative habitat use by tigers, breeding and litter size of tigers, and tiger-human interactions.

The field data collected for 18 months (September 2001-February 2003), and their analysis and comparison with other relevant studies, provided baseline information on the tiger and its prey. The specific objectives were achieved. My findings will add significantly to good knowledge of the tiger and its prey in the Sundarbans and this will be useful in strengthening the management and conservation of the tiger and its prey there. However, I must stress that some results were based on assumptions or on interviewing, hence the relevant findings should not be treated as perfect. Such limitations may lead to biases and the conclusions are only really relevant to the areas surveyed.

8.2 CONCLUSIONS

8.2.1 Prey Population Structure and Density

In the Sundarbans East Wildlife Sanctuary (WS) spotted deer (*Cervus axis*) and rhesus macaque (*Macaca mulatta*) are more social (i.e. group living) prey species than wild boar (*Sus scrofa*), lesser adjutant (*Leptoptilos javanicus*), red junglefowl (*Gallus gallus*) and ring lizard (*Varanus salvator*). The percentage of pre-reproductive age classes (juveniles and young) is relatively low in all the potential prey species, which may indicate a lower optimum density for these habitats. There are more females than males in spotted deer, wild boar and rhesus macaque, but less females than males in red junglefowl. Deer fawns are most commonly sighted during January-July, i.e. late winter and early summer, which agrees with Schaller's (1967) findings. Compared to other studies elsewhere (Eisenberg and Lockhart 1972, Karanth and Sunquist 1992), all the three sizable prey species (spotted deer, wild boar and rhesus macaque) tend to live in relatively smaller groups in the Sundarbans (Table 8.1). This is probably an adaptation of these species to adjust to the mangrove habitat, which is very different from other habitat types. The spotted deer is the dominant prey species both in terms of individual density and biomass density. One reason for this dominance is that there is no major competitor of the spotted deer in the Sundarbans. The wild boar density is relatively low. The total ungulate density in the Sundarbans (Table 8.1) is lower than in most of the tiger ranges in the Indian sub-continent.

Table 8.1 Prey group size, individual density and biomass density in the Sundarbans East Wildlife Sanctuary

Prey species	Group size	Individual density (no. individuals/km^2)	Biomass density (kg/km^2)
Spotted deer	5.7	20.9	983
Wild boar	1.4	0.5	15
Rhesus macaque	4.1	6.5	26
Lesser adjutant	1.2	0.6	2
Red junglefowl	1.2	7.0	4
Ring lizard	1.0	7.9	8

Using the prey density estimate, the tiger density in the Sundarbans East WS has been inferred at 4.3 tigers/100 km^2 (excluding cubs), which indicates that there might be around 200 tigers in the Bangladesh Sundarbans. This rough estimate of the tiger population is much lower than most of the previous estimates (Hendrichs 1975; Bangladesh Forest Department and Department of Zoology, University of Dhaka, 1982; Bangladesh Forest Department 1992, 2004; Tamang 1993, Reza 2000). Compared with most tiger ranges in the Indian sub-continent, the tiger biomass in the Sundarbans is higher compared to the ratio of tiger to large herbivore prey biomass. This is probably because there is no other large carnivore in the Sundarbans to share large prey animals.

8.2.2 Prey Selection

In the Sundarbans East WS the spotted deer is the main prey of the tiger, represented in 78% scats and kills, and 29.9% individual prey animals killed by tigers. Since the spotted deer is the largest prey in the Sundarbans, it supports the theory that tigers prefer to hunt large prey species (Schaller 1972, Karanth and Sunquist 1995). The spotted deer alone forms 80.1% of the consumed prey biomass, which means that the existence of the tiger in the Sundarbans is almost entirely dependent on the spotted deer. Although tigers eat wild boar, rhesus macaque, lesser adjutant and some other smaller prey animals, their biomass contributions to tiger diet are very low. Tigers also ingest some soil and sungrass blades, probably to meet nutrient requirements, scour the digestive system for internal parasites and/or for better digestion. In general the trend of prey selection depends on prey size and abundance, but based on numbers, wild boar and lesser adjutant are the two high-ranking prey species, because their selection were higher in comparison to their abundance. This is probably because these two species are easy to hunt and tigers might want a change of taste from their common foods. Most of the tiger kills are adult animals in good condition. This makes sense, because tigers get more meat from such an animal, but in some studies on carnivores (Hornocker 1970, Mech 1970, Schaller 1972, Curio 1976, Vitale 1989) sub-standard prey animals were more frequently taken, because they are less adapted to escape. Tigers play the key role in shaping the deer population in the Sundarbans.

8.2.3 Relative Habitat Use

The mean density of tiger signs (total of all types of signs) were not significantly different across four different habitat types (mangrove woodlands, grasslands, sea beaches and transitional zones), but the mean densities of feeding, resting, defaecation and interaction signs were significantly different across four different habitat types, whereas the mean densities of movement, scratch-scent-urinal and ‘others’ (hunting, drinking, etc.) signs were not. It indicates that tigers probably have habitat preference for some activities, e.g. they prefer to defaecate in dry sand mounds and besides footpaths.

Similar patterns of the densities of movement and feeding, as well as resting and defaecation signs, in different habitats indicate that tigers probably prefer similar habitat types (habitats with good cover) for movement and feeding, and prefer to defaecate where they rest (at the end of the rest).

Tigers prefer soft-barked trees for scratches, more specifically *Syzygium* sp. and *Lannea coromandelica*. The heights of scratches normally vary between 0.3-1.5 m from the ground.

8.2.4 Breeding and Litter Size

In the Sundarbans tigers probably breed all through the year, but the breeding peak is in the winter (October-March), since both male-female and mother-cub(s) interaction signs were higher in winter. This is probably because the winter is relatively less wet and stormy, hence cub mortality is probably low. Calls are normally heard in the probable mating season (August-October). Only one cub is commonly seen with the mother (60.7% observations), but two or three cubs are also seen. The mean litter size is 1.4 in the Sundarbans, which is lower than the litter sizes reported in other ranges (Sankhala 1978a, Smith and McDougal 1991, Tamang 1993). This might either be because cub mortality in early life is much higher in the Sundarbans or the tough habitat and limited prey forced the tiger population to produce smaller litter sizes. Notably, my estimate of litter size was based on observations of the number of small cubs accompanied by mother, so this does not represent the actual litter size at the time of birth. The birth seasons of spotted deer fawns and tiger cubs have no significant correlation, but the latter probably follows the former about six months later.

8.2.5 Tiger-human Interactions

The rate of tiger casualty by humans and human casualty by tigers is very high in the Sundarbans. A total of 7 tigers and 41 humans were killed in only 18 months (September 2001-February 2003) in the Bangladesh Sundarbans. Tiger-human conflict is much higher in winter in comparison to summer, probably because the breeding peak of tigers is in winter when some tigers are pushed out of the forest due to increased intra-specific competition. Most of the killed tigers are middle-aged (68%) males

(73%), and most of the killed humans are middle-aged (73%). The main reason for tiger-killing by people are attacks on humans and cattle (76%), but poaching is also a significant reason (19%). Tigers straying into villages around the Sundarbans are more vulnerable. Since most of the tigers were killed as a result of attacking people, and most of the killed tigers were middle-aged and healthy, man-eating has probably become a normal feeding behaviour of some tigers in the Sundarbans. This is different from most other findings elsewhere (Seidensticker *et al.* 1976, McDougal 1987, Sunquist and Sunquist 1988, Nyhus and Tilson 2004). The pattern of tiger attack on different age or professional classes of humans generally follows availability, but attacks are relatively high on middle-aged people. This is probably because middle-aged people are more available, and larger, and hence more rewarding in terms of energy gain. Tigers kill people mainly by a lethal bite on the neck-head region of the victim (92%).

The majority of the local people rely only on spiritual protection from the tiger (53%). Those who have ever seen live tiger(s), 47% saw them in the wilderness of the Sundarbans. Of wild tiger sightings by local people, 23% are of killed tigers. This indicates a high rate of tiger-killing in the locality. Only 5% of the local people properly know about the existence of Bangladesh Wildlife Act 1974. Many local people believe in the medicinal use of tiger parts (42%). This is an indication that there is a significant demand of tiger parts in the local villages. Interestingly, despite all the fatal encounters, 75% of the local people want the tiger to remain in the Sundarbans, so that the forest and wildlife could be protected from poachers.

A total of 2.8% of the animal protein consumed by local people surveyed comes from tiger prey (spotted deer, wild boar and red junglefowl). Although this proportion is insignificant, if this is extrapolated against thousands of people living around the Sundarbans, it will be evident that hundreds of prey animals are killed every year. Prey protein is more expensive (mean = US $ 1.95/kg) than non-prey protein (mean = US $ 0.97/kg). Prey protein, particularly deer meat, is a delicacy and not always available in the market. When it comes to the market everybody wants to buy it.

8.2.6 Comparative Issues

Although the spotted deer population is quite healthy in the Sundarbans (see Chapter 3), poaching and consumption by local people seems to be high (see Chapter 7). Since the tiger population mainly depends on spotted deer (see Chapter 4), over time deer poaching may have detrimental effects on the persistence of tigers. Spotted deer is probably the limiting factor for the tiger population in the present context. Although still minor, direct poaching of tigers is also a threat. If 500 deer are required to sustain one tiger in the wild (Karanth 2001), then the poaching of one tiger is equivalent to the poaching of 500 deer.

Other than the prey size and availability, prey selection by tigers (see Chapter 4) might also be influenced by the season, since tigresses normally have their cubs in winter (see Chapter 6) and at that time they need to hunt more frequently (Karanth 2001).

Relative habitat use by tigers (see Chapter 5) might depend not only on the availability of different habitat types and tiger behaviour, but also on the prey species density and distribution pattern in different habitat types (see Chapter 3), and breeding season (see Chapter 6) of tigers.

The climate (see Chapter 2) probably has a significant effect on the breeding season of tigers (see Chapter 6), but it might be harmonised with the pattern of prey availability and prey breeding season (see Chapters 3 and 6).

The interactions between tigers and humans (see Chapter 7) might not only depend on the man-eating behaviour of the tiger or anthropogenic factors, but also on lower availability of normal prey in some areas of the Sundarbans (see Chapter 3) and the breeding season of tigers (see Chapter 6).

8.3 CONSERVATION IMPLICATIONS

My findings will be useful in strengthening the conservation of the tiger and its prey in the Sundarbans in various ways. In comparison to the entire Sundarbans, the high density of spotted deer in the Sundarbans East WS (which has some grassland pockets) indicates that the existence of some grassland pockets is good for the spotted deer.

Knowledge of prey population structure and density will be useful in temporal monitoring of the status of prey population in the Sundarbans East WS.

Since the bulk of the tiger diet is the spotted deer, the existence of the tiger is almost entirely dependent on the existence of the spotted deer. More emphasis should be given to the management of spotted deer to maintain the tiger population. Scientific study of the wild boar population is required to know the reason for its relatively low density, although suitable habitats remain available. Then, initiatives should be taken to increase the wild boar population so that it forms an alternative food source for tigers. Re-introduction of the wild buffalo (*Bubalus bubalis*; became extinct in the Sundarbans by 1925-1930) could also be considered to form an alternative prey population, but this would be very expensive and if the causes of extinction are not resolved, the re-introduction will not be successful. Introduction of domestic buffalo, which freely graze in the north-eastern Sundarbans (e.g. in Ar-rubaier) for about six months and are probably already familiar to the tiger (since tigers sometimes prey on them) would be relatively cheap and easy. This can make a feral buffalo population.

Habitat diversity in the Sundarbans should be maintained since it is crucial for the maintenance of some activities of the tiger. Sungrass cutting should be allowed, because otherwise the sungrass will die and the areas will be gradually encroached by woodlands and bushes. While mangrove woodlands are popular for tigers, so are grasslands. Instead of six months (currently allowed by the Forest Department), however, the sungrass cutters should be allowed to stay and work in the Sundarbans for only two to three months. This is because a large number of sungrass cutters disturbs wildlife. Initiatives should be taken to increase the habitat diversity wherever possible.

Since the breeding peak of tigers is probably in winter, this season should remain undisturbed. Unfortunately, winter is also the main tourist season, i.e. the main disturbance season. To compromise, some tourist zones should be demarcated (which will exclude the important areas for tigers) and tourists should be allowed only in these areas. Presently tourists can go anywhere in the Sundarbans after taking an ordinary entry permit and paying revenue. Controlled ecotourism should be developed so that both the Government and the local people benefit financially. Although seldom seen by visitors, the presence of large carnivores contributes to the richness of visitors' experience (Leslie 2001).

In order to reduce the conflict between tigers and humans, local people should be motivated not to kill wild animals or use any wildlife products; alternative livelihoods should be made available (e.g. local ecotourism organisations, cottage industries, etc.) and existing anti-poaching regulations should be implemented properly. Education campaigns might help reduce the risks of human casualties by tigers (Sanyal 1987, Beier 1991, Rajpurohit and Krausman 2000). Support for endangered species conservation will emerge when people believe this effort enhances the prospects of a materially, emotionally, and spiritually worthwhile life for themselves, their families, and their communities (Dinerstein 1998). Development of management solutions for situations where tigers live alongside people is a high priority for conservationists (Nowell and Jackson 1996). Fencing along the forest boundaries in high-conflict areas might reduce the tiger straying into the villages.

In the Sundarbans, local people should always work in groups, each individual should carry a big stick (mainly to show the tiger a ‘weapon’) and each group should keep a dog on chain (so that it barks out while the tiger is around and people get some time to climb up a tree or get together); I believe these will help to reduce human casualties. Although face-masks (used at the back of the head so that the tiger thinks that he is being watched) and electrified dummy humans are used in the Indian Sundarbans (Chowdhury and Sanyal 1985b), I do not think these would fool a man-eating tiger, because they are extremely clever. Even if these work, the man-eating tiger might soon realise the deception and become more efficient at human killing. Like other cats, tigers are quick learners (Karanth 2001). Since winter is the main conflict season, work permits should be reduced in winter as much as possible; especially work permits for honey gathering should be reduced.

In order to strengthen the local support for conservation, at least a token compensation should be given to the victim families for the loss of their relatives, serious injuries and the loss of cattle to tigers (Karanth and Madhusudan 2002, Nyhus *et al.* 2003). The compensation should be strictly controlled, so that there is no fraud. More local people should be employed in the Forest Department and in the tourism industry, so that the local community realise the benefit of conservation. Some community services like hospitals and schools should be provided by the Forest Department in order to reduce the stress between the Forest Department and the local people. The Forest Department should develop local intelligence networks to collect information to aid detection and prevention of poaching.

8.4 FUTURE RESEARCH

Based on my PhD project experience, I have identified that tiger density (absolute and relative) and tiger-human conflict (addressing the possible solutions of conflict, route of black marketing of poached tiger and its prey, effect of tourism, etc.) are the two highest priorities for further research, if we are to conserve tigers in this area. My PhD project was just a beginning and further research is urgently needed to ensure better management of the tiger and its prey as well as to find ways to reduce tiger-human conflict. My new post-doctoral research project would be a continuation of my previous work. As a direct conservation initiative, a medium-scale motivation and awareness campaign will be conducted under the proposed project, so that the local people can become more aware of the role of the tiger in ecosystem functioning and how it is linked with their own livelihood. At least two wildlife research students from the local Universities, and six local people, will be employed and trained in order to be directly involved with this project as a scheme to develop human resources and capacity building.

In general, the objective of the proposed new project is to *know the absolute and relative densities of tigers and gather relevant information on tiger-human conflict that can be used to reduce the conflict in the Sundarbans mangrove forest of Bangladesh*. The specific objectives are as follows –

1. **Absolute density of tigers –** To date there is no accurate estimate of tiger density in the Bangladesh Sundarbans based on modern research techniques, i.e. camera-trapping, telemetry or DNA fingerprinting. The capture-recapture model data, derived from camera-traps, will be used to estimate tiger density of a sample area in the Sundarbans East WS.

2. **Relative density of tigers –** Based on fresh tracks of tigers on the riverbanks, the relative density of tigers in different blocks (three blocks in three sanctuaries and three blocks outside the sanctuaries) of the Bangladesh Sundarbans will be identified. This will allow temporal monitoring of the tiger population trend. Moreover, based on this and the absolute density of tigers in the sample area, the total tiger population in the Bangladesh Sundarbans will be estimated.

3. **Tiger-human conflict –** Some possible techniques (e.g. keeping big sticks with each individual and one pet dog with each group) will be introduced in some experimental groups of workers to test the effectiveness of saving human lives from man-eating tigers. The way people work in the Sundarbans, their precautions for tiger attacks and other relevant information will be recorded by accompanying them in the field. The disturbance caused by the workers will be recorded at the same time. Emphasis will also be on learning the route of black marketing of poached tiger and prey, so that poaching can be reduced.

4. **Impact of tourism –** The impact of tourism on tigers and their prey, as well as on the Sundarbans in general, will be monitored mainly to identify the level of disturbance, threats and pollutions as well as the economic gain to the Government (in terms of revenue earning) and the local community.

5. **Motivation and awareness –** A medium-scale motivation and awareness campaign will be conducted in the schools, colleges, and other public gathering places (e.g. mosques) in adjacent villages in order to inform people about the importance of tiger conservation in the maintenance of ecosystem functioning and better livelihood for the local people. Public knowledge on how to avoid man-eating tigers will be enriched. Moreover, seminars will be organised and newspaper articles will be produced in order to inform and encourage the policymakers, intellectuals and other educated bodies of Bangladesh.

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APPENDICES

Appendix I Status and distribution of wild cats and primates in Bangladesh (N.B. This paper was prepared during the PhD course and it is now in press on *Bangladesh Journal of Life Sciences*)

STATUS AND DISTRIBUTION OF WILD CATS AND PRIMATES IN BANGLADESH

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Key words: Cats, primates, status, distribution, Bangladesh

Abstract

The status and distribution of wild cats and primates in Bangladesh have been described in this paper. Major habitats were visited between 2000 and 2002 in order to observe animals, their signs, and interview local people. Four out of eight species of cats and seven out of ten species of primates have been identified as Rare in Bangladesh. The present distribution of every species of cats and primates has been chalked out. New distributional ranges of the Asiatic golden cat in Bagerhat district, hanuman langur in Satkhira district and hoolock gibbon in Kaptai National Park are unique records.

INTRODUCTION

The status and distribution of wild cats (Family: Felidae) and primates (Family: Hylobatidae, Colobidae, Cercopithecidae and Loridae) of Bangladesh have been reported by Khan (1979, 1981, 1982, 1985, 1986), Green (1978), Gittins (1980), Khan and Ahsan (1981), Gittins and Akonda (1982), Ahsan (1984), Sarker and Sarker (1988) and Feeroz *et al.* (1995). It is evident that most of the above-mentioned surveys were conducted 15-25 years ago. This survey was an attempt to visit different types of wildlife habitats in Bangladesh and report the present status and distribution of wild cats and primates.

There are 36 species of wild cats in the world of which 11 are found in tropical Asia (Nowell and Jackson 1996) and 8 in Bangladesh (Khan 1982, 1985, 1986). Of the 200-230 species of non-human primates in the world (Cowlishaw and Dunbar 2000), 25 are found in South Asia (Roonwal and Mohnot 1977) and Bangladesh has 10 of them in its territory (Khan 1982, 1985; Ahsan 1984). Out of eight species of wild cats in Bangladesh, five are globally threatened (tiger, clouded leopard, fishing cat, golden cat and marbled cat) (IUCN 2003) and six are nationally threatened (tiger, leopard, clouded leopard, fishing cat, golden cat and jungle cat) (IUCN Bangladesh 2000). In case of ten species of non-human primates in Bangladesh, five are globally threatened (hoolock gibbon, capped langur, pig-tailed macaque, Assamese macaque and stump-tailed macaque) (IUCN 2003) and eight are nationally threatened (hoolock gibbon, pig-tailed macaque, rhesus macaque, crab-eating macaque, capped langur, Phayre's langur, hanuman langur and slow loris) (IUCN Bangladesh 2000).

Study Area

Bangladesh is a small sub-tropical country located between the Himalayas and the Bay of Bengal, geographically between 20°34′-26°38′ N latitudes and 88°01′-92°41′ E longitudes. Except some hilly areas in the southeast (SE) (Greater Chittagong and Chittagong Hill Tracts) and northeast (NE) (Greater Sylhet), the country is largely composed of floodplains and deltas. The climate is tropical monsoon type. The average annual rainfall in the country is about 3,000 mm. The temperature normally varies between 10-35°C. There are three major forest types; i.e. mangrove forests (mainly the Sundarbans in the southwest), mixed-evergreen forests (in Greater Sylhet, and Greater Chittagong and Chittagong Hill Tracts in the NE and SE) and moist deciduous forests (in Madhupur Tract and northern Greater Mymensingh in the central region, and in Greater Rangpur in the northwest); totally covers about 5% of the country (Figure 1).

MATERIAL AND METHODS

The status and distribution of cats were recorded either by direct observations, footprints, specimens, parts of animals preserved to local hunters or through interviewing experienced local people, while primates were recorded either by direct observations, calls or interviewing local people. Pictures of animals (from Prater 1971) were also shown to local people while interviewing them. Local names of different species were collected while interviewing. Sightings of young animals and other important observations were also noted. Similar methods were also considered by other workers (e.g. Ahsan 1984, Khan 1986, Feeroz *et al.* 1995).

Each of the species was considered in one of the four categories of the status, i.e. 1) Very Common – a species recorded in 75-100% of the visits, 2) Common – recorded in 50-74% of the visits, 3) Uncommon – recorded in 25-49% of the visits, and 4) Rare – recorded in fewer than 25% of the of the visits. For each species, only the visits in its potential habitats were considered.

In total 150 days were spent in the field in different seasons during 2000-2002. All the protected areas of the country (five National Parks, eight Wildlife Sanctuaries and one Game Reserve) as well as some other important habitats were visited. The investigation was conducted on foot, through the forest and village paths, but a dinghy was used in the creeks of the Sundarbans. In most of the cases local guides were hired during investigation in the field. Field surveys were mainly conducted in the morning and afternoon, but no survey was conducted during heavy rainfall because of poor visibility and because both cats and primates are less active during the rain. The observations were mainly made by unaided eyes, but one pair of binoculars (Tesco 7-21 × 40) was used for a better observation of animals whenever necessary.

RESULTS AND DISCUSSION

This field survey has identified some shrinkage of the previous distributional range, as well as the presence of the species in new areas in some cases. The populations of most of wild cats and primates have been decreased. The present assessed status of cats and primates have been compared with earlier status reported by Khan (1982) about twenty years ago (Figures 2 and 3). The status of four of eight species of cats and three of ten species of primates have become more dire than 1982. However, for the rest of the species, the status remained unchanged not necessarily mean that the population remained unchanged, but the change is either not very dramatic or the previous status was probably an underestimation. Four species of cats and seven species of primates are now Rare, whereas two species of cats and five species of primates were Rare in 1982. There is no recent sighting of a few species (Asiatic golden cat, marbled cat, crab-eating macaque and stump-tailed macaque). Probably they are now at the brink of extinction in Bangladesh. It is remarkable that all the ranges of urban primates are mostly restricted to the areas of Hindu communities. Due to religious beliefs, the Hindus are more respectful and sympathetic to primates that allow them to survive in the urban areas. All the local names mentioned in this paper were found to use by local people in Bangladesh. In case of local names used only in a region, the name of that region has given in round brackets. The findings of this survey, together with relevant discussion, are given below –

Wild Cats

1. Tiger, *Panthera tigris* (Linnaeus, 1758)
   Local name: bagh, mama, gobagha (Madhupur Tract), goira goma (Madhupur Tract)
   Status: Uncommon

Once the tiger was found in all the forested areas of the country, now the only stable population is in the Sundarbans mangrove forest (Figure 4). It was found that the density of the tiger in the Sundarbans varies from north to south, following the density of its prey. Based on the relative abundance of pugmarks, the highest density of the tiger was recorded in the forest-grassland mosaic in the south. The grassland pockets are ideal habitats for the tiger prey, and thus provide higher carrying capacity for the tiger. Vagrant tigers from the forests of India and Myanmar visit the bordering mixed-evergreen forests of the SE, and rarely NE, of Bangladesh. There are reports of vagrant tigers in Kassalong Reserve Forest, Chittagong Hill Tracts. A tiger was seen in Laxmichhari Range, Kassalong Reserve Forest, in 1984. A vagrant tiger was shot dead in Patharia hill, Greater Sylhet, in 1985. The last resident tiger in the Greater Chittagong and Chittagong Hill Tracts (Mainimukh) was until 1979 (G.M.M.E. Karim pers. comm. 1998), in Greater Sylhet (Srimangal) until 1962, in the Madhupur Tract (Madhupur National Park) until 1963 and in Greater Rangpur (Tetulia) until 1962.

2. Leopard, *Panthera pardus* (Linnaeus, 1758)
Local name: chita bagh, fuleshwari bagh (Madhupur Tract), nageshwari bagh (Madhupur Tract, Greater Sylhet), tikkapora bagh (Greater Sylhet)
Status: Rare

The leopard was found in almost all over Bangladesh, except the Sundarbans (but might existed in the fringing areas), until 1940 (Khan 1986). Now there are only some small fragmented populations left in the country, only to some patches of the mixed-evergreen forests of the SE and NE, and there are some vagrant leopards occasionally visit the bordering forests. In the SE region, the recent records of this species were in: Khagrachari in 2002, Teknaf Game Reserve in April 2000 and Rangamati North Forest Division (Rangipara Forest Beat) in 1998. In the NE region, the presence of the leopard was recorded in: Adampur forest in 2002, Kanaighat (vagrant) in 2002, Barolekha (Sandergoal) in November 2000, Srimangal (Satgaon Tea Estate) in June 1999, Rema-Kalenga Wildlife Sanctuary in October 1998 (call heard by the author), Juri Range in 1992, Lawachara National Park in 1986 and Raghunandan Range in 1982. The leopard existed in the Madhupur Tract and in the forests of Greater Rangpur (Tetulia) until 1971. However, a vagrant leopard came to Dahuk, Tetulia, and was shot dead by the Bangladesh Rifles (BDR) people in June 2000. A vagrant leopard killed a cow in Lauchapra forest, Balijhuri Range, Mymensingh Forest Division, in August 2000. The only report of the sighting of a 'black panther' (a melanic form of the leopard) in Bangladesh was in Gobaichari, Pablakhali Wildlife Sanctuary, in 1956 (G.M.M.E. Karim pers. comm. 1998).

3. Clouded leopard, *Neofelis nebulosa* (Griffith, 1821)
Local name: gechho bagh, lamchita
Status: Rare

Local people in the mixed-evergreen forests of the NE and SE have seen the clouded leopard. The species is extremely shy and secretive and hence people could rarely see them. One was hunted from Nirala Tea Estate, Srimangal, Moulvibazar, in February 1984 (S.R. Dev pers. comm. 2002). Two cubs were caught in the forests of Chandanaish, Chittagong, in November 1999 and were handed over to Chittagong Zoo authority.

4. Fishing cat, *Prionailurus viverrinus* (Bennett, 1833)
Local name: mechho bagh, maichha bagh, baghailla (Greater Sylhet), daash bagh (Greater Barisal)
Status: Uncommon

The fishing cat was found widely distributed but relatively more common in Greater Sylhet region. This region has a combination of *haors* (large marshlands), forests and tea estates that made an ideal habitat for the species. It is commonly seen in the fringing areas of *haors.* Four kittens of which two were fully albino and two kittens with one fully albino were caught from Hail Haor area of Srimangal, Moulvibazar, in January 2000 and July 2000, respectively. Moreover, one fully albino adult was caught from the same area in August 2001 (specimens seen in Mr. Sitesh R. Dev's private zoo in Srimangal). It means that the gene responsible for albinoidism is well-represented in the gene pool of fishing cats in this area. The species is also common in the southwestern districts. It has also been recorded in the Sundarbans and in many other forests and villages of the country, but absent in the cities and towns.

5. Jungle cat, *Felis chaus* Guldenstaedt, 1776
Local name: bon biral, wap (Greater Mymensingh)
Status: Common

The jungle cat was found the commonest and most widely distributed species among the wild cats of Bangladesh, which was recorded in all the forests and villages surveyed during this study. However, they are absent in the cities and towns. A kitten was caught in Jahangirnagar University, Savar, Dhaka, in January 1995.

6. Leopard cat, *Prionailurus bengalensis* (Kerr, 1792)
Local name: chita biral (Greater Khulna)
Status: Uncommon

The leopard cat was found quite common in the Sundarbans, the mixed-evergreen forests of the NE and SE, as well as the villages and/or tea estates in the adjacent areas of these forests. Khan (1985) reported its absence in the Sundarbans, though later on he saw it in the northern Sundarbans (Khan 1986), but this survey identified the largest population of this species in the Sundarbans. The coat colour of the leopard cat in the Sundarbans and in the adjacent villages is slightly different from those found in the Greater Sylhet region.

7. Asiatic golden cat, *Catopuma temmincki* (Vigors and Horsfield, 1827)
Local name: sona bagh (Greater Khulna)
Status: Rare

Khan (1982, 1986) had collected one skin of a freshly killed Asiatic golden cat from the Chittagong Hill Tracts that confirmed the presence of this species in Bangladesh. During this survey, one sight record of the Asiatic golden cat was collected which was in Fakirhat, Bagerhat, in August 1967 (S. Khan pers. comm. 2002), from where the local name 'sona bagh' was recorded. No other report/sign of the Asiatic golden cat was found, but it might still occur in the mixed-evergreen forests and the adjacent areas of the SE and NE.

8. Marbled cat, *Pardofelis marmorata* (Martin, 1837)
Local name: not recorded
Status: Rare

There is no documented record of the presence of the marbled cat in Bangladesh, but Husain (1974) believes that the species was present in Bangladesh. No report/sign of this species was found during this survey, but the global distribution of the species (Prater 1971, Nowell and Jackson 1996, Sunquist and Sunquist 2002) does indicate that it might exist in the mixed-evergreen forests and adjacent areas in the SE and NE of Bangladesh.

Wild Primates

1. Hoolock gibbon, *Bunipithecus hoolock* (Harlan, 1834)
Local name: ulluk
Status: Rare

The original distribution of the hoolock gibbon was all over the mixed-evergreen forests of the NE and SE, and the deciduous forests in the north of Greater Mymensingh. During this survey, the species was seen in Lawachara National Park, Satchori Reserve Forest and Rema-Kalenga Wildlife Sanctuary in the NE of Bangladesh. Moreover, interviewing local people reveals its presence in Juri Range, Moulvibazar. In the SE of

Bangladesh, it was recorded in Chunati Wildlife Sanctuary and Kaptai National Park. The characteristic calls of at least two gibbons were heard at Sitapahar of Kaptai National Park during this survey (in April 2000). This is the first record of the hoolock gibbon in Kaptai National Park. Moreover, people reported the occurrence of this species in some other fragments of mixed-evergreen forests of the NE and SE. It was heard from the local people that they used to hear gibbon calls in Lauchapra forest, Balijhuri Range, Mymensingh Forest Division, until 1985. This area is very close to the Indian state of Meghalaya. There are previous reports of hearing calls by the local people in the same area (Khan 1982, 1985; Ahsan 1984, Sarker and Sarker 1988). By this time that population might have gone extinct, or went to the Indian forests. Young animals commonly seen with the mother during April-May.

2. Capped langur, *Trachypithecus pileatus* (Blyth, 1843)
Local name: mukhpora hanuman, lal hanuman (Greater Sylhet), hanuman
Status: Common

Even 35 years ago, the capped langur was distributed throughout vast area of deciduous forests of the Madhupur Tract and northern areas of Greater Mymensingh as well as in the mixed-evergreen forests of the NE and SE. The species still has wide distributional range, but the population has been greatly reduced and fragmented. It is still common in Madhupur forest, but not present in the central and southern parts of the Madhupur Tract. The total population in Madhupur forest has come down to about 1,000 individuals, whereas Gittins (1980), and Gittins and Akonda (1982), had calculated the deciduous forest population as 13,200. People of Gazni forest, Mymensingh Forest Division, report that they rarely see the capped langur. In the NE forests, the species was seen in Lawachara National Park, Rema-Kalenga Wildlife Sanctuary, Satchori Reserve Forest, Adampur forest, Raghunandan Range and Juri Range. In the SE forests, it was recorded in Teknaf Game Reserve, Chunati Wildlife Sanctuary and Khagrachari. There is no record of this species east of the river Jamuna/Brahmaputra, including the Sundarbans. Hence, the report of the occurrence of 5.1 capped langurs per km^2 in the forests of Dinajpur, Rangpur and the Sundarbans (Akonda 1979) was a wrong assumption, which was also pointed out by Ahsan (1984). Capped langur babies were seen all through the year, but most commonly in early winter (October-December). Interestingly, a baby was seen lactating, for a short time, from another mother of the same group.

3. Phayre's langur, *Trachypithecus phayrei* (Blyth, 1847)
Local name: kalo hanuman (Greater Sylhet), diklenji (Greater Sylhet), hanuman
Status: Rare

The Phayre's langur was originally distributed throughout the mixed-evergreen forests of the NE and SE, but now there are only a few small populations left, more commonly in the forests of the NE than SE. During this survey the species was seen in Rema-Kalenga Wildlife Sanctuary, Juri Range, Raghunandan Range, Satchori Reserve Forest and Adampur forest in the NE. No recent sight record of this species in the forests of the SE, but might still occur in suitable habitats. Ahsan (1984) reported its occurrence in the forests of the NE and SE. Not all the habitats in the SE, suitable for this species, could be surveyed. Young animals were seen in January, April and October.

4. Hanuman langur, *Semnopithecus entellus* (Dufresne, 1797)
   Local name: hanuman
   Status: Rare

The hanuman langur is localised only in some towns and villages in Greater Jessore region. During this survey the species was seen in Keshabpur, Jessore. A baby was seen with a group in May 2000. The population has come down to a critical level due to indiscriminate killing as a pest. People killed a total of 20 langurs in April 1999 by offering them poisonous water in a hot day. The local people have seen this species in Keshabpur and Manirampur in Jessore, Maheshpur in Jhenaidah, Jibannagar in Chuadanga, and there is only one, but authentic, sight record of at least two hanuman langurs in Kalaroa town, Satkhira, in 1999 (S.A. Momen pers. comm. 2000; a local schoolteacher). This was probably a vagrant group, but this is the first record of the hanuman langur in Satkhira district.

5. Pig-tailed macaque, *Macaca nemestrina* (Linnaeus, 1766)
   Local name: kulu bandor (Greater Sylhet)
   Status: Rare

During this survey the pig-tailed macaque was seen in Lawachara National Park, Rema-Kalenga Wildlife Sanctuary and Satchori Reserve Forest in the NE. The species also exists in some other mixed-evergreen forest fragments in the NE and SE. The last sighting in the SE was in Cox's Bazar in early 1980s (Ahsan 1984). Young animals were seen in early winter (October-December).

6. Rhesus macaque, *Macaca mulatta* (Zimmermann, 1780)
   Local name: banor, bandor
   Status: Common

The rhesus macaque is the commonest and most widely distributed non-human primate species in Bangladesh, as also pointed out by Ahsan (1984). Among the forested areas, it was seen in the Sundarbans, in many mixed-evergreen forest fragments in the NE (Lawachara National Park, Rema-Kalenga Wildlife Sanctuary, Satchori Reserve Forest, Raghunandan Range, Juri Range, Adampur forest, etc.) and SE (Chunati Wildlife Sanctuary, Teknaf Game Reserve, Pablakhali Wildlife Sanctuary, Kaptai National Park, Khagrachari, etc.), and in the deciduous forests in Madhupur and in the northern areas of Greater Mymensingh (Gazni forest and Balijhuri Range). It is absent in the deciduous forests in Bhawal and in Greater Rangpur, but the species was present in Tetulia until 1971. The average group size of the rhesus macaque in Bangladesh is five (n = 68 groups, from different habitats). The most successful population is in the Sundarbans where the largest group observed, had 39 individuals. In the Sundarbans, the macaques have been observed jumping from the tree to the water at the creek, 5 m below, probably to have fun; one individual repeated the jump for three times. Young macaques were seen all through the year, but most commonly in winter (November-February). The urban populations were seen in Old Dhaka, Dhamrai, Gazipur (Bormi Bazar), northwest Narshingdi and Madaripur (Char Muguria), but the species occurs in some other urban areas as well.

7. Crab-eating macaque, *Macaca fascicularis* (Wroughton, 1915)
Local name: parailla banor (Greater Chittagong; 'parailla banor' literally means 'mud-dwelling macaque')
Status: Rare

The crab-eating macaque has the most localised distribution in Bangladesh. The reports were only from the patchy mangroves in the Naaf estuary, Teknaf Range, and in Chakoria Sundarban, in Cox's Bazar district (Khan 1982, Ahsan 1984, Feeroz *et al.* 1995). This is the westernmost end of the global range of this species. There is no recent sight record of the crab-eating macaque in Chakaria Sundarban, since the mangrove habitat has been totally converted to shrimp farms. The local people have informed that the last group of this species was seen there during 1992-1993 when a few mangrove trees were still existed. In the small patch of mangroves in the Naaf estuary, including Jolirdia Island, the local people claimed the sightings of this species during this survey. There might be a few individuals still survived in that mangrove patch. Sarker and Sarker (1988) reported the occurrence of this species in the Sundarbans, but it was not found in the Sundarbans. Although the habitat in the Sundarbans would be suitable for them, their global distribution was never up to the Sundarbans. The species is at the verge of extinction in Bangladesh.

8. Assamese macaque, *Macaca assamensis* McClelland, 1839
Local name: not recorded
Status: Rare

Once the Assamese macaque was distributed throughout the mixed-evergreen forests of the NE and parts of the Chittagong Hill Tracts in the SE, but there is no recent record from the Chittagong Hill Tracts. During this survey (in May 2002) one Assamese macaque was seen in Satchori Reserve Forest in the NE. Since it is difficult for the local people to distinguish this species from other species of macaques, the claims of sightings of this species by the local people were ignored. The species was not seen, nor even claimed the sightings by the local people, in the Sundarbans and in the deciduous forests. Perhaps its previous record in the Sundarbans (Prater, 1971) was a mistake, which was also pointed out by Ahsan (1984).

9. Stump-tailed macaque, *Macaca arctoides* Geoffroy, 1831
Local name: not recorded
Status: Rare

The previous report of the stump-tailed macaque's distribution was along the mixed-evergreen forests of the NE and SE (Khan 1982, Ahsan 1984). There is no recent sight record of this species in Bangladesh. During this survey nothing could be recorded about the status and distribution of this species, but the species might still occur in the mixed-evergreen forest patches.

10. Slow loris, *Nycticebus coucang* (Boddaert, 1785)
Local name: lojjaboti banor, lajuk banor
Status: Uncommon

The slow loris was originally distributed all over the mixed-evergreen forests and deciduous forests of the country. During this survey their presence were recorded in some mixed-evergreen forest patches in the NE and SE, and in the deciduous forests in the northern areas of Greater Mymensingh (Karnajhara Beat, Balijhuri Range, Mymensingh Forest Division). Two of them were caught in Karnajhara Beat in 1995.

Due to its shy and nocturnal habits, only a few sightings by the local people could be recorded.

Nothing was recorded about the occurrence of the dusky langur, *Trachypithecus obscurus* (Reid, 1837). Probably the only sight record of this species by Mountfort (1969) in Sylhet was a wrong identification of the Phayre's langur. No other surveys (Gittins 1980, Ahsan 1984, Feeroz *et al.* 1995) have found this species in Bangladesh.

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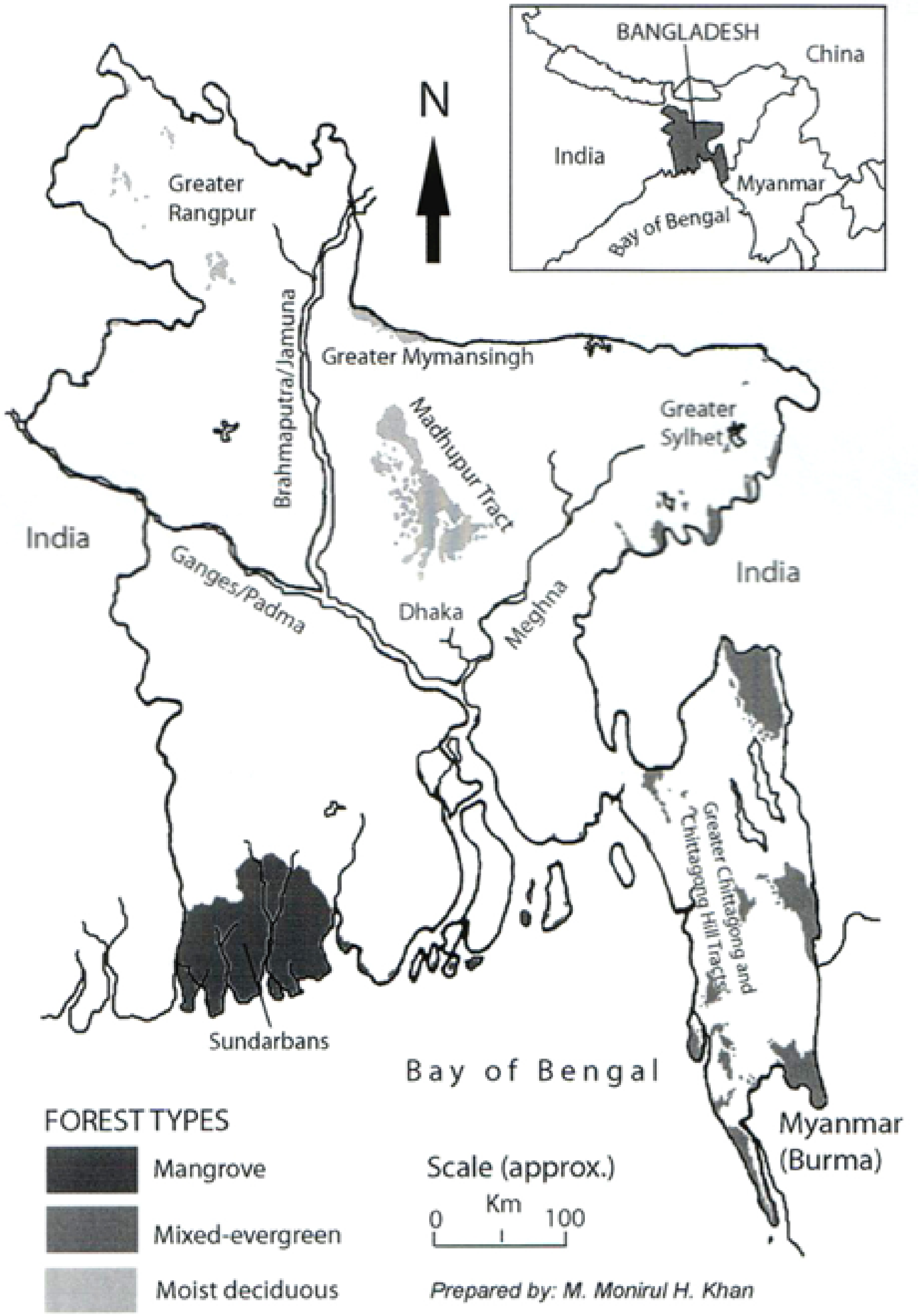

Figure 1. Forested areas of Bangladesh.

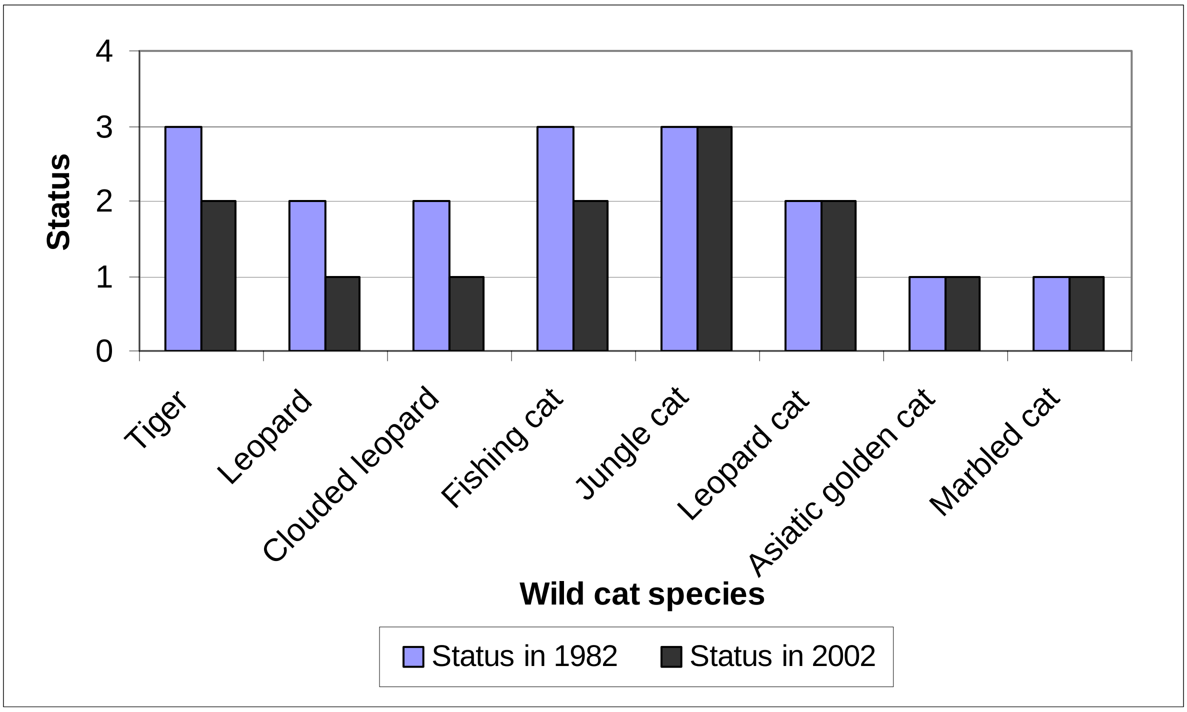

Figure 2. Status change of wild cats in Bangladesh from 1982 (Khan 1982) to 2002 (this survey). Here 1 = Rare, 2 = Uncommon, 3 = Common, and 4 = Very Common.

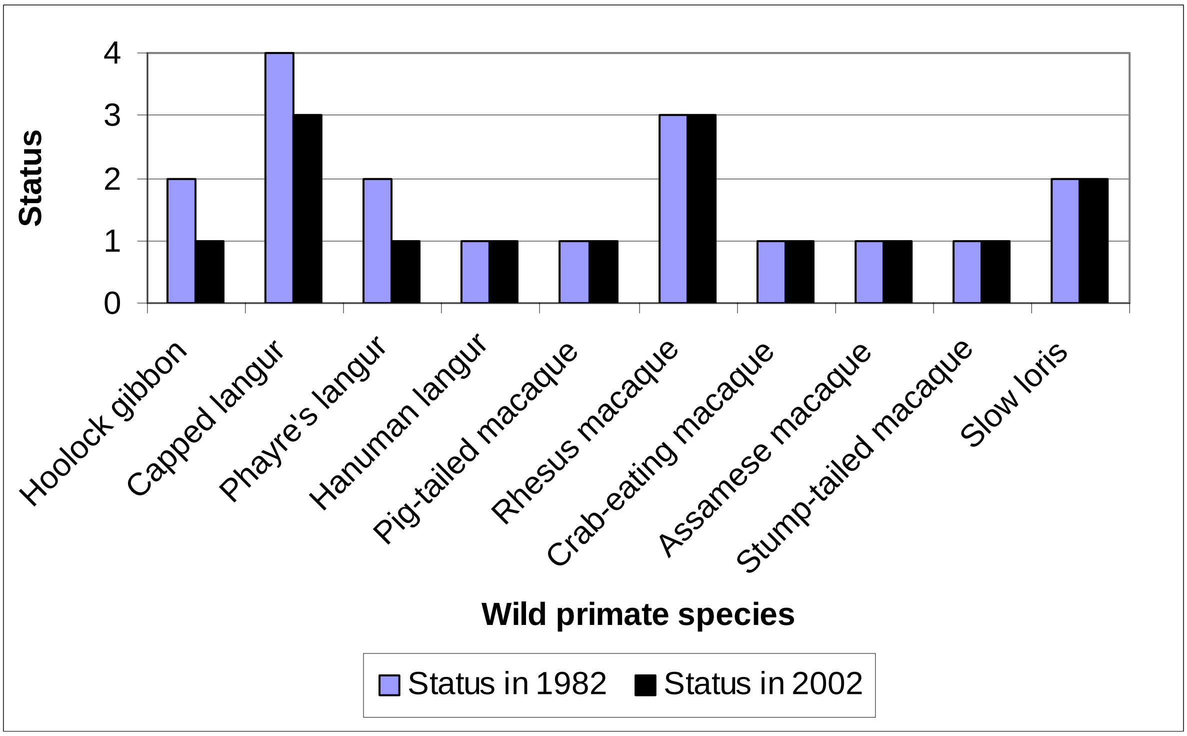

Figure 3. Status change of wild primates in Bangladesh from 1982 (Khan 1982) to 2002 (this survey). Here 1 = Rare, 2 = Uncommon, 3 = Common, and 4 = Very Common.

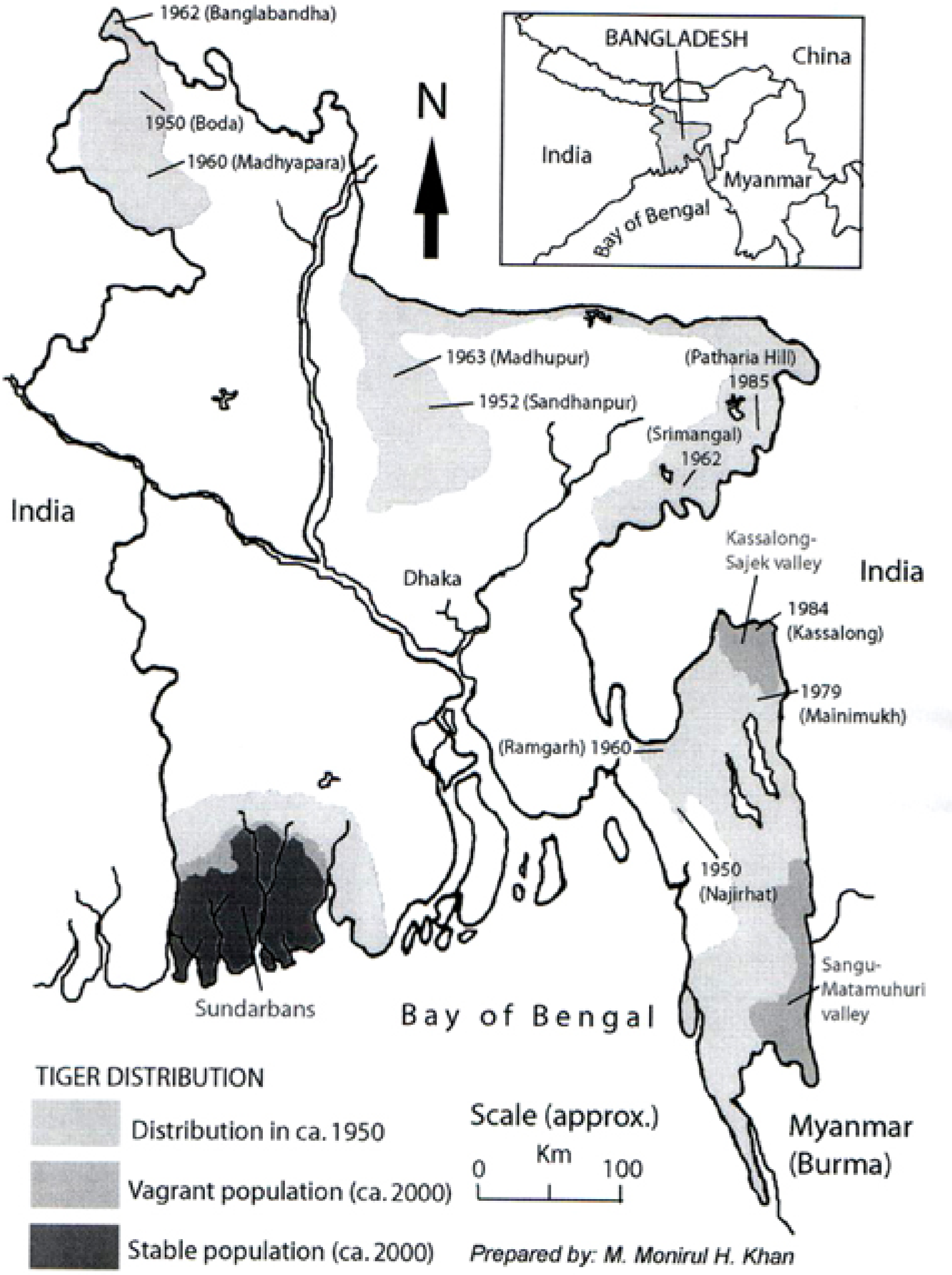

Figure 4. Tiger distribution in Bangladesh in ca. 1950 and ca. 2000.

Appendix II Food habit of the leopard cat *Prionailurus bengalensis* in the Sundarbans East Wildlife Sanctuary of Bangladesh [N.B. This paper was prepared during the PhD course and it has been published in *Zoos' Print Journal* 19(5): 1,475-1,476]

FOOD HABIT OF THE LEOPARD CAT *PRIONAILURUS BENGALENSIS* (KERR, 1792) IN THE SUNDARBANS EAST WILDLIFE SANCTUARY OF BANGLADESH

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Abstract

Food habit of the leopard cat *Prionailurus bengalensis* in the Sundarbans East Wildlife Sanctuary, Bangladesh, was studied on the basis of 21 scats and 12 kills. The mean weight of a dry scat was 20.5 g. Like in most of its global range, the leopard cat was found to prefer rats and mice (found in 52.4% of samples) in the Sundarbans East Wildlife Sanctuary. Other food items are insects (28.6%), birds (23.8%), plant material (19%), agamids (4.8%) and crabs (4.8%).

Keywords

Leopard cat, *Prionailurus bengalensis*, food habit, Sundarbans

Introduction

The leopard cat *Prionailurus bengalensis* has the broadest geographic distribution of all the Asian lesser cats (Sunquist & Sunquist, 2002). It is found in twenty-one Asian countries and it varies so much in colouration and size that it was originally thought to be several different species given many different names, including Jerdon's cat, Elliot's cat, Sumatra cat and Chinese cat (Guggisberg, 1975; Sunquist & Sunquist, 2002). It occurs in a broad spectrum of habitats, from tropical rain forest to temperate broadleaf and, marginally, coniferous forest, as well as shrub forest and successional grasslands (Nowell & Jackson, 1996). There are eight species of wild cats found in Bangladesh (Khan, 1982; 1986) of which the leopard cat is one of the smallest species. The species has a wide distributional range in Bangladesh, but because of the lack of information it falls under Data Deficient category in a national level (IUCN-Bangladesh, 2000). The present study aims at providing some information on the food habit of this elusive species.

Study Area and Methods

The entire Sundarbans is an area of about 10,000 km^2 in the Ganges-Brahmaputra delta of Bangladesh and India, but roughly 60% of this forest lies in the southwest of Bangladesh and the rest 40% is in the South-East of the West Bengal state of India

(Figure 1). The monthly mean temperature and relative humidity normally varies from 23°C (during December-January) to 35°C (during May-June) and from 70% to 80% respectively. There are three wildlife sanctuaries in the Bangladesh Sundarbans that together form a UNESCO World Heritage Site. The Sundarbans East Wildlife Sanctuary is one of these three sanctuaries (Figure 1). This is an area of 312 km^2 at the southeastern end of the Sundarbans, considered to be the richest part of the Sundarbans. Geographically the area is located between 21°47′-22°03′ N latitudes and 89°46′-89°55′ E longitudes.

The leopard cat scats were collected from the Sundarbans East Wildlife Sanctuary. Monthly field visits were conducted during September 2001-February 2003. The leopard cat is the commonest lesser cat in the Sundarbans (Khan 2004). Although there are jungle cats (*Felis chaus*) and fishing cats (*Prionailurus viverrinus*) in the Sundarbans, but jungle cats are found mainly in the fringing areas far away from the Sundarbans East Wildlife Sanctuary and the scats of a fishing cat are bigger than that of a leopard cat. Since most of the ground in the Sundarbans is soft, the footprints near scats could be observed, which helped to identify leopard cat scats. The scat samples were collected, and dried if necessary, in the field. These were brought to the laboratory where these were weighed by using a Lark JPT-2 (range: 0.1-200 g) beam balance. Then each of the scats were washed and strained in order to separate and identify prey remains. Similar method was followed by Hoogerwerf (1970), Inoue (1972), Rabinowitz (1990), etc. Moreover, notes were taken whenever remains (mainly feathers) of killed birds were found in the field. The footprints around the kill were used to make sure that it was killed by a leopard cat.

Results and Discussion

Most of the scats were found in dry sandy areas, which indicate that leopard cats prefer to defaecate in dry sandy areas. The mean weight of a dry scat was found 20.5 g (n = 21, range = 4.1-59.3 g, SD = 15.91668). The scat analysis shows that, rats and mice (Family: Muridae) are the main prey of the leopard cat, which was found in 52.4% of the scat samples. Insects and birds are the second and third on the menu, which were in 28.6% and 23.8% of the scat samples respectively. Significant proportion (over half of the volume) of soil was found in one scat, but it was not considered as a food item. The frequency of occurrence (percentage of samples) of food items in the scats of leopard cats in the Sundarbans East Wildlife Sanctuary has shown in Table 1.

Leopard cats normally consume the entire kill, but in case of birds, they leave the feathers of their kills. A total of 12 remains of birds, i.e. feathers, were found in the field, of which the red junglefowl (*Gallus gallus*) was the commonest. However, nothing could be concluded about the preference of bird species on the basis of kill remains because of small sample size. The number of kills of different species of birds has shown in Table 2.

There are a number of reports on the food habit of leopard cats in different parts of its global range, but there is no previous report from Bangladesh. In general, leopard cats feed on a variety of small prey, including mammals, lizards, amphibians, birds and insects (Sunquist & Sunquist, 2002). In Pakistan, the primary food item is small birds, but they also eat wood mice, flying squirrels, etc. (Roberts, 1977). In Java, Indonesia, the main prey are rats and mice, but a large number of leaves of one species of herb was also found in the scats (Hoogerwerf, 1970). In Kaeng Krachan National Park, Thailand, rats and mice were found to be the main prey, but they also prey on tree shrews and hares (Grassman, 1998). In Huai Kha Khaeng Wildlife Sanctuary, Thailand, a total of fourteen prey species were identified from the scats of leopard cats, but rats were the dominant prey (Rabinowitz, 1990). Rats were also found to be the dominant prey in Tsushima Island, Japan, but they also eat moles, birds, amphibians and insects (Inoue, 1972). In contrast, rats and mice (most probably the commonest species was long-tailed tree mouse *Vandeleuria oleracea*) were found to be the dominant prey in the Sundarbans East Wildlife Sanctuary, along with insects, birds, etc. (Table 3). In Tabin, Malaysia, small mammals were found to form 96 percent of the diet of leopard cats (Rajaratnam, 2000), whereas in the Sundarbans East Wildlife Sanctuary, small mammals form 52.4 percent of the diet (Table 3).

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Table 1. Frequency of occurrence (percentage of samples) of food items in the scats of leopard cats in the Sundarbans East Wildlife Sanctuary of Bangladesh

Food item	**Frequency of occurrence (% of samples; n = 21)**
Mammals (small; rats and mice)	52.4
Birds (small and medium)	23.8
Agamids	4.8
Crabs	4.8
Insects (grasshoppers, beetles, etc.)	28.6
Plant material (seeds, fruits, leaf blades, etc.)	19.0

Table 2. Number of kills (remains) of different species of birds by leopard cats in the Sundarbans East Wildlife Sanctuary of Bangladesh

Bird species	**Number of kills**
Red junglefowl *Gallus gallus*	5
Green-billed malkoha *Phaenicophaeus tristis*	3
Large-tailed nightjar *Caprimulgus macrurus*	3
Mangrove pitta *Pitta megarhyncha*	1

Table 3. A comparison of the food habit of leopard cats in Huai Kha Khaeng Wildlife Sanctuary (Thailand), Tsushima Island (Japan) and Sundarbans East Wildlife Sanctuary (Bangladesh)

Food item	**Frequency of occurrence (% of samples) in the scats**		
	Huai Kha Khaeng (n = 52) (Rabinowitz, 1990)	**Tsushima Island (n = 230) (Inoue, 1972)**	**Sundarbans East (n = 21) (this study)**
Small mammals	93.9	89.0	52.4
Birds	1.9	41.7	23.8
Reptiles	9.6	3.8	4.8
Amphibians	0	10.0	0
Fish	0	6.5	0
Crab	1.9	0	4.8
Insects	0	43.9	28.6
Plant material	48	92.6	19.0

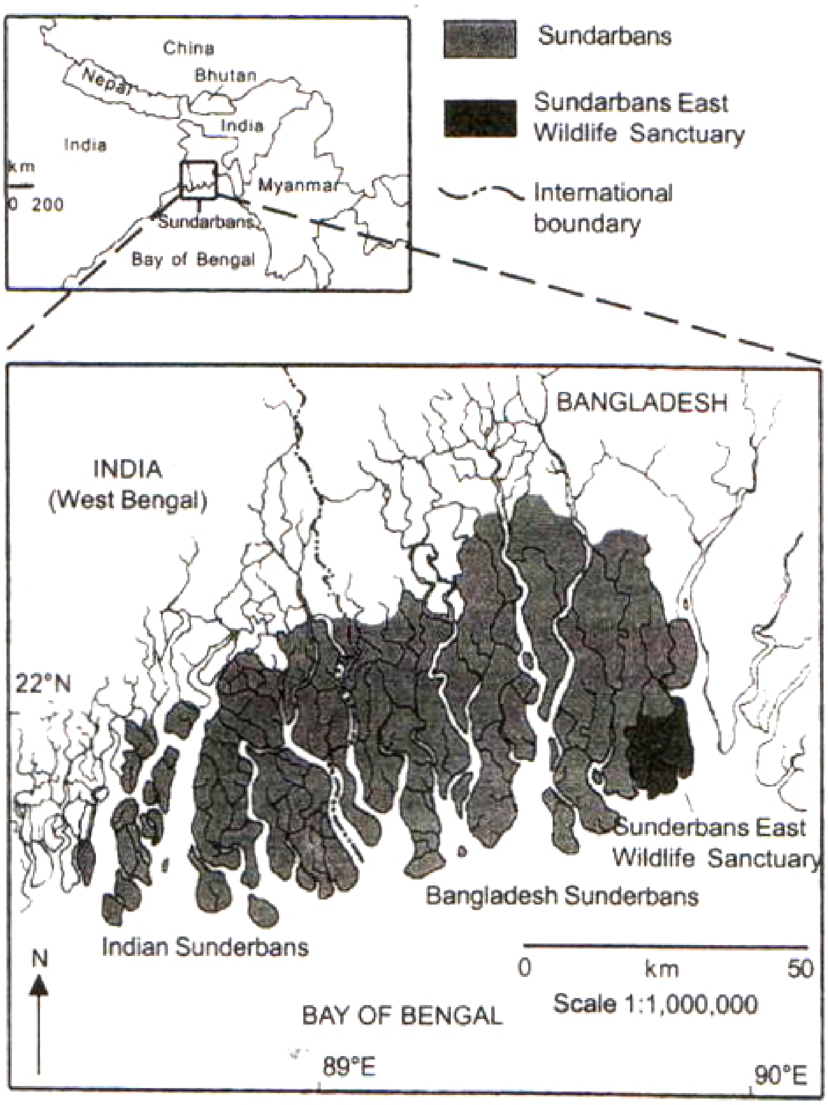

Figure 1. The Sunderbans of Bangladesh and India showing Sundarbans East Wildlife Sanctuary

Appendix III An article entitled 'The Sundarbans' [N.B. This article was prepared during the PhD course and has been published in a book entitled *Wilderness – Earth's Last Wild Places* (ed. P.R. Gil), Cemex, Mexico City / Conservation International and Sierra Madre, pp. 280-289]

THE SUNDARBANS

M. MONIRUL H. KHAN

The Sundarbans, located on the border between Bangladesh and West Bengal state in India, is the world's largest tidal mangrove forest. The region treated here covers about 10,000 km^2, of which 62% lies in the southwest of Bangladesh (between 21°30′-22°30′ N latitudes and 89°00′-89°55′ E longitudes) and the remaining 38% in the southeast of West Bengal in India (between 21°32′-22°40′ N latitudes and 88°05′-89°00′ E longitudes). Roughly 80% of this region remains intact, although the size of the Sundarbans as a whole has been reduced. The total mangrove area of the world has been estimated to be around 166,700 km^2 (Choudhury et al., 2001), which means that this one region accounts for about 6% of all mangroves on Earth. The Bangladesh Sundarbans cover an area of about 5,770 km^2, of which 1,750 km^2 is water, in the form of rivers, canals and creeks. It also represents about 44% of the total forested area of the country, and contributes about 50% of the revenue of the forestry sector (Tamang, 1993). The Indian Sundarbans is variously estimated from 3,000 km^2 to 4,263 km^2, of which about 1,781 km^2 is water.

The Sundarbans mangrove swamp is of recent origin, formed by eroded soil from the Himalayas carried by the Ganges, Brahmaputra, Meghna and many other river systems. These rivers deposited their silt at the apex of the Bay of Bengal and gave rise to the Sundarbans. Literally 'Sundarbans' means 'beautiful forests'; the name perhaps derived from a common timber tree 'sundri' (*Heritiera fomes*), which means 'beauty'. The word 'mangrove' itself is a combination of the Portuguese 'mangue' and English 'grove', and can refer to an ecological group of holophytic plant communities belonging to 12 genera in 8 families, or a complex of plant communities that fringe sheltered tropical shores, or more specifically, according to some authors, the vegetation formation below the high tide mark (Seidensticker and Hai, 1978). The fragile and intricate mangrove ecosystem depends on many variable components, but mainly on water salinity. The most striking adaptations of the mangrove plants are the various forms of aerial roots necessary to meet the oxygen requirement for respiration. Three ecological zones, the freshwater zone, the moderately saline water zone and the saline water zone, can be distinguished in the Sundarbans according to salinity and species composition.

The mean annual rainfall in the Sundarbans varies from 1,600 mm to 2,790 mm. The annual temperature varies from 20°C (December-January) to 35°C (May-June). The mean annual relative humidity varies between 70-88 %.

Although there are other extensive mangrove areas within some of the major tropical wilderness areas (Amazonia, New Guinea, Congo), the Sundarbans are the only exclusively mangrove area to be profiled in this book.

Biodiversity

Unlike other mangrove forests, the Sundarbans is rich in biodiversity, especially in mangrove-oriented species. One reason for this richness is that the Sundarbans is both a tropical moist forest and a wetland with mudflats and beaches. Plant diversity in the Sundarbans is relatively well documented. A total of 334 species of vascular plants belonging to 245 genera have been recorded from the Sundarbans and adjoining forests (Prain, 1903), of which at least 123 are present in the Bangladesh portion (Karim, 1994a). The region is particularly rich in mangrove tree species, with about 80% of the known species found in the Bangladesh Sundarbans. *Heritiera fomes*, *Excoecaria agallocha* and *Sonneratia apetala* are the most common. There are also 12 species of shrubs or scandant shrubs, 11 species of climbers, 13 species of orchids and seven epiphytic ferns (Karim, 1994a). Non-vascular plants are less well known, but 34 species of algae have been recorded thus far (Karim, 1994a). The Indian part of the Sundarbans is relatively less diverse. A total of 29 families and 49 genera have been reported, including 36 true mangrove species, 28 mangrove associates and 7 obligatory mangrove species. There are 30 species of arborescents, 20 shrubs and 20 herbs. *Excoecaria agallocha* and *Ceriops decandra* are the most common tree species in the Indian Sundarbans (Chaudhuri and Choudhury, 1994).

In terms of vertebrates, a total of 245 non-fish species have been recorded in the Sundarbans. This includes 174 birds, 54 mammals, 14 reptiles and 3 amphibians, none of them endemic (WWF, in prep.).

The Sundarbans is also rich in fish, and is an important commercial fishing area. The Bangladesh portion supports 53 species of pelagic fish and 124 species of demersal fish (Acharya and Kamal 1994), while 250 species of fish have been recorded on the Indian side (Chaudhuri and Choudhury, 1994).

The rich fish and other aquatic fauna of the Sundarbans also support a diverse range of bird species. Of 10 kingfisher species found in Bangladesh, eight are found in the Sundarbans. The Asian openbill (*Anastomus oscitans*) is an important resident bird species, and, as might be expected, herons, egrets, storks, kingfishers, eagles, kites, owls, waders, and ducks are common.

Of the 54 mammal species in the Sundarbans, the most common species are spotted deer (*Axis axis*), wild boar (*Sus scrofa*) and rhesus macaque (*Macaca mulatta*). Sadly, at least five of the most striking large mammals of the Sundarbans have become extinct since the beginning of the 20th century, including Javan rhinoceros (*Rhinoceros sondaicus*), wild buffalo (*Bubalus bubalis*), gaur *(Bos frontalis),* swamp deer or barasingha (*Cervus duvaucelii*) and hog deer (*Axis porcinus*) (De 1990, Khan 1982). However, the majestic Bengal tiger (*Panthera tigris tigris*) still survives.

The majority of the reptile species are lizards, represented by 10 species, but there are also three turtles, and one crocodilian, the estuarine or saltwater crocodile (*Crocodylus porosus).*.

Flagship Species

The Bengal tiger is the supreme flagship species of the Sundarbans, and, in global terms, by far the most important species there. Indeed, the global reputation of the Sundarbans is based on the presence of the tiger, and the future of this magnificent predator and its mangrove habitat is intricately intertwined. Globally, the tiger is considered Endangered, but the Bangladesh population is considered Critically Endangered at the national level (IUCN – Bangladesh, 2000). As a whole, the Sundarbans may harbor as many as 400-500 tigers, a number comparable to that of the Siberian tiger (*Panthera tigris altaica*) in the Russian Far East and making it one of the two largest surviving populations of tiger on Earth (WWF, 1999). However, based on camera trappings done by Karanth and Nichols (2000) in the Indian Sundarbans, the estimated tiger density is only 0.84 tigers/100 km^2, much lower than previously estimated on the basis of the pugmarks. On the other hand, Seidensticker (1986) noted that the size of the Sundarbans made it likely that a large population of tigers could continue to be maintained there for the next 50, 100 or even 200 years from now.

The Sundarbans tiger is also world-renowned because of the frequency of man-eating incidents in the region. Officially, tigers killed a total of 544 humans (22.6 humans/year) in the Bangladesh Sundarbans in the period between 1975 and 1999, while on the other hand, 45 tigers were killed by humans (1.8 tigers/year) during that same time (Khan 2001). In the Indian Sundarbans, tigers caused about 1,500 human deaths (75 humans/year) in the last twenty years (Chaudhuri and Choudhury, 1994). However, the number of humans killed each year is very low in relation to the number of people working in the Sundarbans (probably less than 0.05%), Seidensticker and Hai (1978) argued that, even in the Sundarbans, there is less risk of dying from a tiger attack than from driving a car in most developed countries.

Another flagship species in the Sundarbans is the saltwater or estuarine crocodile (*Crocodylus porosus*). A wide-ranging species, the Bangladesh population, like that of the tiger, has also been identified as Critically Endangered at the national level (IUCN-Bangladesh, 2000). Khan (1982) estimated about 200 individuals in the Bangladesh Sundarbans on the basis of several different visits, and the population is believed to have declined in recent years. Like the tiger, this crocodile is also a man-eater, having killed an average of six people per year in the Indian Sundarbans.

Other than the tiger and the crocodile, the Sundarbans provide extensive habitats for some globally and/or nationally (in Bangladesh) threatened species, including the river terrapin (*Batagur baska*), the olive ridley turtle (*Lepidochelys olivacea*), the two-banded monitor (*Varanus salvator*), the rock python (*Python molurus*), the masked finfoot (*Heliopais personata*), the Indian skimmer (*Rynchops albicollis*), greater spotted eagle (*Aquila clanga*), the white-bellied sea eagle (*Haliaeetus leucogaster*), the lesser adjutant (*Leptoptilos javanicus*), the Ganges river dolphin (*Platanista gangetica*), and the hoary-bellied Himalayan squirrel (*Callosciurus pygerythrus*).

Among the plants, the best flagship species is the mangrove, *Heritiera fomes, w*hich dominates the richest parts of the region. It is especially dominant in the eastern part of the Bangladesh Sundarbans, but uncommon on the Indian side, where it can be considered threatened. To some extent, this species is an indicator of the level of natural resource exploitation since it is the most important commercial species. In the Bangladesh Sundarbans, four species of *Bruguiera* were once common, but recent surveys confirmed the presence of only one (*B. parviflora*). In addition, several other plants like *Cynometra* spp., *Amoora cuculata* and *Rhizophora* spp. are threatened due to unregulated felling, with *Rhizophora* being on the brink of extinction in the Indian Sundarbans. Other species that may be considered threatened include *Aegiceras corniculatum*, *Heritiera fomes*, *Kandelia kandel*, *Nypa fruticans*, *Sonneratia acida*, *Sonneratia apetala* and *Sonneratia caseolaris*.

Human Cultures

Although villages surround almost the entire Sundarbans, with the exception of the southern coast, there is virtually no permanent settlement in the forest itself. However, local people depend on the natural resources of the Sundarbans for their survival, and they do live temporarily within the forest in the harvest season, with the Bangladesh portion providing employment for more than 350,000 people. They work as 'bawalis' or woodcutters, 'mouals' or honey gatherers, 'jaleys' or fishermen, and collectors of nipa (*Nypa fruticans*) leaf and thatching grass (*Imperata* spp.).

Although there is a dense population surrounding the Sundarbans, the region itself on the Bangladesh side is uninhabited. On the Indian side, there are only about 3,000 people living permanently in the region (Chaudhuri and Choudhury, 1994), meaning that the population density for the region as defined here would be only about 0.3 people/km2.

Threats

Overexploitation of natural resources to meet the needs of a growing population is the major threat to the Sundarbans. Over the past 200 years, the whole Sundarbans has been reduced by more than 50% for agriculture and human settlements (Karim, 1994b), and a number of tree species have also been overexploited. Thankfully, the creation and protection of reserves and the reduction of the rate of legal harvest of forest products have considerably slowed these problems. Environmental awareness and the growing strength of the forest department have played particularly important key roles in stopping encroachment, which has been negligible in the last 20 years.

An inventory carried out in the Bangladesh Sundarbans in 1985, documented the depletion of two mangrove species, *Heritiera fomes* and *Excoecaria agallocha*, through legal and illegal harvesting, to the point that they were down by 40 and 45% respectively since a 1959 inventory. Similar trends were observed in the Indian Sundarbans, where a total of 322 km^2 of tidal mangroves was lost in the period 1960-1980 (Chaudhuri and Choudhury, 1994). The scattered mangrove woodlands in the private lands around the Sundarbans once served as buffer zones, but these have now been almost entirely converted for prawn (*Penaeus monodon*) culture. A further impact of prawn culture is the collection of shrimp fry by local people, a process that also kills the fry of many non-target fish and crustacean species.

Poaching is also a problem. There is no legal hunting in the Sundarbans, but spotted deer is subjected to severe poaching for its meat and hide. One kilogram of deer meat brings US $2 in local markets, a high price, and this species is common and easily hunted. Tiger poaching is rare, but does occur. In May of 2001, the Bangladesh Rifles (BDR) seized 12 tiger skins from poachers in Kaliganj, near the Sundarbans (The Daily Ittefaq, Dhaka, May 7, 2001).

Changes in water salinity due to the alteration of freshwater flow also affect the mangrove communities. Mangrove species distribution is strongly influenced by the extent of freshwater influx, either from rainfall or from rivers. The wildlife in the mangroves show a similar pattern. The main cause of river flow alteration is the construction of barrages, embankments and cuts to drive flow in different directions. Two notable interventions are the Farakka Barrage in the Ganges in West Bengal, India, and the Halifax Cut between the Madhumati and Nabaganga rivers in Bangladesh. The Ganges-Kobodak Irrigation Project in Bangladesh, consisting of 38.8 km of flood protection embankments and 1,655 km of large and small channels, is another major intervention. About 3,700 km of earth embankments have been constructed upstream of the Bangladesh Sundarbans to control saline water intrusion into agricultural fields, enclosing 13,000 km^2 of land. However, this is nothing new. Over the last two centuries, a number of drainage systems have been constructed upstream of the Indian Sundarbans, causing a series of ecological changes.

Potential sea level rise due to global warming is yet another serious threat. The predicted sea level rise of 83 cm by the year 2050 could very well be disastrous for the Sundarbans. Fortunately, however, the huge silt supply from upstream and the natural process of deltaic development might help to counteract sea level rise. Mangroves tend to migrate landward in the face of gradual sea level rise, but this process will be difficult in the Sundarbans area because human settlements and crop fields dominate the entire upstream area.

Although siltation has a positive role in combating sea level rise, it also poses a threat to the Sundarbans. Siltation blocks creeks (which are in effect the blood vessel of the region) and consequently the nutrient cycle of the mangrove ecosystem. Moreover, excessive siltation may result in respiratory shock (by blocking pneumatophores) and nutrient stress that reduce growth or even kill mangrove plants. In parts of the Sundarbans, there are now patches of dying *Heritiera fomes*, *Xylocarpus mekongensis* and *Bruguiera sexangula*, which are the result of excessive siltation.

Although still minor, pollution is a growing threat to the Sundarbans, with at least 20 types of insecticides, 18 fungicides, 2 rodenticides, a number of fertilizers currently in use in Bangladesh. These agro-chemicals are carried downstream in the Sundarbans and incorporated into the food chain, with the usual biological magnification at higher trophic levels. Industrial waste is also indiscriminately discharged into river water upstream of the Bangladesh Sundarbans. Khulna Newsprint Mill alone continuously releases about 4,500 m^3 of wastewater. Oil spills also sometimes occur in the Sundarbans, originating from Mongla Port (immediately upstream from the Bangladesh Sundarbans) and from ships and motorboats. In 1994, oil spills from a cargo ship caused instant mortality of mangrove seedlings, grasses, fishes, shrimps and many other organisms. On the Indian side, untreated sewage discharges from Calcutta also represent a considerable threat.

Natural disasters like cyclones also cause considerable damage to the Sundarbans, and are not infrequent. Since about one-tenth of the world's tropical cyclones occur in the Bay of Bengal. Many large trees are blown down and others face major loss of branches and leaves. After the most catastrophic cyclone in 1988, about 9,200,000 ft^3 of timber and 5,800,000 ft^3 of firewood were collected from damaged trees in the Bangladesh Sundarbans (Karim, 1994b). Many animals were also killed during this event, including eight tigers.

Conservation

Despite major human pressure on the natural resources of the Sundarbans, the area is still relatively intact and supports relatively healthy populations of plants and animals. This mainly because of its natural inaccessibility, but fear of man-eating tigers and a growing concern for biodiversity conservation also play a role. In addition, government agencies, like the Bangladesh Forest Department, also give maximum effort to protecting this unique resource and patrol it regularly.

The entire Sundarbans was declared a forest reserve as far back as 1875-1876, and entry without permit was prohibited from that time on. In order to further conserve the biodiversity of the Bangladesh Sundarbans, the Government of Bangladesh established three wildlife sanctuaries (Sundarbans East Wildlife Sanctuary, Sundarbans South Wildlife Sanctuary and Sundarbans West Wildlife Sanctuary) in 1977. These three sanctuaries initially covered an area of 323.8 km^2, but this was increased to 1,397 km^2 in 1996 – almost 14% of the entire region. The following year, in December 1997, UNESCO also declared these a World Heritage Site. In addition, the wildlife of the Bangladesh Sundarbans is protected under the Bangladesh Wildlife (Preservation) (Amendment) Act 1974, and thus should not be killed or captured.

The wildlife sanctuaries are primarily for the protection of wildlife, inclusive of all natural resources such as vegetation, soil and water. The Government of Bangladesh, with other national and international partners, also runs several projects in the Bangladesh Sundarbans. These provide scientific guidelines and on-the-ground efforts on behalf of biodiversity conservation on the Bangladesh side, including the Sundarbans Wildlife Management Plan: Conservation in the Bangladesh Coastal Zone, Integrated Resource Development of the Sundarbans Reserved Forest, Development of Wildlife Conservation and Management, Project Tiger, Forest Resource Management Project, and the Biodiversity Conservation in the Sundarbans Project. In addition, there are several small-scale captive breeding programmes for spotted deer and estuarine crocodile at Karamjal in the Bangladesh Sundarbans, and special measures to protect habitats of the estuarine crocodile in Mrigamari and several other sites.

On the Indian side, the entire Indian Sundarbans (100%) and its surrounding area (south of the Dampier-Hodges Line) has been declared a Biosphere Reserve. The total area of this reserve is 9,630 km^2 of which mangrove forests cover 3,000-4,263 km^2. This reserve has four zones, a core zone, a manipulation zone, a restoration zone and a development zone. This reserve supports the largest single tiger population in India, and also has populations of a number of other nationally threatened species like fishing cat (*Prionailurus viverrinus*), estuarine crocodile, olive ridley turtle (*Lepidochelys olivacea*), river terrapin (*Batagur baska*), and several monitor lizards (*Varanus* spp.), with wildlife being protected under the Wildlife Protection Act 1972.

Included within this Biosphere Reserve are one national park and three wildlife sanctuaries. The national park was declared in 1989, it covers 1,330 km^2, and like its counterparts on the Bangladesh side, it has also been recognized as a World Heritage Site. The three wildlife sanctuaries, Sajnakhali, Lothian Island, and Holiday Island were established in 1976, and cover 406.3 km^2. These sanctuaries protect a number of plant communities, but were mainly established to serve as refuge for the Bengal tiger and its prey. To provide further protection, a total of 2,585 km^2 of the Indian Sundarbans was taken under Project Tiger in 1973, and declared the Sundarbans Tiger Reserve. This reserve has been successful in that the tiger population there has at least remained stable or perhaps even increased.

Finally, the Government of West Bengal, under its Integrated Wasteland Project, has also initiated ecological restoration of 247.5 km^2 of degraded forests and 27.5 km^2 of cleared land and mudflats in the Indian Sundarbans and has undertaken captive breeding and reintroduction programs for the estuarine crocodile and the olive ridley turtle (Chaudhuri and Choudhury 1994).

Looking at the region as a whole, 3,133 km^2 - or over 30% - is protected under either national parks or wildlife sanctuaries, with the entire Indian side receiving additional recognition as a Biosphere Reserve.

Ultimately, the future of the Sundarbans will depend on strong commitment by the governments of Bangladesh and India and active participation by the international conservation community – all of which be needed to ensure proper management, restoration and other critical activities. However, it spite of the many pressures, the prospects for maintaining this wilderness in one of the most densely population regions on Earth appear to be quite good.

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Appendix IV An article entitled 'Mysterious Tigers of the Sundarbans' [N.B. This article was prepared during the PhD course and it is now in press on a book entitled *Tiger: A Natural and Cultural History* (ed. V. Thapar), CDS Books and Two Brothers Press]

MYSTERIOUS TIGERS OF THE SUNDARBANS

M. Monirul H. Khan

Out of fear and respect people call them *Mama* (means 'uncle'). Both Muslims and Hindus worship them. They are rarely seen, but they kill many people every year. They are the mysterious tigers of the Sundarbans—the least known to scientists of all the world's tigers, the only ones that live in mangroves and yet one of the most thriving populations. The Sundarbans are the largest single mass of tidal mangrove forest on Earth, covering an area of about ten thousand square kilometers (nearly four thousand square miles) in the Ganges-Brahmaputra delta of Bangladesh and India. Roughly sixty percent of this forest is in Bangladesh and the rest in India. Here, the tiger is the flagship species and supreme predator.

Mangroves are very different from other tiger habitats. With the rapid decline of the evergreen and deciduous forests in the north, east and west of the area—and the subsequent diminution of the prey population—tigers find the Sundarbans a relatively safe but challenging place to colonize. They have to adapt to the semiaquatic ecosystem, facing a lot of water and mud, and thus they need to swim much more than any other tiger population. This is probably why the Sundarban tigers are thinner than other populations of the same subspecies.

The tiger is classified by the World Conservation Union (IUCN) as a globally endangered species, but its conservation status in Bangladesh is even more dire: there, it is identified as critically endangered. And yet, the question of how many tigers there are in the Sundarbans is a puzzling one that has yet to be answered confidently. Using Mel Sunquist's crude estimate of one adult tiger in every forty square kilometers (15.4 square miles) in Nepal's Royal Chitwan National Park, John Seidensticker believes that there is room for about 250 adult tigers in the entire Sundarbans. With the use of camera traps in the Indian part of the Sundarbans, Ullas Karanth and James Nichols have estimated the tiger density to be only 0.8 tigers per hundred square kilometers, which would mean there are only about eighty individuals in the entire area. However, based on recent pugmark censuses, the tiger population has been estimated to be 362 in the Bangladesh Sundarbans and 263 in the Indian Sundarbans—a total of 625 tigers. These figures are the ones officially used in the two countries. From them it is clear that pugmark-based estimates are much higher than other estimates, which challenges the validity of the pugmark-based census method, at least in the Sundarbans. While following tiger tracks in the Sundarbans East Wildlife Sanctuary (WS), I observed that pugmarks of the same tiger vary in different soil types. Not only that, some pugmarks produced in the early winter (i.e., after the last rain) remained intact for more than two months. If we imagine the number of intact pugmarks produced by any one tiger during that period (thousands indeed!), it is only natural that any estimates from pugmark studies will be inaccurate, because it is virtually impossible to prove that all the pugmarks in different soil types are actually produced by the same individual. It should be mentioned here that most of the pugmark censuses were conducted in the winter, when it is relatively dry and thus convenient for census work. Unfortunately, the wide availability of the pugmarks apparently gives some the idea that tiger density is extremely high in the Sundarbans, which is not correct.

I have worked on the tiger and its prey in the Sundarbans East WS, where I have estimated the density of sizable prey (spotted deer and wild boar, together contribute about eighty percent of the diet of the tiger). The prey density on land was found to be forty-three individuals per square kilometer (one hundred and eleven per square mile). Since half of the Sundarbans East WS's 312 square kilometers is deep-water bodies such as rivers and estuaries, I estimate a total prey population of around 6,700 individuals. Assuming that tigers crop about 10 percent of the large ungulate population annually, and assuming a kill rate of fifty prey animals per tiger per year, this area might support around thirteen tigers (excluding cubs), i.e. four tigers per hundred square kilometers (eleven tigers per hundred square miles). The presence of some grassland pockets in this area has made it one of the richest parts of the Sundarbans, with perhaps the highest density of tigers and prey. Given this rough estimate in one of the richest areas of the Sundarbans, we can expect a maximum of a few hundred tigers in the entire region—more specifically, three hundred in total: two hundred in the Bangladesh part and one hundred in the Indian.

It is very difficult to estimate the actual tiger population in such an inaccessible habitat—a tangle of water, mud, and dense vegetation. However, the exact number is not very important, so long as there is a sufficiently large and viable population. The population trend is rather more important, and this can be easily monitored from tiger signs. Despite all the deadly conflicts with people, it is still relatively stable, thanks to the natural inaccessibility of the habitat and human fear of man-eating tigers. Since the ecosystem is tidal, the land is suitable neither for agriculture nor for human settlement: this is the main reason why such a huge forest remains intact in one of the most densely populated areas in the world. Perhaps the tiger population in the Sundarbans is one of the largest unfragmented populations on Earth. For these reasons, the area offers vital potential for long-term tiger conservation.

Unlike other tigers, those in the Sundarbans have a reputation for eating people. Officially, tigers killed a total of 173 humans (17.3 per year) in the Bangladesh Sundarbans between 1993 and 2002. During the same period, humans killed thirty tigers (3 per year). However, based on field survey it was found that, between September 2001 and February 2003, a total of forty-one humans were killed by tigers while seven tigers were killed by humans, although officially these figures are only five and four respectively. Since the Sundarbans are big and inaccessible, not all the reports of human and tiger deaths reach the forest department. Moreover, since many of the human victims were illegal intruders, their deaths were not officially recorded. On the other hand, a report quoted the death of ten humans in eleven months (April 1999–February 2000) in the Indian Sundarbans. However, the number of humans killed each year is very low in relation to the number working in the Sundarbans (possibly less than 0.05 percent).

In other tiger ranges, man-eating tigers are rare and are usually either old or injured tigers; in the Sundarbans, however, both healthy and old tigers were found to become man-eaters. There are several theories regarding why this should be: water salinity (some experts think that drinking of saline water might make the tiger more aggressive) and availability of human beings as an easy prey are two of a number of suggested causal factors, but neither has any concrete evidence to prove the hypothesis. Hence, it might be better to conclude that the man-eating habit is simply a behavioral character of some tigers in the Sundarbans. It is possible that in the past some tigers of the western Sundarbans might have encountered many dead bodies (perhaps as the outcome of a tidal wave, cyclone, or epidemic disease), which gave them the opportunity to taste human flesh. Once they learned that human beings were “edible,” they became man-eaters. The trend then transferred and spread from generation to generation. It is very likely that if the mother is a man-eater, the cubs will learn to consider humans as part of their normal menu.

Based on interviews with local people, newspaper reports and forest department records, I found that man-eating tigers mainly hunt middle-aged people (73 percent of their victims are in the thirty-to-fifty age group), perhaps because people of this age are the most available kind (45 percent) in the Sundarbans. Most of the victims (92 percent) were attacked from behind and grabbed by the neck or head.

Human kills were found to have been carried from the spot of attack as little as a few meters or up to eight kilometers (five miles). Of the few who survived tiger attacks, 67 percent did not have a neck or head bite. Most (53 percent) of the people of the Sundarbans rely only on spiritual protection from the tiger. Interestingly, despite many fatal encounters with tigers, 75 percent of the people interviewed said that they wanted the tiger to survive in the Sundarbans, because once it was gone poachers would have nothing to fear and would destroy the area by cutting down trees and killing wild animals, as a result the local people would lose their livelihood.

I have recorded that individuals isolated from a group are the most vulnerable to man-eating tigers. Working in groups, with everyone carrying a big stick, and keeping a pet dog (which must be chained) with each team might be a useful form of protection. Face masks at the back of the head (in order to confuse the tiger about which is the front and which the back of a human) and electrified dummy humans are used in the western Sundarbans, but it might not be wise to assume that man-eating tigers are stupid enough to be fooled by these devices!

Every year, people in the Sundarbans sacrifice live goats and chickens, releasing them in areas where they are ultimately killed and eaten by the wildlife. Some people of the Muslim community believe that the tiger was born from the menstrual blood of the great mother Fatema, which is why it has a strong odor. People also believe that the man-eating tiger is actually an evil spirit named *Ufari* (literally means something that comes from above). The *Ufari* comes from the sky and sits at the top of a tree. Due to the weight of the *Ufari*, the tree starts bending. Once the top of the tree touches the ground, the *Ufari* takes the shape of a tiger that kills people. Whenever people talk about the tiger, they do so very respectfully. They carry sacred beads and threads given to them by spiritual leaders in the belief that these will protect them from man-eating tigers. People also put sacred red flags in the area in which they work so that the tiger cannot approach them. Furthermore, they do not usually go to work in the Sundarbans without a companion of the “same blood”—that is, a close relative such as a brother or son. This is because they believe that if a man-eating tiger attacks someone in the group, everyone other than a close relative will run away to save himself. People always try to work in groups, and many groups have a professional spiritual man, locally known as the *Gunin* or *Guni,* who is believed to have the spiritual power to lock the jaws of the tiger and move it away so that people can work freely. The *Guni* carries a big stick and carefully watches the surroundings while others work. The verses he uses to deter the tiger are considered top secret and are not normally revealed. Three of them, translated, are: "Sunken on the blood, the soul from the blood [tiger], if you look toward my people, [you will have to] tear out your own penis and eat"; "In the name of Ali, in the name of Fatema, hey bastard [tiger], get lost"; and "Mother Fatema, [I have] come to your forest, please keep me in mind."

The growing concern for tiger conservation among government bodies, international organizations, and people in general is affirmative progress on the road to ensuring that the tiger survives. This magnificent creature has lived in the incredible wilderness of the Sundarbans for hundreds of years, intimately intertwined with the history and culture of the region; hence, the tiger is the national animal of both Bangladesh and India. It is the heart of the Sundarbans. As Asir Johnsingh said, "Saving the tiger is a challenge for mankind." We do need to take it as a challenge. We cannot let the tiger become extinct.

M. Monirul H. Khan is a wildlife biologist working on the tiger and other wild animals of Bangladesh. Currently he is at the final stage of his Ph.D. degree at the University of Cambridge, U.K. He conducted his Ph.D. fieldwork on the ecology and conservation of the tiger in the Sundarbans of Bangladesh. He was involved with a number of wildlife projects in Bangladesh, and has written fifteen scientific articles and many popular articles. Mr. Khan is also a keen wildlife photographer.

Appendix V Tiger sightings during fieldwork (September 2001-February 2003) in the Sundarbans East Wildlife Sanctuary

Sl. no.	Date	Time and duration (approx.)	Location	Habitat type	Closest sighting distance (m) (approx.)	Age and sex of the tiger	Note
1	09 August 2001	1630 h, 20 minutes	Jamtala, Katka	Grassland	180	Adult, probably ♀	Luckily, the first sighting of the tiger was in the first trip, i.e. during the reconnaissance survey. After hearing calls of two tigers we climbed up 'Tonmoy' tower and saw this tiger sitting in the grassland and looking at us from c. 180 m distance.
2	12 September 2001	1725 h, few seconds	Bank of Kochikhali creek, Kochikhali	Mangrove woodland	10	Adult ♀	We were on a dinghy entering deep into the forest through a narrow creek. Suddenly we got a strong smell (a mixture of rotten meat and cooked Bashmati rice). In few seconds we saw the glance of a medium-sized tiger running away. Since it was getting dark, and we saw it for few seconds, we were not sure whether it was really a tiger or not, we went down and found the remains of a spotted deer kill and fresh pugmarks of a tigress. The smell was probably coming from the kill.
3	18 October 2001	1500 h, 15 minutes	Northern end of Jamtala grassland, Katka	Grassland	50	Adult ♂	At first we saw some fresh pugmarks on the sand, then saw the tiger who produced those. It was walking through open areas of the grassland. We started following it from ca. 150 m behind. Then it sat for defaecation, like the dogs do, and scratched the soil towards the scat after the defaecation. By the time it defaecated, we went in 50 m distance. At the time when it turned toward the woodland, I made a whistle to to attract it and get a photo with the face. It gave the chance and started running for the forest.
4	19 October 2001	0630 h, 10 minutes	Katka river, Katka	River	250	Adult ♂	After hearing repeated calls of a pair (?) of tigers in two sides of the river, we saw a tiger from our houseboat. The tiger was crossing the river in the early morning c. 350 m away from us. By the time we started the boat and started approaching, it went to the other bank (from where probably the female called), looked at us, and went inside the mangrove woodland. It was probably the same adult male mentioned in sl. no. 3.

Appendix V Continued

5	20 November 2001	1315 h, -	Southern Kochikhali	Grassland	-	Sub-adult ♂	It was a dead tiger that we found. After watching many fresh pugmarks and scats, we climbed up a big *Syzygium* tree to wait for the tiger. We were in the tree for two hours and half, getting a repugnant smell time to time. We thought it might be from a tiger kill. After getting down we started looking for the source of smell and found a dead sub-adult male tiger in the grassland. Head-body length was 128 cm and tail length was 66 cm. It was probably killed by another male tiger in a territorial conflict a few days ago. It had many scratch marks on its body. Probably it was killed about 10 m away and dragged this distance. The sungrass was flattened in the entire area and there were many tiger hairs, which indicate a deadly fight before the sub-adult was killed. We immediately informed the Forest Office in Kochikhali and helped the Forest Department personnel to collect the dead body of the tiger.
6	22 November 2001	1610 h, several seconds	Bank of Kochikhali creek, Kochikhali	Mangrove woodland	150	Adult ♀	We were on a dinghy in the creek. Suddenly we heard the *tao-tao-tao* alarm calls of spotted deer in a small open area in the bank of the creek. The deer herd started running away immediately afterwards. We became attentive, looking for the tiger. In few seconds we saw the tiger walking slowly through the edge of the open area and the woodland. We immediately moved our boat behind a bush at the bank of the creek, but the tiger did not wait. We went there and found the fresh pugmarks of an adult female.
7	23 December 2001	0930 h, few seconds	Close to Kochiklali mosque, Kochikhali	Transition between mangrove woodland and grassland	15	Probably a sub-adult	At the start of a line-transect sampling, I was recording the geographic location in the data sheet. By that time one of my three field assistants (Hashem Gazi) went ahead close to the dense woodland. Suddenly an 'animal' started growling and ran towards Hashem ahead of me. I looked in that direction and glimpsed an animal. It happened so suddenly that Hashem fell down while moving round. We went to help him and moved away a little in a relatively open grassland. We were discussing whether it was a tiger or a wild boar, the latter also growls and charges people some times. A group of four sungrass cutters saw the whole event from a distance. They came close to us, and to show their courage, went close to the woodland ignoring my suggestion of not going there. At that time the animal typically growled loudly and rushed, and the sungrass cutters ran away in fear leaving their slippers behind. We also had to run away with them, because there was no tree in the vicinity to climb up. The latter growl confirmed that it was a tiger.

Appendix V Continued

8	30 January 2002	1900 h, few seconds	Kochikhali creek, Kochikhali	Creek	70	Adult ♂ and ♀ (pair)	At night I was going to the toilet at the rear end of our houseboat. It was very low tide at the creek. Suddenly I heard the bold sound of a big animal jump on the creek and started walking loudly in the mud. I was almost sure that it was a tiger. I rushed inside the boat, brought the torch out and turned it on, but could not see anything. After few minutes all my assistants went back inside the houseboat and I proceeded to enter the toilet. At that time the whole sequence was repeated. I immediately turned the torch on and directed towards the sound and saw the blazing bluish-white reflection from the eyes of a tiger. It was on the muddy bank of the creek. It looked at me, and then jumped up the bank and went to the forest. The next morning we went there to investigate on the pugmarks which showed that there was a pair of tigers crossed the creek, but we could not see the first one, because by the time I brought my torch out, it crossed the creek and went inside the forest.
9	8 March 2002	1600 h, 20 minutes altogether	Saper creek, Supati	Mangrove woodland	6	Young ♂	This young tiger was sitting at the bank of a narrow creek during low tide, probably in order to catch fish or crabs. After watching our dinghy, it went inside dense bush in mangrove woodland along the bank of the creek and started watching us. We also watched and photographed it for about 15 minutes. Then it moved away. We turned round and went to that direction through the creek, but could not find it. When we were coming back, we found it at the same area where we first saw it. After few minutes it again vanished inside the forest. We again turned round and look for it, but could not find it. Again while returning, we found it at the first-sighting area for a very short time. Then we moved our boat behind some vegetation and spent an hour, but it did not appear again.
10	15 March 2002	1410 h, 20 minutes altogether	Southern end of Jamtala grassland, Katka	Transition between mangrove woodland and grassland	250	Adult ♂	After arriving in Katka we heard that a pair of tigers have been repeatedly seen in Jamtala meadow for the last three days. We immediately went to 'Tonmoy' tower and started searching for the tiger by the binoculars. After ten minutes I found it sitting in the grassland. It was facing opposite to us. After about 10 minutes, it started moving. We saw the serpentine movement of its striped back in the grassland. It went away from our sight, but after half an hour, at a short distance from its initial location, a herd of spotted deer started making alarm calls and the tiger was visible for a short time. Then we climbed down and rushed to that area, but could not find it.

Appendix V Continued

11	15 April 2002	0830 h, 1 minute altogether	Pond for the tiger, Kochikhali	In and around a pond	12	Sub-adult	At first I saw the back of this tiger from far away. It was walking along the grassland close to a pond that was dug for tigers so that they get freshwater to drink. When we went close to the pond we could not find it. Suddenly one of my assistants saw it in the pond, half submerged in the water. There was very little water on that small pond, so it was more like a depression on the grassland. In few seconds after my assistant saw it, we saw it springing out of the pond in one big jump and run away.
12	15 April 2002	1240 h, several seconds	Close to the pond for the tiger, Kochikhali	Transition between mangrove woodland and grassland	200	Adult, probably ♀	On the same day we saw the tiger mentioned in sl. no. 11, we took a position away from the pond (on the bank of another pond that has concrete benches) hoping that the tiger might reappear. After about one hour, we saw an adult tiger (probably the resident tigress of that area and the mother of the sub-adult tiger we saw at the same day) walking along the edge of the forest. Before entering the forest it rose its head and watched the surroundings. Then we went to that area, but could not find it.
13	21 April 2002	1100 h, few seconds	North from Katka Forest Office, Katka	Mangrove woodland	30	Adult, probably ♂	While in the forest we saw many pugmarks of a huge male and an adult female. We went to the top of a small mound from where one of my assistants first saw the big tiger walking away through dark and dense *Ceriops decandra* bush under mangrove woodland. My assistant showed me immediately and I saw it walking away very slowly and silently.
14	19 June 2002	1815 h, few minutes	Close to Kochikhali mosque, Kochikhali	Grassland	120	Sub-adult	It was late afternoon when we were returning from the fieldwork. I saw many spotted deer still grazing in the meadow and thought that the tiger might come out to hunt. We sat on the concrete benches on the bank of a pond in the meadow. After only 15 minutes I saw a sub-adult tiger coming out from the *Acrostichum aureum* to the grassland, intending to cross the small patch of grassland and go to the mangrove woodland on the opposite side. It stopped in the middle of the grassland where it suddenly moved its head and tail because a black drongo (*Dicrurus macrocercus*) was repeatedly swooping towards its head. When we started approaching it, it saw us and ran back to the *A. aureum* bush.
15	23 August 2002	0920 h, 1 minute	Kochikhali creek, Kochikhali	Creek	150	Adult	It was a very rainy day and I was on the houseboat inquiring about recent tiger sightings with two Forest Department staff. It was high tide and many things were floating with strong current of the creek. Suddenly I saw something like a floating log, but also like a swimming tiger. I immediately looked through the binoculars and found that it was a tiger swimming across the creek. It was already very close to the opposite bank, so by the time I brought my camera out, it vanished to the forest in the other bank. We immediately went to the bank by our dinghy, but could not find it.

Appendix VI The birds of the Sundarbans East Wildlife Sanctuary of Bangladesh (N.B. This paper was prepared during the PhD course and has been submitted in the journal *Forktail*)

Species diversity, relative abundance and habitat use of the birds in the Sundarbans East Wildlife Sanctuary of Bangladesh

M. MONIRUL H. KHAN

The study was conducted in the Sundarbans East Wildlife Sanctuary of Bangladesh, for 18 months (September 2001 – February 2003), but the birds were counted from line transects only in two sampling periods in summer and winter. A total of 198 species was recorded, including four globally threatened species, of which 134 (68%) were resident and the rest 64 (32%) migrant. The overall species diversity index value was found quite high (3.865 in Shannon-Wiener formula), but it was higher in summer (3.973) than in winter (3.299). Among the total 198 species, 51 (26%) were Very Common, 42 (21%) Common, 48 (24%) Uncommon and 57 (29%) Rare. A total of 87 (44%) species used mangrove woodlands, 29 (15%) grasslands, 52 (26%) mudflats and 30 (15%) transitional zones as primary habitats. The sighting of the Streak-breasted Woodpecker *Picus viridanus* is the only record in the Indian Subcontinent after 1958. The Buffy Fish Owl *Ketupa ketupa* is the second record for Bangladesh. Until recently, the species was not record in the Indian Subcontinent after early 20th century. Moreover, at least 12 species of birds have been recorded for the first time in the Sundarbans of Bangladesh.

INTRODUCTION

The Sundarbans is a very unique ecosystem where many species of birds have been adapted. This is the largest single tract of tidal mangrove forest in the world. Some of the bird species found in this ecosystem may be designated as 'mangrove specialists'. The Sundarbans harbour some species of globally and nationally threatened birds.

There are quite a few scientific reports on the birds of the Sundarbans of Bangladesh. Rashid *et al.* (1994) first prepared a relatively complete checklist of birds where he mentioned the occurrence of 315 species in the Bangladesh Sundarbans. However, this checklist was prepared on the basis of his and others' observations as well as the hypothetical assumption of the occurrence of many species. Hence, there are many species in the list that are undoubtedly absent, e.g. Common Starling *Sturnus vulgaris*, Bar-tailed Treecreeper *Certhia himalayana*, Crested Bunting *Melophus lathami*, etc. Husain *et al.* (1983) studied the summer birds of the Bangladesh Sundarbans' Nilkamal Sanctuary, and Islam *et al.* (1999) studied the winter birds of the Bangladesh Sundarbans. Sarker and Sarker (1986) worked on the status and distribution of the birds of the Bangladesh Sundarbans. Rashid and Scott (1990) reported some waders of the Bangladesh Sundarbans. Khan (1986) reported the wildlife (including birds) in Bangladesh mangrove ecosystem. Rashid (1967), Husain (1967), Husain (1979), Khan (1982), Sarker and Sarker (1988), Harvey (1990), and Thompson and Johnson (1996) have produced lists of birds in Bangladesh where they have indicated that many of the species are found in the Sundarbans. Subsequent reports on notable birds (Thompson *et al.* 1993, Thompson and Johnson 2003) have updated the knowledge of the status and distribution of many species of birds in Bangladesh.

STUDY AREA

The entire Sundarbans is an area of about 10,000 km^2 in the Ganges-Brahmaputra delta of Bangladesh and India. Roughly 60% of this forest lies in the south-west of Bangladesh and the rest is in the south-east of the Indian state of West Bengal (Figure 1). Geographically the area is located between 21°30′-22°30′ N latitudes and 88°05′-89°55′ E longitudes. The monthly mean temperature and relative humidity normally varies from 23°C (during December-January) to 35°C (during May-June) and from 70% to 80% respectively. There are three wildlife sanctuaries in the Bangladesh Sundarbans (Sundarbans East, Sundarbans South and Sundarbans West) that together form a UNESCO World Heritage Site. The Sundarbans East Wildlife Sanctuary is one of these three sanctuaries (Figure 1). This is an area of 312 km^2 at the south-eastern end of the Sundarbans, and considered to be their richest part because of the diversity of habitats and richness of big mangrove trees as a result of less salinity. The present study was conducted in the Sundarbans East Wildlife Sanctuary, mainly looking at the species diversity, relative abundance and habitat use of the birds. Field notes were taken on the ecology, feeding and breeding activities of some birds.

The diversity of habitats has made the Sundarbans East Wildlife Sanctuary a unique place for birds. There are four major habitat types: 1) mangrove woodlands – areas dominated by mangrove trees like *Heritiera fomes*, *Excoecaria agallocha*, *Sonneratia apetala*, etc., totally covers about 70% of land part of the Sanctuary, also includes creeks because these are intertwined with mangrove woodlands; b) grasslands – open meadows with *Imperata cylindrica*, *Acrostichum aureum*, *Myriostachya wightiana*, etc., totally covers about 10% of land part of the

Sanctuary; c) mudflats – relatively open muddy and sandy tidal flat lands close to water, including sea beach, totally covers about 6% of land part of the Sanctuary; and d) transitional zones – areas that fell in none of the above-mentioned three categories, such as areas between mangrove woodland and grassland, characterised by having few trees and sometimes reeds, totally covers about 14% of land part of the Sanctuary. It should be mentioned here that, half of the Sundarbans East Wildlife Sanctuary is under deep water in the form of estuaries and big rivers.

METHODS

The birds were identified and recorded directly in the field in every month over an 18-month period (September 2001 – February 2003). The fieldwork was carried out for about a week in every month. The observations, made with 7-21 × 40 binoculars, were mainly in the mornings and evenings when the birds were most active. In many cases, photographs of the birds were taken in order to confirm the identification afterwards. Grimmett *et al.* (1998), and Ali and Ripley (1987) were used to identify the birds. Inskipp *et al.* (1996) was followed for the systematic list, English names and scientific names.

The birds were counted in two sampling periods: in summer (June 2002 – August 2002) and in winter (December 2002 – February 2003). These are the two main seasons in the Sundarbans. The summer is hot and wet whereas winter is cool and dry. A total of 22 days were spent in three months in each of these seasons to count birds from line transects covering all four major habitat types (mangrove woodlands, grasslands, mudflats and transitional zones). A total of 60 km transects were made in each season. The distance of transects was measured by a GPS (Garmin 12XL). The same transects were repeated in two seasons for a better comparison of the species diversity in summer and winter. The counts in both seasons were used to calculate the overall species diversity index of the study area. The software programme PC-ORD, Version 4.10 (MjM Software Design 1999), was used to calculate the species diversity indices. Both Shannon-Wiener Index and Simpson's Index were calculated. The basic assumptions of these two indices (Krebs 1999) were adequately met in the field conditions. The theory of Shannon-Wiener Index is –

$$H' = \Sigma\ (p_i)(log_2 p_i)$$

where H' = Shannon-Wiener index of diversity

p_i = Proportion of total sample belonging to ith species

On the other hand, the theory of Simpson's Index is –

$$1 - D = 1 - \Sigma\ (p_i)^2$$

where $(1 - D)$ = Simpson's index of diversity

p_i = Proportion of individuals of species i in the community

The relative abundance of birds was assessed by direct observation in the field, i.e., Very Common – a species seen in 75-100% of the observation-days, Common – seen in 50-74% of the observation-days, Uncommon – seen in 25-49% of the observation-days, and Rare – seen in fewer than 25% of the observation-days; Resident – the species always lives in Bangladesh and normally breeds in Bangladesh; Migrant – the species does not live in Bangladesh all through the year and breeds elsewhere. Records were taken when resident birds were observed to make significant local movements. In case of migratory birds, only the winter months were considered to assess the status, since they normally spend only the winter in Bangladesh. A similar method was followed by Khan (1980), Husain *et al.* (1983), Islam *et al.* (1999), Khan and Islam (2000), Das *et al.* (2000), etc. The primary habitat of each species of birds was identified on the basis of their maximum number of observations in one of the four habitat types mentioned earlier, but it does not mean that the species used only that habitat.

RESULTS AND DISCUSSION

Species diversity

A total of 198 species of birds were seen during the present study (see Appendix), of which 134 (68%) were resident and the rest 64 (32%) were migrant. This is nearly one-third of the total bird species recorded in Bangladesh. Out of these 198 species, 123 (62%) species were non-passerine and the rest 75 (38%) were passerine birds. In contrast, Rashid *et al.* (1994) reported the occurrence of 315 species of birds in the entire Bangladesh Sundarbans of which 231 (73%) were resident and the rest 84 (27%) were migratory. Islam *et al.* (1999) found 181 species of birds in winter months in the entire Bangladesh Sundarbans, of which 131 (72%) species were resident and 50 (28%) were migrant. Notably, the Sundarbans East Wildlife Sanctuary is only about 5% of the entire Bangladesh Sundarbans. It is remarkable that, unlike many other mangrove forests, the avian species diversity is very high in the Sundarbans. This is probably because the Sundarbans is a tangle of forests and wetlands, and hence can support both the forest-dwelling species as well as the wetland species.

The overall avian species diversity index value in the Sundarbans East Wildlife Sanctuary was found 3.865 in Shannon-Wiener formula and 0.9375 in Simpson's formula. For biological communities, Shannon-Wiener index of species diversity does not seem to exceed 5.0 (Washington 1984). Since the index value is close to 5.0, it may be concluded that the avian species diversity was high in the Sundarbans East Wildlife Sanctuary. Although the total number of species was higher in winter, but the total bird population was much higher at the same time owing to the influx of migratory birds from the Himalayas and the colder regions of Asia and Europe. Hence the species diversity index value is higher in summer than in winter. In Shannon-Wiener formula the index value in summer and winter were 3.973 and 3.299 respectively. On the other hand, in Simpson's formula these two values were 0.9683 and 0.8727 respectively. This is the first report of species diversity index for any biological community in the Sundarbans. The species diversity index is used to compare the species richness among different ecosystems.

Relative abundance and habitat use

The relative abundance shows that a total of 51 (26%) species were Very Common, 42 (21%) Common, 48 (24%) Uncommon and 57 (29%) Rare, i.e. the highest percentage of birds was Rare. A total of 87 (44%) species primarily used mangrove woodlands, 29 (15%) used grasslands, 52 (26%) used mudflats and 30 (15%) used transitional zones as primary habitats. It is clear that, most of the species primarily used mangrove woodlands including creeks, most of the species were found to use more than one habitat. In case of mangrove woodlands there were relatively more habitat available than used, but in case of mudflats it's the other way round. In case of grasslands and transitional zones the habitat use was roughly proportional to the habitat available (Figure 2).

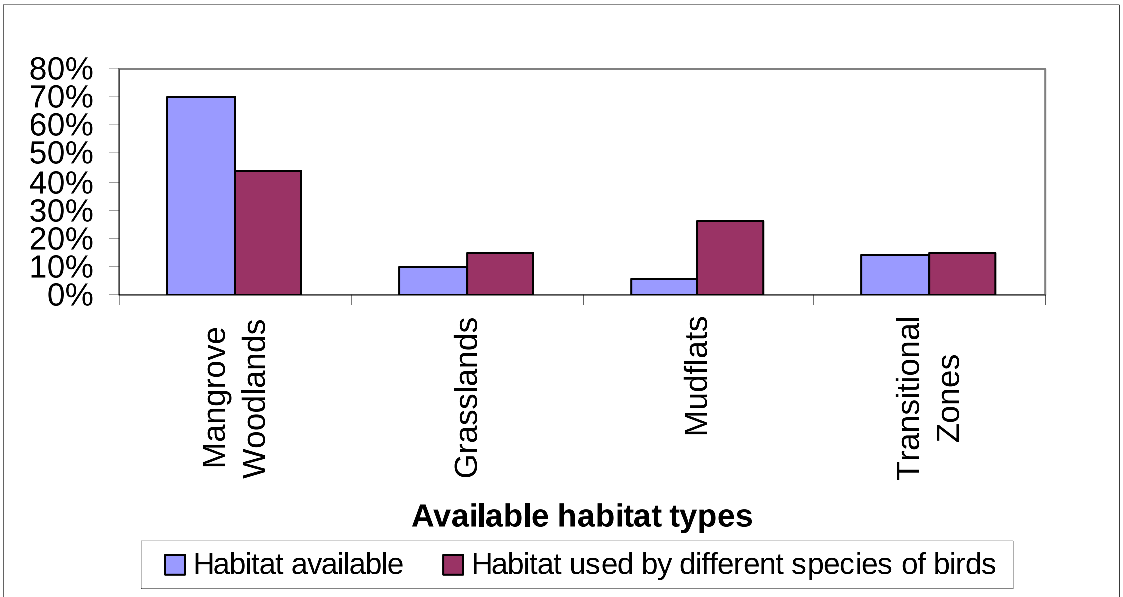

Figure 2. Habitats available and habitats used by different species of birds in the Sundarbans East Wildlife Sanctuary.

Significant records

Among the birds sighted in the Sundarbans East Wildlife Sanctuary, four species are globally threatened (Masked Finfoot *Heliopais personata*, White-rumped Vulture *Gyps bengalensis*, Greater Spotted Eagle *Aquila clanga* and Lesser Adjutant *Leptoptilos javanicus*: BirdLife International 2001) and seven species are nationally threatened (Dollarbird *Eurystomus orientalis*, Ruddy Kingfisher *Halcyon coromanda*, Brown Fish Owl *Ketupa zeylonensis*, Masked Finfoot, White-bellied Sea Eagle *Haliaeetus leucogaster*, Malayan Night Heron *Gorsachius melanolophus* and Lesser Adjutant: IUCN-Bangladesh 2000). Moreover, Brown-winged Kingfisher *Halcyon amauroptera*, Black-headed Ibis *Threskiornis melanocephalus* and Mangrove Pitta *Pitta megarhyncha* are globally Near Threatened (BirdLife International 2001).

MASKED FINFOOT *Heliopais personata*

The Masked Finfoot is a globally Vulnerable species (BirdLife International 2001). It was seen quite often, all through the year, which indicates that it is resident in the Sundarbans. The sighting months were October 2001, November 2001, December 2001, February 2002, April 2002, August 2002, October 2002, and December 2002. Females were seen more often than males. A pair with two juveniles were seen in October 2001 and another pair was seen in April 2002. It was found to forage even at the darkness of the evening. Seen feeding on small crabs during low tide, and resting under the bush in the bank of creeks. When alarmed, it prefers to run to the bush in the bank of creeks rather than to fly. Run on the water surface before flying. Flight is just above the water surface. Utters harsh *keek-keek-keek* call specially when starts flying, or rarely mild *peek peek peek* while foraging.

WHITE-RUMPED VULTURE *Gyps bengalensis*

The White-rumped Vulture is globally Critically Endangered (BirdLife International 2001). It is locally common in the fringing areas of the Sundarbans, but only one group of seven individuals was seen flying in the sky of the study area in September 2002. The local fishermen had informed me that vultures rarely come down to the mudflats of the Sundarbans East Wildlife Sanctuary.

GREATER SPOTTED EAGLE *Aquila clanga*

The Greater Spotted Eagle is a globally Vulnerable species (BirdLife International 2001). The Greater Spotted Eagle was seen only twice, on the estuary of a big river (Baleshawr). It is occasionally seen in the mudflats of big rivers and estuaries (Meghna, Jamuna and Padma) of Bangladesh.

LESSER ADJUTANT *Leptoptilos javanicus*

The Lesser Adjutant is a globally Vulnerable species (BirdLife International 2001), but it was quite commonly seen in almost all months of the study period, which indicates that it a common resident in the Sundarbans. Juvenile birds were seen for three times, all in October 2002. Normally seen singly, but pairs or family parties of 3-6 individuals were also seen. On three occasions I found remains of Lesser Adjutant in the scats of the Tiger *Panthera tigris*. The kill remains were also found for five times. It becomes a victim of the tiger probably when it forages on foot in grassy areas.

BROWN-WINGED KINGFISHER *Halcyon amauroptera*
Although the Brown-winged Kingfisher is a globally Near Threatened species (BirdLife International 2001), it is locally very common in the Sundarbans. It was seen in all months during the study period, in most of the observation-days.

BLACK-HEADED IBIS *Threskiornis melanocephalus*
The Black-headed Ibis is a globally Near Threatened species (BirdLife International 2001). During the present study, only one pair of Black-headed Ibis was sighted and that sighting was in September 2002. Although this species is rare in the Sundarbans, it is quite common in Meghna estuary, about 100 km eastwards from the Sundarbans.

MANGROVE PITTA *Pitta megarhyncha*
The Mangrove Pitta is a globally Near Threatened species (BirdLife International 2001). In the Indian Subcontinent it is found only in the Sundarbans. Details of its breeding are not recorded in the region (Grimmett et al. 1998). During the present study the Mangrove Pitta was seen in September 2001, November 2001, January 2002, February 2002, April 2002, June 2002, August 2002 and January 2003. The sightings indicate that the species is a resident in the Sundarbans. A bird was seen carrying an invertebrate in its bill in September 2001, which indicates that it probably then had nestlings to feed. A juvenile was seen in February 2002.

STREAK-BREASTED WOODPECKER *Picus viridanus*
The Streak-breasted Woodpecker was sighted and photographed during the present study. The only certain record of this species in the Indian Subcontinent was one specimen collected from Burigoalini, about 50 km south-west of Khulna (i.e. north-western end of the Bangladesh Sundarbans) on 12 April 1958, but it was misidentified and subsequently described as the Laced Woodpecker *Picus vittatus* (Paynter 1970, Short 1973, Harvey 1990, Grimmett et al. 1998). Rasmussen (2000) compared this specimen with the specimens of Streak-breasted Woodpecker collected from adjacent Myanmar and concluded that the species is actually Streak-breasted Woodpecker. However, she agreed that unlike typical South-East Asian specimens, the plain throat and breast is common among the north-western populations of this species. During the present study I have noticed that they indeed have plain throat and apparently plain breast. Lower mandible was bright yellow, which supports its

identification as Streak-breasted Woodpecker. It was sighted in September 2001, October 2001, November 2001, April 2002, June 2002, September 2002, October 2002 and December 2002. From the observations it is clear that the species is resident in the Sundarbans. A parent and a juvenile seen foraging together in June 2002, and a pair seen foraging in September 2002.

BUFFY FISH OWL *Ketupa ketupa*

The Buffy Fish Owl was sighted and photographed during the present survey in the Sundarbans East Wildlife Sanctuary. The species was recorded for the first time in Bangladesh by Neumann-Denzau and Denzau (2003) when this paper was in preparation. I saw it in January 2002, September 2002, October 2002 and January 2003. Most sightings were in trees on the bank of narrow creeks. The records indicate that the species is probably resident in the Sundarbans. In the Indian Subcontinent, there has been no record of Buffy Fish Owl since the early 20^{th} century (Baker 1922-30, Stevens 1915). Grimmett *et al.* (1998) commented that it was recorded in east Assam (India) in early 20^{th} century; presumably once resident, current status unknown, no recent published records. Konig *et al.* (1999) give the present western limit of this species as southern Myanmar. In its global range, it is a resident or exceptionally a vagrant bird found in woody areas near water, such as wooded banks of rivers, also in mangrove forests (Konig *et al.* 1999). It is evident that the discovery of this bird in the Sundarbans has stretched its westernmost global distribution up to south-west Bangladesh, though this area is only about 300 km away from Myanmar border. Both Buffy Fish Owl and Streak-breasted Woodpecker are basically South-East Asian species. Their presence indicates that, some birds with South-East Asian affinity are found in the Sundarbans, as also pointed out by Paynter (1970), and Neumann-Denzau and Denzau (2003).

GREAT THICK-KNEE *Esacus recurvirostris*

In Bangladesh, the Great Thick-knee is found only in the Sundarbans. It was mentioned as a winter visitor (Harvey 1990, Grimmett 1998), but during the present study it was seen all through the year on the sandy beaches in the south-east of the sanctuary (Katka-Kochikhali, Dimer Char and Pokkhir Char). Moreover, two nests were found in February 2002 and March 2002; each had two pale buffy eggs with dark brown patches. The nest was a simple depression in the dry sand, with few dry twigs, in the upper part of the beach. Pairs were seen in October 2002, December 2002, January 2003 and February 2003. Based on these observations it can be concluded that the species is resident in the Sundarbans. Other than in pairs, they were commonly seen in small parties or rarely singles. The biggest party of 8 birds were seen in October 2001. Injury feigning (by sitting on the knees and hopping) was displayed by one of the pair in December 2002.

NEW RECORDS IN THE BANGLADESH SUNDARBANS

The present study recorded at least 12 species of birds for the first time in the Bangladesh Sundarbans. These are Blue-breasted Quail *Coturnix chinensis*, Spot-billed Duck *Anas poecilorhyncha*, Speckled Piculet *Picumnus innominatus*, Dollarbird, Blue-eared Kingfisher *Alcedo meninting*, Orange-breasted Green Pigeon *Treron bicincta*, Indian Pitta *Pitta brachyura*, Black-naped Oriole *Oriolus chinensis*, Lesser Racket-tailed Drongo *Dicrurus remifer*, Scaly Thrush *Zoothera dauma*, Yellow-eyed Babbler *Chrysomma sinensis* and Ruby-cheeked Sunbird *Anthreptes singalensis*. However, these species were previously recorded in other areas of Bangladesh.

Harvey (1990) compiled the status and distribution of birds in Bangladesh. According to this compilation the status and distribution of the above-mentioned birds are: Blue-breasted Quail – former resident in open country; Spot-billed Duck – rare winter visitor in north-east, north-west and central regions in wetlands; Speckled Piculet – local resident in the north-east in forests, Dollarbird – local winter visitor in the south-east and north-east in forests; Blue-eared Kingfisher – rare resident in south-east, east-central, south and central regions in wooded wetlands; Orange-breasted Green Pigeon – local resident in north-east, south-east and north-west in forests and woodlands; Indian Pitta – rare resident in central region in woodlands; Black-naped Oriole – local winter visitor in north-east, central and south-east regions in wooded areas; Lesser Racket-tailed Drongo – local winter visitor in north-east, south-east and central regions in forests; Scaly Thrush – former winter visitor in south-east in woodlands, Yellow-eyed Babbler – local resident in north-east in scrub; and Ruby-cheeked Sunbird – locally common resident in north-east, south-east and central regions in forests and woodlands including mangroves.

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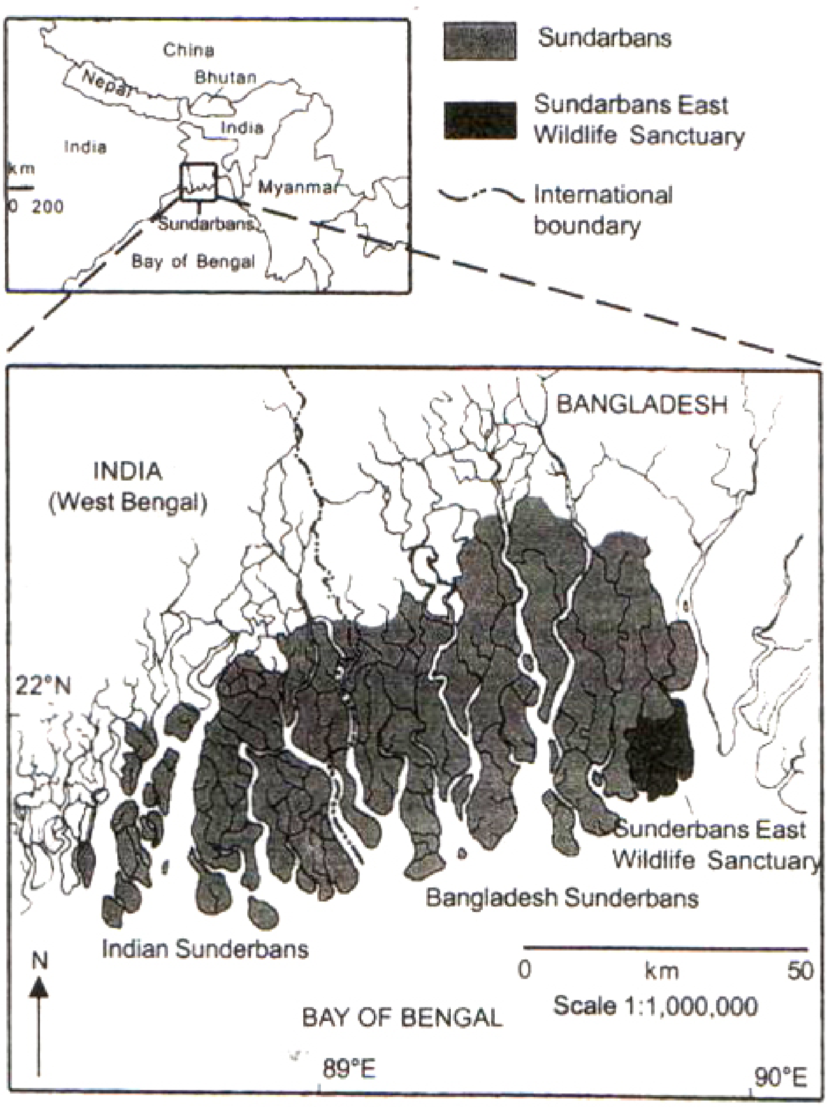

Figure 1. The Sunderbans of Bangladesh and India showing Sundarbans East Wildlife Sanctuary

APPENDIX

List of birds seen in the Sundarbans East Wildlife Sanctuary with their relative abundance and primary habitat

Species according to Orders and Families	Relative abundance, Resident/Migrant	Primary habitat
ORDER: GALLIFORMES		
FAMILY: PHASIANIDAE		
BLUE-BREASTED QUAIL *Coturnix chinensis*	uc, R	g
RED JUNGLEFOWL *Gallus gallus*	vc, R	w
ORDER: ANSERIFORMES		
FAMILY: DENDROCYGNIDAE		
LESSER WHISTLING-DUCK *Dendrocygna javanica*	r, R	m
COTTON PYGMY-GOOSE *Nettapus coromandelianus*	r, R	m
GADWALL *Anas strepera*	uc, M	m
SPOT-BILLED DUCK *Anas poecilorhyncha*	r, R	m
RED-CRESTED POCHARD *Rhodonessa rufina*	r, M	m
TUFTED DUCK *Aythya fuligula*	uc, M	m
ORDER: PICIFORMES		
FAMILY: PICIDAE		
EURASIAN WRYNECK *Jynx torquilla*	r, M	t
SPECKLED PICULET *Picumnus innominatus*	uc, R	w
GREY-CAPPED PYGMY WOODPECKER *Dendrocopos canicapillus*	c, R	t
FULVOUS-BREASTED WOODPECKER *Dendrocopos macei*	vc, R	w
RUFOUS WOODPECKER *Celeus brachyurus*	c, R	w
GREATER YELLOWNAPE *Picus flavinucha*	uc, R	w
STREAK-BREASTED WOODPECKER *Picus viridanus*	r, R	w
STREAK-THROATED WOODPECKER *Picus xanthopygaeus*	uc, R	w
GREY-HEADED WOODPECKER *Picus canus*	uc, R	w
COMMON FLAMEBACK *Dinopium javanensis*	uc, R	t
BLACK-RUMPED FLAMEBACK *Dinopium benghalense*	vc, R	w
GREATER FLAMEBACK *Chrysocolaptes lucidus*	vc, R	w
FAMILY: MEGALAIMIDAE		
LINEATED BARBET *Megalaima lineata*	c, R	w
COPPERSMITH BARBET *Megalaima haemacephala*	uc, R	w
ORDER: UPUPIFORMES		
FAMILY: UPUPIDAE		
COMMON HOOPOE *Upupa epops*	c, R	g
ORDER: CORACIIFORMES		
FAMILY: CORACIIDAE		
INDIAN ROLLER *Coracias benghalensis*	uc, Rm	t
DOLLARBIRD *Eurystomus orientalis*	r, Rm	w
FAMILY: ALCEDINIDAE		
COMMON KINGFISHER *Alcedo atthis*	vc, R	w
BLUE-EARED KINGFISHER *Alcedo meninting*	uc, R	w
FAMILY: HALCYONIDAE		
BROWN-WINGED KINGFISHER *Halcyon amauroptera*	vc, R	w

RUDDY KINGFISHER *Halcyon coromanda*	uc, R	w
WHITE-THROATED KINGFISHER *Halcyon smyrnensis*	vc, R	w
BLACK-CAPPED KINGFISHER *Halcyon pileata*	vc, R	w
COLLARED KINGFISHER *Todiramphus chloris*	vc, R	w
FAMILY: CERYLIDAE		
PIED KINGFISHER *Ceryle rudis*	r, R	m
FAMILY: MEROPIDAE		
GREEN BEE-EATER *Merops orientalis*	vc, Rm	g
BLUE-TAILED BEE-EATER *Merops philippinus*	vc, Rm	g
CHESTNUT-HEADED BEE-EATER *Merops leschenaulti*	c, Rm	g
ORDER: CUCULIFORMES		
FAMILY: CUCULIDAE		
CHESTNUT-WINGED CUCKOO *Clamator coromandus*	r, Rm	w
COMMON HAWK CUCKOO *Hierococcyx varius*	vc, R	w
INDIAN CUCKOO *Cuculus micropterus*	vc, Rm	w
EURASIAN CUCKOO *Cuculus canorus*	uc, Rm	w
PLAINTIVE CUCKOO *Cacomantis merulinus*	c, Rm	g
ASIAN KOEL *Eudynamys scolopacea*	vc, R	w
GREEN-BILLED MALKOHA *Phaenicophaeus tristis*	vc, R	w
FAMILY: CENTROPODIDAE		
GREATER COUCAL *Centropus sinensis*	vc, R	w
ORDER: PSITTACIFORMES		
FAMILY: PSITTACIDAE		
ROSE-RINGED PARAKEET *Psittacula krameri*	c, R	w
ORDER: APODIFORMES		
FAMILY: APODIDAE		
ASIAN PALM SWIFT *Cypsiurus balasiensis*	vc, R	t
ORDER: STRIGIFORMES		
FAMILY: STRIGIDAE		
EURASIAN EAGLE OWL *Bubo bubo*	uc, R	w
BROWN FISH OWL *Ketupa zeylonensis*	uc, R	w
BUFFY FISH OWL *Ketupa ketupa*	uc, R	w
BROWN WOOD OWL *Strix leptogrammica*	r, R	w
FAMILY: CAPRIMULGIDAE		
LARGE-TAILED NIGHTJAR *Caprimulgus macrurus*	vc, Rm	w
INDIAN NIGHTJAR *Caprimulgus asiaticus*	r, Rm	w
ORDER: COLUMBIFORMES		
FAMILY: COLUMBIDAE		
ORIENTAL TURTLE DOVE *Streptopelia orientalis*	r, Rm (M)	t
SPOTTED DOVE *Streptopelia chinensis*	vc, R	g
EURASIAN COLLARED DOVE *Streptopelia decaocto*	vc, R	g
EMERALD DOVE *Chalcophaps indica*	uc, R	w
ORANGE-BREASTED GREEN PIGEON *Treron bicincta*	c, Rm	w
POMPADOUR GREEN PIGEON *Treron pompadora*	c, R	t
YELLOW-FOOTED GREEN PIGEON *Treron phoenicoptera*	uc, R	t
ORDER: GRUIFORMES		
FAMILY: HELIORNITHIDAE		
MASKED FINFOOT *Heliopais personata*	uc, R	w

FAMILY: RALLIDAE		
SLATY-BREASTED RAIL *Gallirallus striatus*	r, R	w
WHITE-BREASTED WATERHEN *Amaurornis phoenicurus*	r, R	w
RUDDY-BREASTED CRAKE *Porzana fusca*	r, R	t
ORDER: CICONIIFORMES		
FAMILY: SCOLOPACIDAE		
PINTAIL SNIPE *Gallinago stenura*	uc, M	g
COMMON SNIPE *Gallinago gallinago*	c, M	g
BLACK-TAILED GODWIT *Limosa limosa*	uc, M	m
WHIMBREL *Numenius phaeopus*	vc, M	m
EURASIAN CURLEW *Numenius arquata*	c, M	m
COMMON REDSHANK *Tringa totanus*	vc, M	m
MARSH SANDPIPER *Tringa stagnatilis*	vc, M	m
COMMON GREENSHANK *Tringa nebularia*	vc, M	m
WOOD SANDPIPER *Tringa glareola*	c, M	m
TEREK SANDPIPER *Xenus cinereus*	r, M	m
COMMON SANDPIPER *Actitis hypoleucos*	vc, M	m
RUDDY TURNSTONE *Arenaria interpres*	r, M	m
SANDERLING *Calidris alba*	uc, M	m
FAMILY: JACANIDAE		
PHEASANT-TAILED JACANA *Hydrophasianus chirurgus*	r, R	t
FAMILY: BURHINIDAE		
GREAT THICK-KNEE *Esacus recurvirostris*	uc, R	m
FAMILY: CHARADRIIDAE		
BLACK-WINGED STILT *Himantopus himantopus*	r, M	m
PIED AVOCET *Recurvirostra avosetta*	r, M	m
PACIFIC GOLDEN PLOVER *Pluvialis fulva*	r, M	m
KENTISH PLOVER *Charadrius alexandrinus*	uc, M	m
LESSER SAND PLOVER *Charadrius mongolus*	vc, M	m
GREATER SAND PLOVER *Charadrius leschenaultii*	c, M	m
GREY-HEADED LAPWING *Vanellus cinereus*	r, M	m
RED-WATTLED LAPWING *Vanellus indicus*	vc, R	g
FAMILY: GLAREOLIDAE		
SMALL PRATINCOLE *Glareola lactea*	r, R	m
FAMILY: LARIDAE		
PALLAS'S GULL *Larus ichthyaetus*	r, M	m
BROWN-HEADED GULL *Larus brunnicephalus*	vc, M	m
BLACK-HEADED GULL *Larus ridibundus*	uc, M	m
GULL-BILLED TERN *Gelochelidon nilotica*	vc, M	m
CASPIAN TERN *Sterna caspia*	r, M	m
GREAT CRESTED TERN *Sterna bergii*	r, M	m
COMMON TERN *Sterna hirundo*	uc, M	m
LITTLE TERN *Sterna albifrons*	vc, M	m
WHISKERED TERN *Chlidonias hybridus*	vc, M	m
FAMILY: ACCIPITRIDAE		
OSPREY *Pandion haliaetus*	r, M	w
BLACK-SHOULDERED KITE *Elanus caeruleus*	uc, R	g
BLACK KITE *Milvus migrans*	uc, R	m
BRAHMINY KITE *Haliastur indus*	vc, R	w

WHITE-RUMPED VULTURE *Gyps bengalensis*	r, R	m
WHITE-BELLIED SEA EAGLE *Haliaeetus leucogaster*	vc, R	w
CRESTED SERPENT EAGLE *Spilornis cheela*	vc, R	w
EURASIAN MARSH HARRIER *Circus aeruginosus*	r, M	g
PIED HARRIER *Circus melanoleucos*	r, M	g
SHIKRA *Accipiter badius*	vc, R	w
GREATER SPOTTED EAGLE *Aquila clanga*	r, M	m
CHANGEABLE HAWK EAGLE *Spizaetus cirrhatus*	uc, R	w
FAMILY: FALCONIDAE		
COMMON KESTREL *Falco tinnunculus*	uc, M	t
PEREGRINE FALCON *Falco peregrinus*	r, M	t
FAMILY: PHALACROCORACIDAE		
LITTLE CORMORANT *Phalacrocorax niger*	r, R	m
FAMILY: ARDEIDAE		
LITTLE EGRET *Egretta garzetta*	vc, R	m
GREY HERON *Ardea cinerea*	r, R	m
GREAT EGRET *Casmerodius albus*	vc, R	m
INTERMEDIATE EGRET *Mesophoyx intermedia*	c, R	m
CATTLE EGRET *Bubulcus ibis*	r, R	m
INDIAN POND HERON *Ardeola grayii*	c, R	w
LITTLE HERON *Butorides striatus*	vc, R	w
BLACK-CROWNED NIGHT HERON *Nycticorax nycticorax*	r, R	g
MALAYAN NIGHT HERON *Gorsachius melanolophus*	r, Rm	w
CINNAMON BITTERN *Ixobrychus cinnamomeus*	r, R	w
FAMILY: THRESKIORNITHIDAE		
BLACK-HEADED IBIS *Threskiornis melanocephalus*	r, R	m
FAMILY: CICONIIDAE		
LESSER ADJUTANT *Leptoptilos javanicus*	c, R	m
ORDER: PASSERIFORMES		
FAMILY: PITTIDAE		
INDIAN PITTA *Pitta brachyura*	r, R	w
MANGROVE PITTA *Pitta megarhyncha*	r, R	w
FAMILY: IRENIDAE		
GOLDEN-FRONTED LEAFBIRD *Chloropsis aurifrons*	uc, R	w
FAMILY: LANIIDAE		
BROWN SHRIKE *Lanius cristatus*	uc, M	t
LONG-TAILED SHRIKE *Lanius schach*	c, R	t
GREY-BACKED SHRIKE *Lanius tephronotus*	r, M	t
FAMILY: CORVIDAE		
RUFOUS TREEPIE *Dendrocitta vagabunda*	c, R	w
HOUSE CROW *Corvus splendens*	c, R	w
LARGE-BILLED CROW *Corvus macrorhynchos*	uc, R	w
ASHY WOODSWALLOW *Artamus fuscus*	vc, R	t
BLACK-NAPED ORIOLE *Oriolus chinensis*	r, M	w
BLACK-HOODED ORIOLE *Oriolus xanthornus*	c, R	w
LARGE CUCKOOSHRIKE *Coracina macei*	vc, R	w
BLACK-WINGED CUCKOOSHRIKE *Coracina melaschistos*	r, M	w
SMALL MINIVET *Pericrocotus cinnamomeus*	vc, R	w
SCARLET MINIVET *Pericrocotus flammeus*	c, R	w

BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*	uc, R	w
WHITE-THROATED FANTAIL *Rhipidura albicollis*	c, R	w
BLACK DRONGO *Dicrurus macrocercus*	vc, R	t
ASHY DRONGO *Dicrurus leucophaeus*	c, M	t
BRONZED DRONGO *Dicrurus aeneus*	vc, R	w
LESSER RACKET-TAILED DRONGO *Dicrurus remifer*	r, M	w
SPANGLED DRONGO *Dicrurus hottentottus*	uc, R	w
GREATER RACKET-TAILED DRONGO *Dicrurus paradiseus*	c, R	w
BLACK-NAPED MONARCH *Hypothymis azurea*	c, R	w
COMMON IORA *Aegithina tiphia*	c, R	w
FAMILY: MUSCICAPIDAE		
BLUE ROCK THRUSH *Monticola solitarius*	uc, M	t
ORANGE-HEADED THRUSH *Zoothera citrina*	r, R	w
SCALY THRUSH *Zoothera dauma*	r, M	w
DARK-SIDED FLYCATCHER *Muscicapa sibirica*	r, M	t
RED-THROATED FLYCATCHER *Ficedula parva*	c, M	w
VERDITER FLYCATCHER *Eumyias thalassina*	uc, M	t
BLUE-THROATED FLYCATCHER *Cyornis rubeculoides*	r, M	w
ORIENTAL MAGPIE ROBIN *Copsychus saularis*	c, R	t
BLACK REDSTART *Phoenicurus ochruros*	r, M	g
COMMON STONECHAT *Saxicola torquata*	uc, M	g
FAMILY: STURNIDAE		
CHESTNUT-TAILED STARLING *Sturnus malabaricus*	c, R	t
ASIAN PIED STARLING *Sturnus contra*	c, R	g
COMMON MYNA *Acridotheres tristis*	uc, R	g
BANK MYNA *Acridotheres ginginianus*	c, R	g
JUNGLE MYNA *Acridotheres fuscus*	vc, R	g
FAMILY: SITTIDAE		
VELVET-FRONTED NUTHATCH *Sitta frontalis*	c, R	w
FAMILY: PARIDAE		
GREAT TIT *Parus major*	vc, R	w
FAMILY: HIRUNDINIDAE		
BARN SWALLOW *Hirundo rustica*	vc, M	m
FAMILY: PYCNONOTIDAE		
RED-WHISKERED BULBUL *Pycnonotus jocosus*	c, R	t
RED-VENTED BULBUL *Pycnonotus cafer*	vc, R	t
FAMILY: CISTICOLIDAE		
ZITTING CISTICOLA *Cisticola juncidis*	vc, R	g
YELLOW-BELLIED PRINIA *Prinia flaviventris*	r, R	g
PLAIN PRINIA *Prinia inornata*	r, R	g
FAMILY: ZOSTEROPIDAE		
ORIENTAL WHITE-EYE *Zosterops palpebrosus*	uc, R	w
FAMILY: SYLVIIDAE		
BLYTH'S REED WARBLER *Acrocephalus dumetorum*	uc, M	t
CLAMOROUS REED WARBLER *Acrocephalus stentoreus*	r, M	t
COMMON TAILORBIRD *Orthotomus sutorius*	c, R	w
COMMON CHIFFCHAFF *Phylloscopus collybita*	uc, M	w
GREENISH WARBLER *Phylloscopus trochiloides*	uc, M	w
ABBOTT'S BABBLER *Malacocincla abbotti*	c, R	w

STRIPED TIT BABBLER *Macronous gularis*	c, R	w
YELLOW-EYED BABBLER *Chrysomma sinensis*	r, R	t
STRIATED BABBLER *Turdoides earlei*	c, R	g
FAMILY: ALAUDIDAE		
BENGAL BUSHLARK *Mirafra assamica*	c, R	g
FAMILY: NECTARINIIDAE		
PALE-BILLED FLOWERPECKER *Dicaeum erythrorynchos*	uc, R	w
RUBY-CHEEKED SUNBIRD *Anthreptes singalensis*	uc, Rm	w
PURPLE-RUMPED SUNBIRD *Nectarinia zeylonica*	r, R	w
PURPLE SUNBIRD *Nectarinia asiatica*	vc, R	w
CRIMSON SUNBIRD *Aethopyga siparaja*	uc, R	w
FAMILY: PASSERIDAE		
FOREST WAGTAIL *Dendronanthus indicus*	c, M	w
WHITE WAGTAIL *Motacilla alba*	vc, M	m
WHITE-BROWED WAGTAIL *Motacilla maderaspatensis*	r, R	m
CITRINE WAGTAIL *Motacilla citreola*	uc, M	m
YELLOW WAGTAIL *Motacilla flava*	r, M	m
GREY WAGTAIL *Motacilla cinerea*	c, M	g
PADDYFIELD PIPIT *Anthus rufulus*	c, R	g
OLIVE-BACKED PIPIT *Anthus hodgsoni*	uc, M	t
BAYA WEAVER *Ploceus philippinus*	vc, R	t
SCALY-BREASTED MUNIA *Lonchura punctulata*	c, R	g

Key

Relative abundance codes: vc = Very Common, c = Common, uc = Uncommon and r = Rare. **Resident/Migrant codes:** R = Resident, Rm = Resident but local migration observed, and M = Migrant. **Primary habitat codes:** w = Mangrove Woodlands including creeks, g = Grasslands, m = Mudflats including sea beaches, t = Transitional Zones.

Appendix VII List of some common plants of the Sundarbans

(Source: Chaffey *et al.* 1985, Hussain and Acharya 1994, personal observation)

Scientific name	Family	Local name	Type of plant
Acanthus ilicifolius	Acanthaceae	Hargoza	Scrambling, woody, thorny herb
Acrostichum aureum	Pteridiaceae	Hoda, hudo	Gregarious fern
Aegialitis rotundifolia	Plumbaginaceae	Dhalchaka	Small tree
Aegiceras corniculatum	Myrsinaceae	Khalisha, khalsi	Shrub or small tree
Amoora cucullata	Meliaceae	Amur	Small tree
Avicennia alba and/or *A. marina*	Avicenniaceae	Sada baen	Small tree
Avicennia officinalis	Avicenniaceae	Baen	Tree
Barringtonia racemosa	Barringtoniaceae	Kumb, kumba	Small tree
Blumea sp.	Compositae	Baria gash, bon gash	Aromatic herb
Brownlowia tersa	Tiliaceae	Sundri lota, lota sundri	Scandent shrub
Bruguiera gymnorrhiza	Rhizophoraceae	Kankra	Tree
Caesalpinia crista	Leguminosae	Kutum katta	Scandent, armed shrub
Cerbera manghas	Apocynaceae	Dagor	Small tree
Ceriops decandra	Rhizophoraceae	Goran	Shrub or small tree
Clerodendrum inerme	Verbenaceae	Sitka, sitki	Scandent shrub
Cynometra ramiflora	Leguminosae	Shingra	Shrub
Cyperus javanicus	Cyperaceae	Kucha, kusha	Grass-like herb (sedge)
Dalbergia candenatensis	Leguminosae	Chanda lota	Scrambling climber
Dalbergia spinosa	Leguminosae	Chanda katta	Scandent, armed shrub
Dendrophthoe falcata	Loranthaceae	Porgassa ?	Woody parasite in tree crown
Derris trifoliata	Leguminosae	Gila lota, gwalae lota, khali lota	Climber
Diospyrus peregrina	Ebenaceae	Gab	Tree
Drypetes sp.	Euphorbiaceae	Achet	Scandent shrub
Eriochloa procera	Graminae	Nol gash	Tall grass
Eugenia fruticosa	Myrtaceae	Ban jam, jam, jam gach	Small tree
Excoecaria agallocha	Euphorbiaceae	Gewa	Tree
Excoecaria indica	Euphorbiaceae	Batla, batul	Small tree
Ficus sp.	Moraceae	Jir	Tree with aerial roots
Flagellaria indica	Flagellariaceae	Abetaa	Climber
Flueggia virosa	Euphorbiaceae	Sitka, sitki	Scandent shrub
Heritiera fomes	Sterculiaceae	Sundri	Tree
Hibiscus tiliaceous	Malvaceae	Bhola	Shrub
Hoya sp.	Asclepiadaceae	Agusha	Climber
Imperata cylindrica	Graminae	Chhan	Grass
Intsia bijuga	Leguminosae	Bhaela, bharal	Small tree
Ipomoea pescaprae	Convulvulaceae	-	Succulent, prostrate herb
Ixora sp.	Rubiaceae	Bon bakul	Small tree
Kandelia candel	Rhizophoraceae	Gura, gurae, gural	Small tree

Appendix VII Continued

Lannea coromandelica	Anacardiaceae	Kocha, ziga	Tree
Leea aequata	Leeaceae	-	Shrub
Lepisanthes rubiginosa	Sapindaceae	Bon lichu	Tree
Luminitzera racemosa	Combretaceae	Kirpa	Small tree
Macrosolen cochinchinensis	Loranthaceae	Porgassa	Woody parasite in tree crowns
Mallotus repandus	Euphorbiaceae	Bon notoy	Scandent shrub
Mucuna gigantea	Leguminosae	Doyalguru, doyarguri	Climber; large seed pods have irritant hairs
Myriostachya wightiana	Gramineae	Dhansi, uri gash	Grass, common on new accretions
Nypa fruticans	Palmae	Golpatta	Palm with underground stem
Pandanus foetidus	Pandanaceae	Kewa katta	Prickley, succulent screw-pine
Petunga roxburghii	Rubiaceae	Narikili	Small tree
Phoenix paludosa	Palmae	Hental	Thorny palm
Phragmites karka	Gramineae	Nol khagra	Tall grass
Pnogamia pinnata	Leguminosae	Karamja, karanj	Small tree
Premna corymbosa ?	Verbenaceae	Serpoli, setpoli	Shrub or small tree
Rhizophora mucronata	Rhizophoraceae	Jhanna, garjan	Tree with stilt roots
Salasia chinensis	Celastraceae	Choyt boroi	Small tree
Sarcolobus globosus	Asclepiadaceae	Bowali lota	Climber
Sonneratia caseolaris	Sonneratiaceae	Choyla, ora	Tree
Sonneratia apetala	Sonneratiaceae	Keora	Tree
Stenochlaena palustris	Blechnaceae	Dheki lota	Climbing fern
Syzygium sp.	Myrtaceae	Bon jam	Tree
Tamarix indica	Tamaricaceae	Nonajhao, jhao	Small tree
Tetrastigma bracteolatum	Vitidiaceae	Golgoti lota	Climber
Thunbergia sp.	Thunbergiaceae	Jermani lota	Climber
Viscum monoicum	Loranthaceae	Shamu lota	Woody parasite in tree crowns
Xylocarpus granatum	Meliaceae	Dhandol	Small tree
Xylocarpus mekongensis	Meliaceae	Passur	Tree
Zizyphus sp.	Rhamnaceae	Bon boroi	Small tree

Appendix VIII List of amphibians, reptiles and mammals recorded during the fieldwork (September 2001-February 2003) in the Sundarbans East Wildlife Sanctuary, together with their respective status and primary habitat (N.B. The list of birds are given in Appendix VI)

Key
Relative abundance codes: vc = Very Common, c = Common, uc = Uncommon and r = Rare. **Primary habitat codes:** w = Mangrove woodlands, g = Grasslands; m = Mudflats (including sea beaches), rivers, creeks and ditches; t = Transitional zones.

AMPHIBIANS

Species according to Orders and Families	Relative abundance	Primary habitat
Order: Anura **Family: Bufonidae**		
1. Common toad *Bufo melanostictus*	r	m
Family: Ranidae		
2. Skipper frog *Euphlyctis cyanophlyctis*	c	m
3. Unidentified *Euphlyctis* sp.	r	m
4. Green frog *Euphlyctis hexadactylus*	c	m
5. Bull frog *Hoplobatrachus tigerinus*	uc	m
6. Cricket frog *Limnonectes limnocharis*	r	m
7. Leaf frog *Rana erythraea*	r	m
Family: Rhacophoridae		
8. Maculated tree frog *Polypedates maculatus*	vc	m

REPTILES

Species according to Orders and Families	Relative abundance	Primary habitat
Order: Crocodylia **Family: Crocodylidae**		
1. Estuarine crocodile *Crocodylus porosus*	uc	m
Order: Testudines **Family: Trionychidae**		
2. Spotted flap shell turtle *Lissemys punctata*	r	m
Family: Cheloniidae		
3. Olive ridley turtle *Lepidochelys olivacea*	uc	m
Order: Lacertilia **Family: Gekkonidae**		
4. Wall lizard *Gekko gecko*	c	w
Family: Agamidae		
5. Common garden lizard *Calotes versicolor*	c	g

Appendix VIII Continued

Family: Scincidae		
6. Common skink *Mabuya carinata*	c	g
7. Himalayan litter skink *Sphenomorphus indicus*?[1,2]	vc	g
Family: Varanidae		
8. Bengal monitor *Varanus bengalensis*	vc	g
9. Two-banded monitor *Varanus salvator*	vc	m
Order: Serpentes **Family: Boidae**		
10. Rock python *Python molurus*	r	g
Family: Colubridae		
11. Short-nosed vine snake *Ahaetulla prasina*[1]	r	g
12. Stripped keelback *Amphiesma stolata*	c	w
13. Dog-faced water snake *Cerberus rhynchops*	vc	m
14. Ornate flying snake *Chrysopelea ornata*	r	w
15. Rat snake *Coluber mucosus*	r	w
16. Common bronzeback tree snake *Dendrelaphis tristis*	r	w
17. Glossy marsh snake *Gerardia prevostianus*	uc	w
18. Common wolf snake *Lycodon aulicus*	r	g
19. Green keelback snake *Macropisthodon plumbicolor* ?	c	m
20. Checkered keelback *Xenochrophis piscator*	uc	m
Family: Elapidae		
21. Monocellate cobra *Naja kaouthia*	uc	w
22. Binocellate cobra *Naja naja*	r	w
23. King cobra *Ophiophagus hannah*	uc	w
Family: Hydrophidae		
24. Hook-nosed sea snake *Enhydrina schistosa*	c	m

MAMMALS

Species according to Orders and Families	Relative abundance	Primary habitat
Order: Chiroptera **Family: Pteropidae**		
1. Flying fox *Pteropus giganteus*	vc	w
2. Indian pipistrelle *Pipistrellus coromandra*	c	w
Order: Primates **Family: Cercopithecidae**		
3. Rhesus macaque *Macaca mulatta*	vc	w
Order: Carnivora **Family: Felidae**		
4. Tiger *Panthera tigris*	r	w
5. Leopard cat *Prionailurus bengalensis*	c	w
6. Fishing cat *Prionailurus viverrinus*	r ?	w ?
Family: Mustelidae		
7. Oriental small-clawed otter *Aonyx cinerea*	uc	m

Appendix VIII Continued

Order: Cetacea **Family: Phoceonidae**		
8. Finless porpoise *Neophocaena phocaenoides* ?	r	m
Family: Platanistidae		
9. Ganges river dolphin *Platanista gangetica*	vc	m
Order: Artiodactyla **Family: Suidae**		
10. Wild boar *Sus scrofa*	c	w
Family: Cervidae		
11. Spotted deer *Cervus axis*	vc	g
12. Barking deer *Muntiacus muntjak*	r	w
Order: Rodentia **Family: Sciuridae**		
13. Hoary-bellied Himalayan squirrel *Callosciurus pugerythrus*	vc	w
Family: Muridae		
14. Long-tailed tree mouse *Vandeleuria oleracea*[1]	vc	w
Family: Hystricidae		
15. Indian crested porcupine *Hystrix indica*	r	g

[1]A new record for the Bangladesh Sundarbans.
[2]Probably a new record for Bangladesh.

Appendix IX The occurrence of an ‘extinct’ hog deer in Bangladesh (N.B. This note was prepared during the PhD course and it is now in press on *Bangladesh Journal of Zoology*)

Scientific Note

THE OCCURRENCE OF AN ‘EXTINCT’ HOG DEER IN BANGLADESH

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The hog deer, *Axis porcinus* (Zimmermann), locally known as ‘Para Harin’, was feared extinct in Bangladesh. There was no recent report on the occurrence of this species in any part of the country. It was known to occur in the mixed evergreen forests of the greater Sylhet region (northeast) and in the Sundarbans mangrove forest (Khan 1985). The Sylhet population said to have disappeared during the liberation war in 1971 (Khan 1985). None reported this species from the Sundarbans in the last few decades (Hendrichs 1975; Khan 1982, 1985, 1987). Sarker and Sarker (1988) mentioned that it was an occasional visitor in the forests of the Sundarbans and Chittagong Hill Tracts.

Based on the information so far available, IUCN Bangladesh (2000), in the Red Book of Threatened Mammals of Bangladesh, declared the hog deer as an ‘extinct’ species in Bangladesh. Prior to this, Khan (1982, 1985, 1987) mentioned it as a ‘possibly extinct’ species. He did not mention about its distribution in the Chittagong Hill Tracts.

In the third week of March 2002, a young male hog deer was trapped by the local tribal people from a grassy hill slope in Guimara, Khagrachari. This deer was rescued from the trappers by the local Forest Department officials. From then on, the deer was being kept in an enclosure in the Divisional Forest Officer’s residence in Khagrachari town.

The size of this deer was slightly bigger than a barking deer, *Muntiacus muntjak*. It had stout appearance, with relatively short legs. Movements like that of a hog, hence the name ‘hog deer’. The fur was brown, paler towards the underparts. Inside of the ears and underside of the tail were white. All these characters coincide with the characters of the hog deer described by Prater (1971). Few white rounded spots along the back indicate that this specimen was young. According to Prater (1971), some young stags and hinds show these spots. It was a male but yet to grow antlers.

Since the nearest Indian forest is at least 50 km away from the spot of trapping (Guimara), and since this species does not migrate, it is certain that this individual was a resident in Bangladesh. According to Prater (1971), the hog deer are generally solitary creatures, and a pair will continue to frequent a particular stretch of grassland. Moreover, an army official in the Guimara Army Camp, Khagrachari, informed that they had shot this type of deer few years ago. The author personally visited the hills of the Guimara area and it was found suitable to support hog deer population.

Based on the above-mentioned information it can be concluded that at least a small population of hog deer still exists in the grassy/bushy hills of the Chittagong Hill Tracts, particularly in the Guimara area. Hence the hog deer is not an extinct species in Bangladesh, but may be considered as a highly endangered species.

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Appendix X A sample interview sheet, similar to one in Bengali used in the Sundarbans and adjacent areas in order to interview local people and record information on different aspects of tiger-human interactions

Name of the interviewee: …………………………………, Age: ………, Profession: …………………….., Marital status: ……………….
Address: ……………………………...………………………………………………………………………………………………
Place of interviewing: ………………………...………………………………………………………., Date: …………..……………

Sl. no.	**Question**	**Answer**							
1	Have you ever seen dead/killed/ injured tiger(s)? If yes, then:	Sl. no.	Dead/killed/ injured	Where	When	Sex (M/F)	Age (adult/ juvenile/young)	Why dead/killed/injured? (if known)	How dead/killed/injured? (if known)
		1							
		2							
		3							
		4							
		5							
		6							
		7							

Sl. no.	**Question**										
2	Have you ever seen killed/ injured human(s) (by tiger)? If yes, then:	Sl. no.	Killed/ injured	Name	Address	Age	Sex	Profession	Place of killing/injury	Dragging distance of the kill	Type of killing/ injury
		1									
		2									
		3									
		4									
		5									
		6									
		7									

Appendix X Continued

3	Have you ever seen tigers in pairs, or tigress with small cubs? If yes: Where and when? How many cubs? What they were doing?	
4	What do you do to protect yourself from the tiger?	Protection type: practical and spiritual/practical/spiritual/none (√)
5	Have you ever seen a tiger anywhere?	In the Sundarbans/adjacent village/zoo/circus (√)
6	What were the conditions of sighted wild tigers?	Normal live/injured/dead/killed (√)
7	Do you know about Bangladesh Wildlife Act 1974?	Don't know/weakly know/properly know (√)
8	Do you believe on the medicinal use of tiger parts?	No/not sure/yes (√)
7.	Do you want to conserve the tiger? Why no/yes?	No/not sure/yes (√)

***Ad libitum* notes:** ……………………..……………………………………………………………………………………………………..

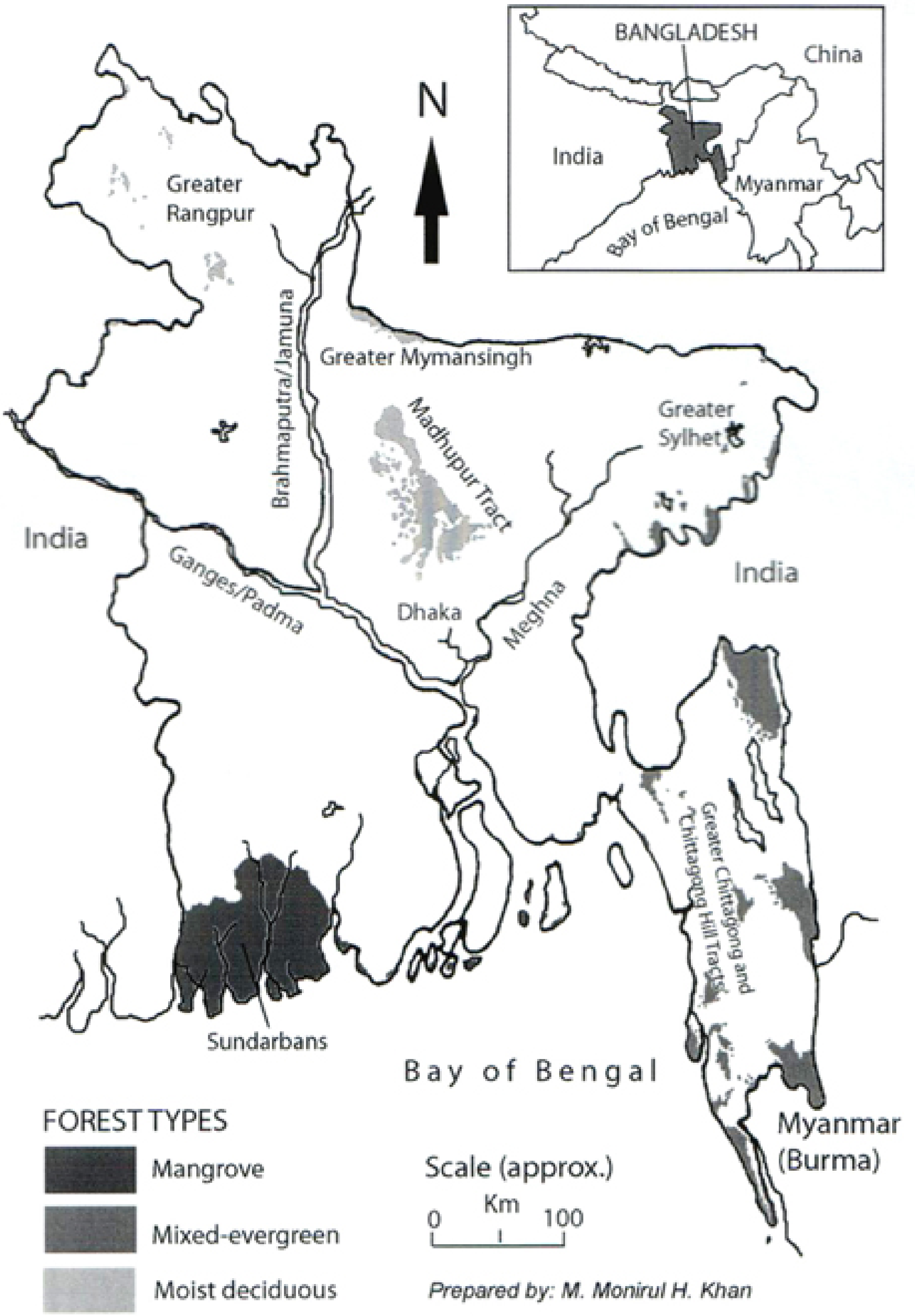


Figure 1. Forested areas of Bangladesh.

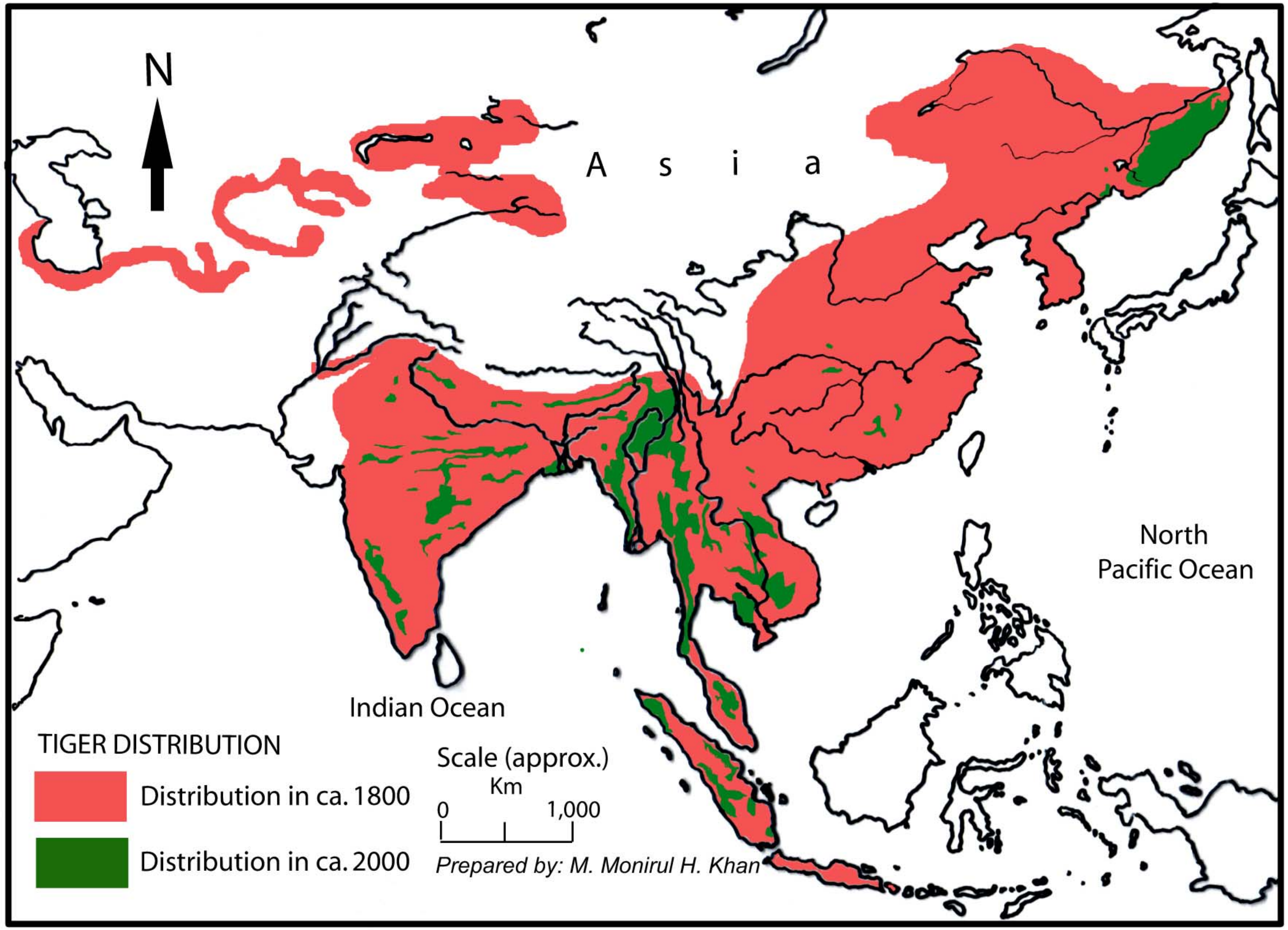


Figure 1.1 Global distribution of the tiger in ca. 1800 and ca. 2000.

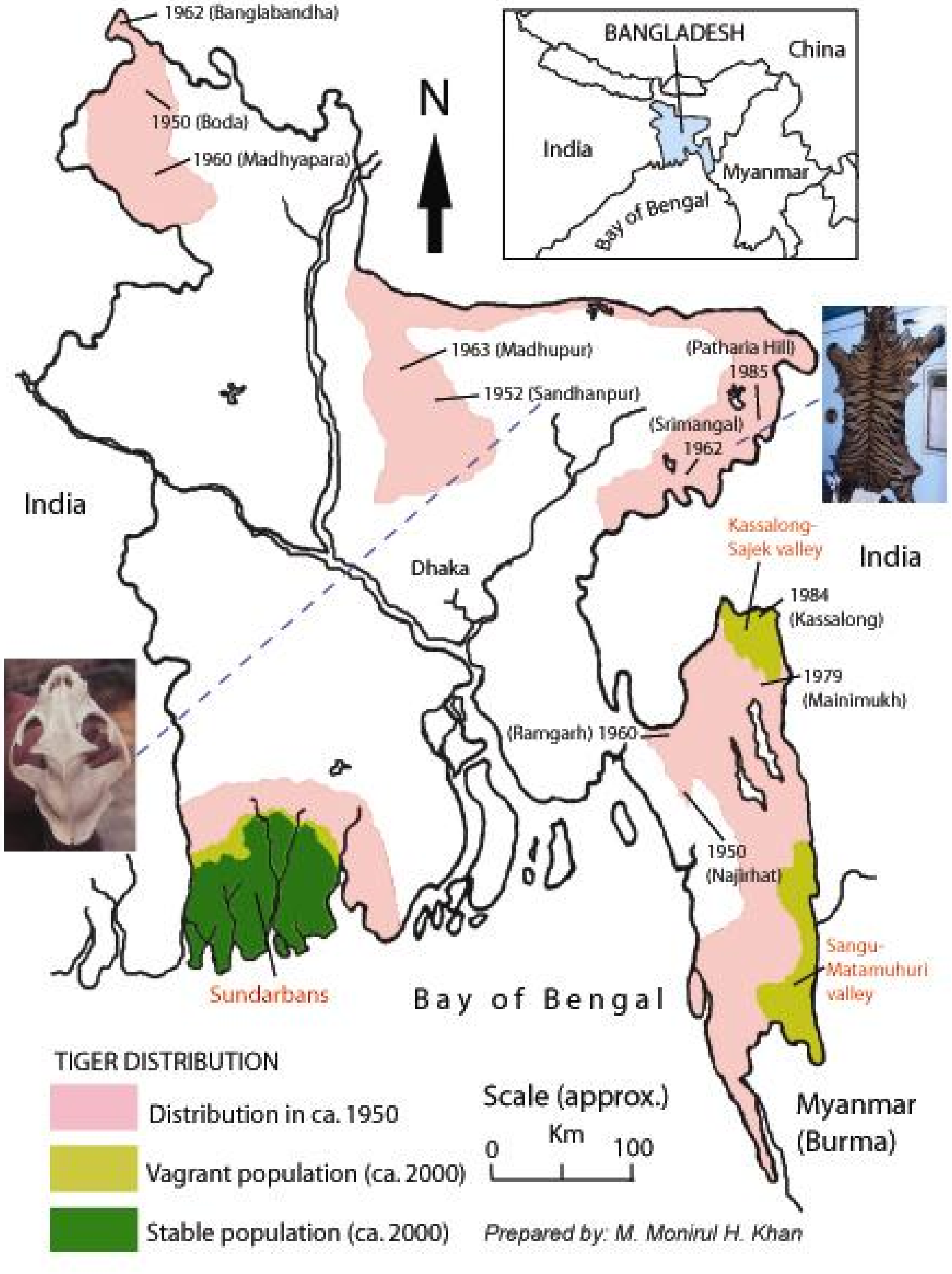


Figure 1.2 Tiger distribution in Bangladesh in ca. 1950 and ca. 2000.

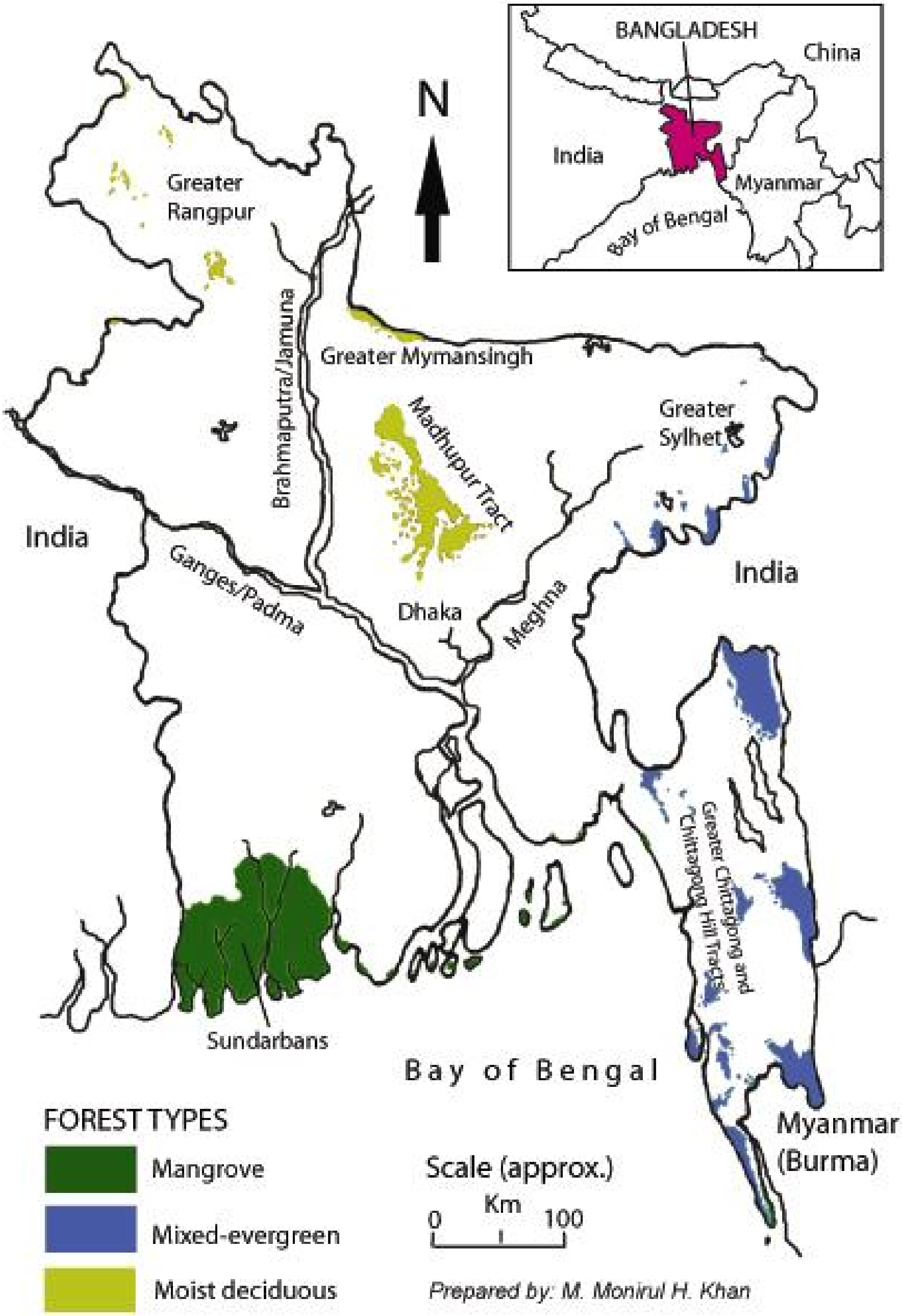


Figure 2.1 Forested areas of Bangladesh.

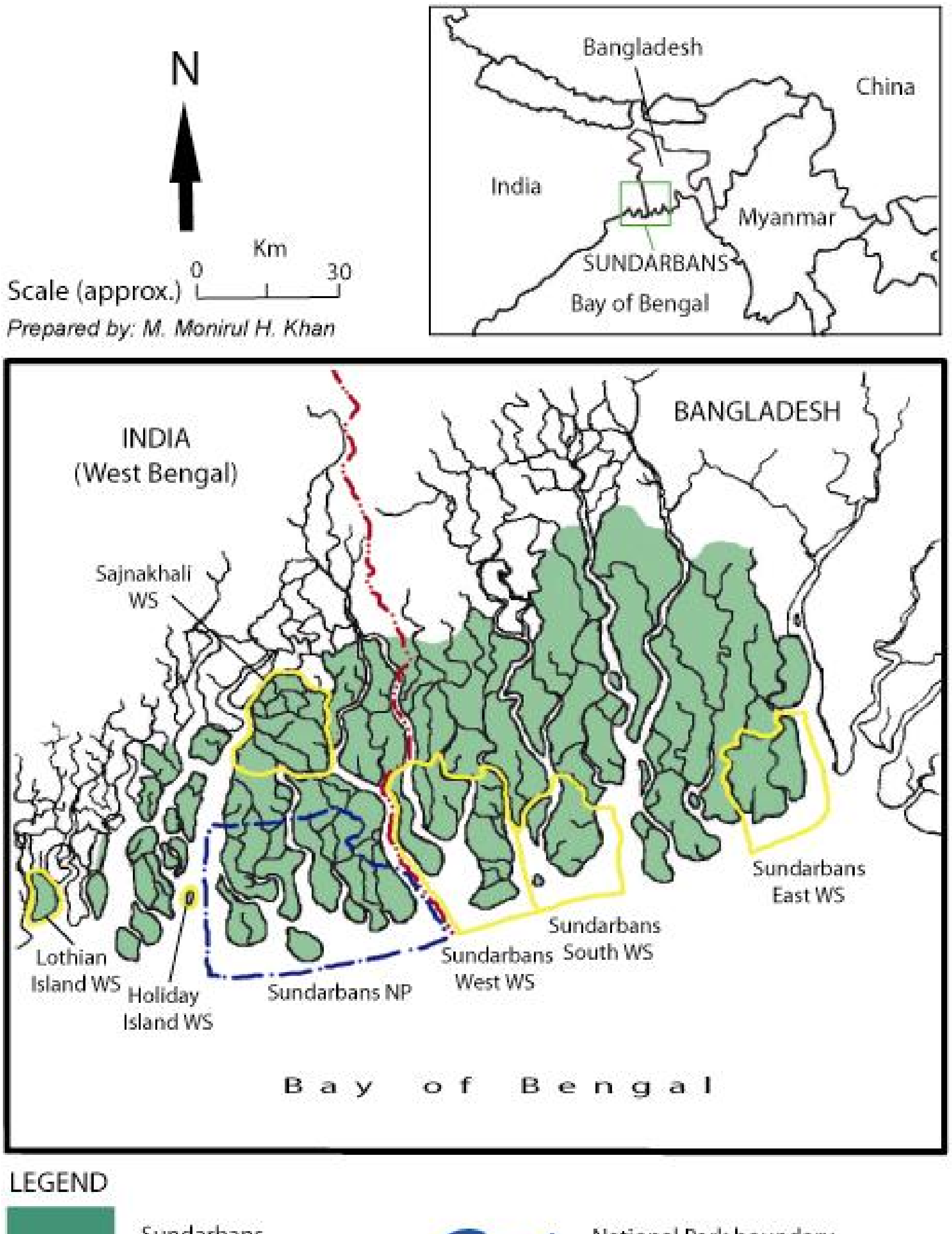


Figure 2.2 The Sundarbans of Bangladesh and India showing the National Park (NP) and Wildlife Sanctuaries (WS).

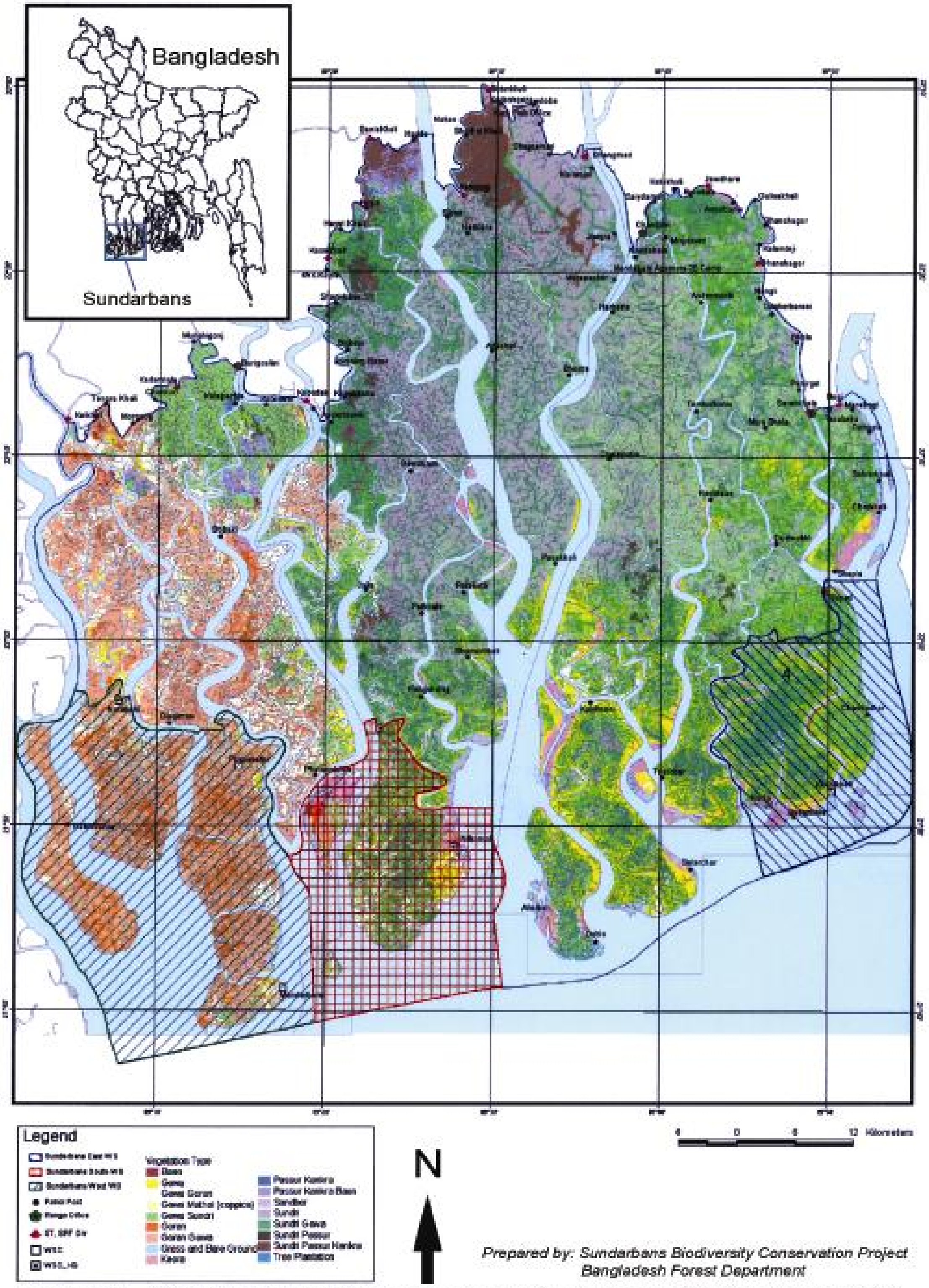


Figure 2.3 The Sundarbans of Bangladesh showing three Wildlife Sanctuaries (WS).

Figure 2.4 The Sundarbans East Wildlife Sanctuary of the Sundarbans of Bangladesh.

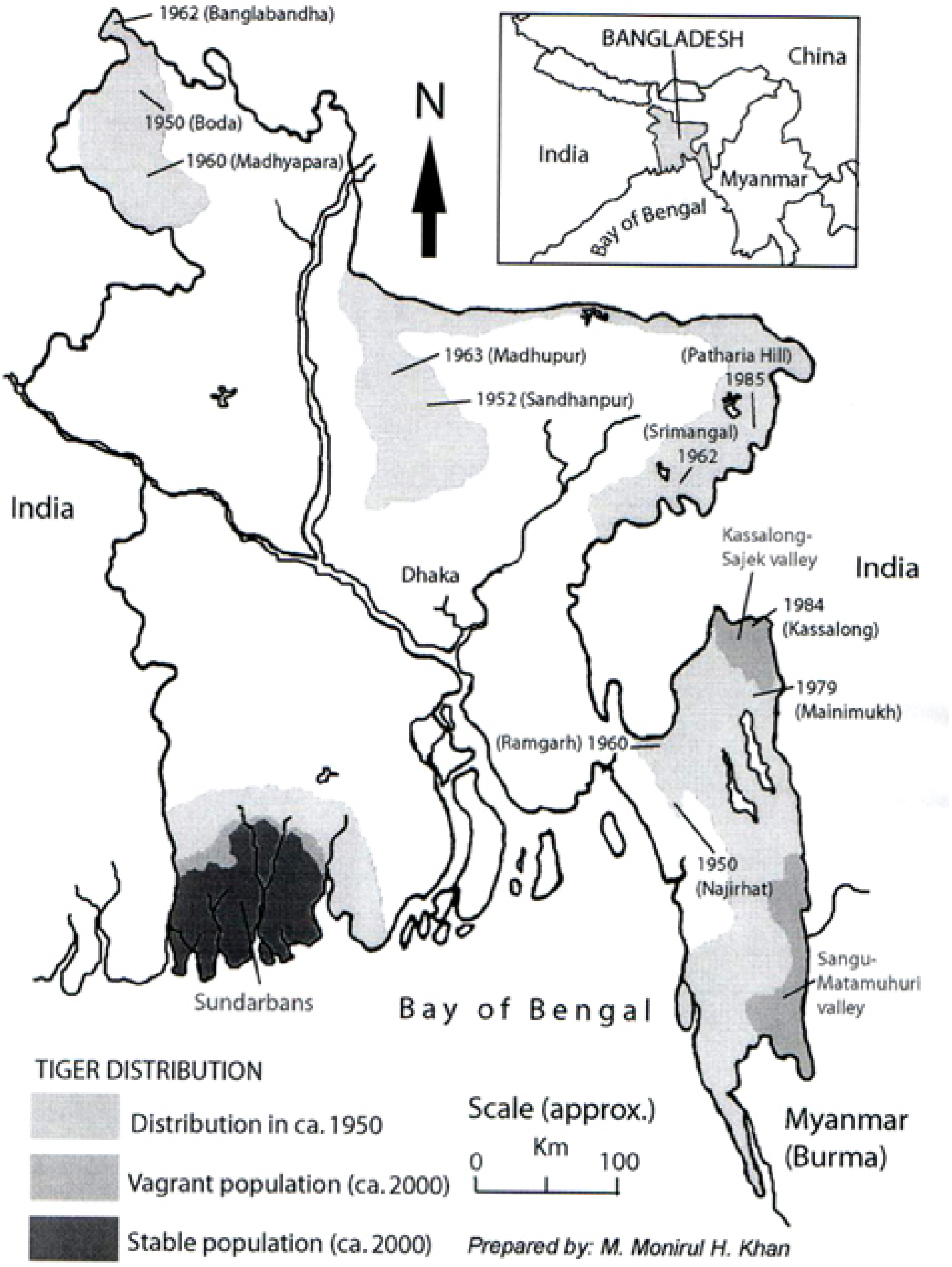
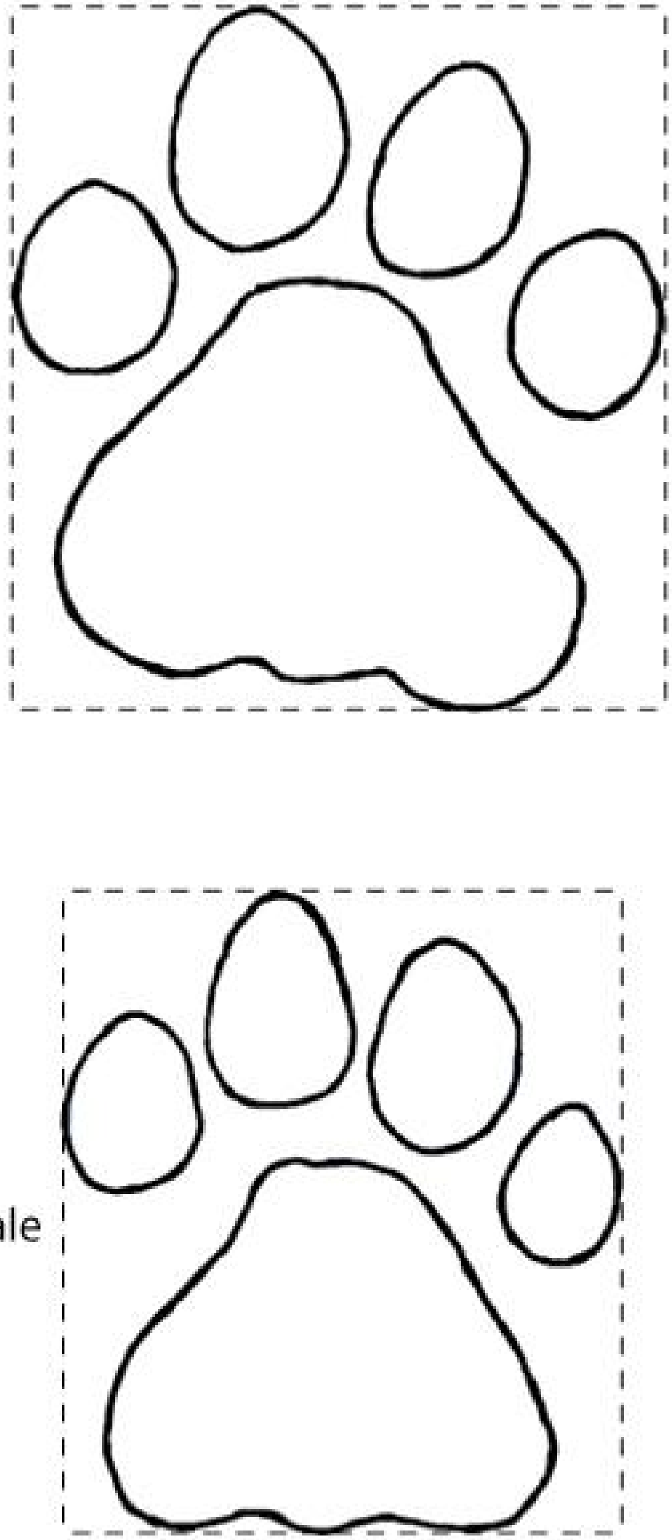


Figure 4. Tiger distribution in Bangladesh in ca. 1950 and ca. 2000.



Male

Female

Figure 6.1 The hind pugmark of a male and a female tiger in natural size.
N.B. The pugmark of a male is larger and can fit into a square box rather than a rectangle box in case of a female.

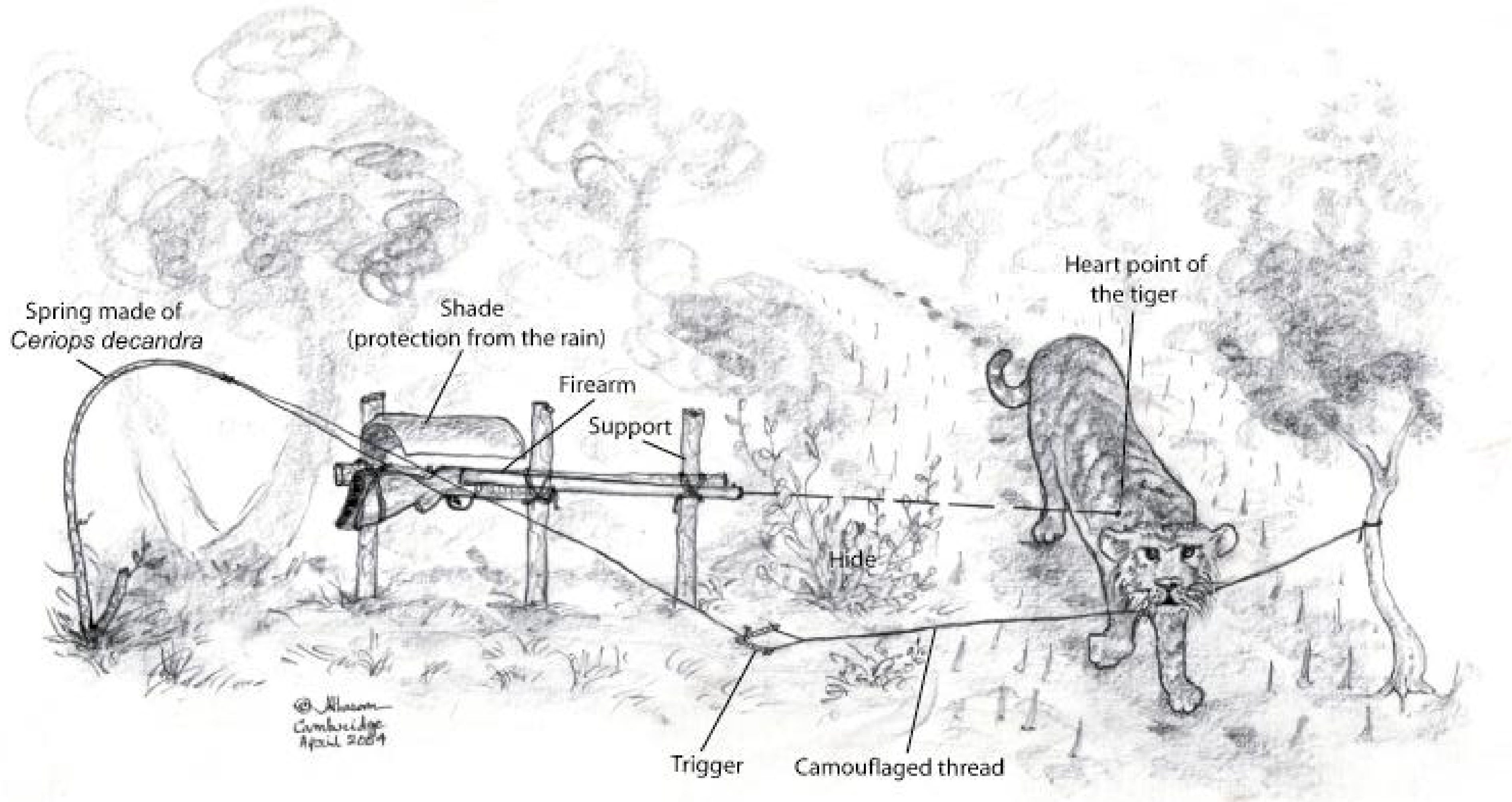


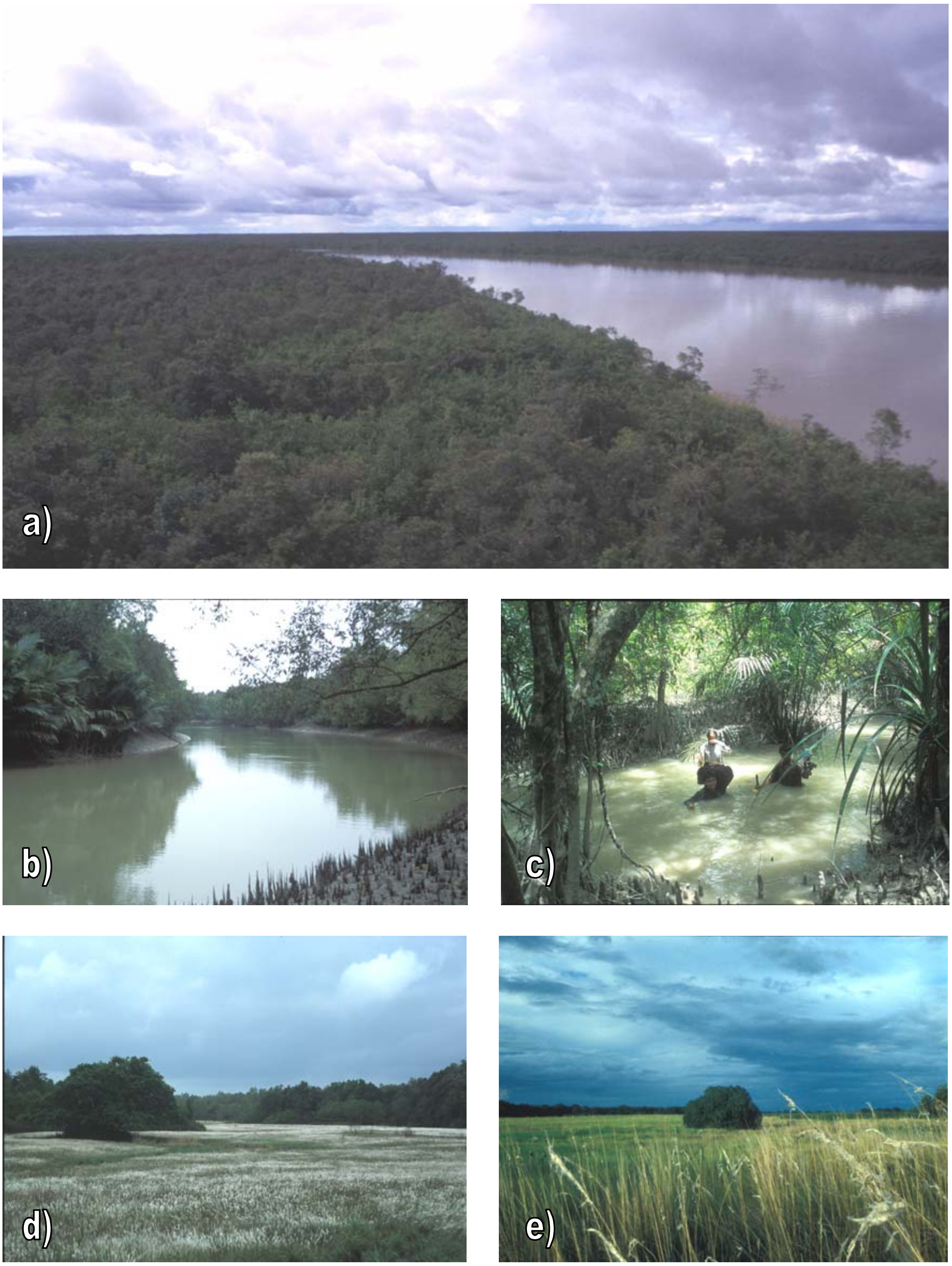
Figure 7.5 Diagram of firearm setting by poachers to kill the tiger.

A curious young tiger in Supati, Sundarbans East Wildlife Sanctuary.

An ancient replica of the tiger found in Razaram Roy's Temple in the vicinity of the Sundarbans.

Stuffed specimens of eight sub-species of the tiger, including three extinct sub-species, in the Natural History Museum, Geneva, Switzerland.

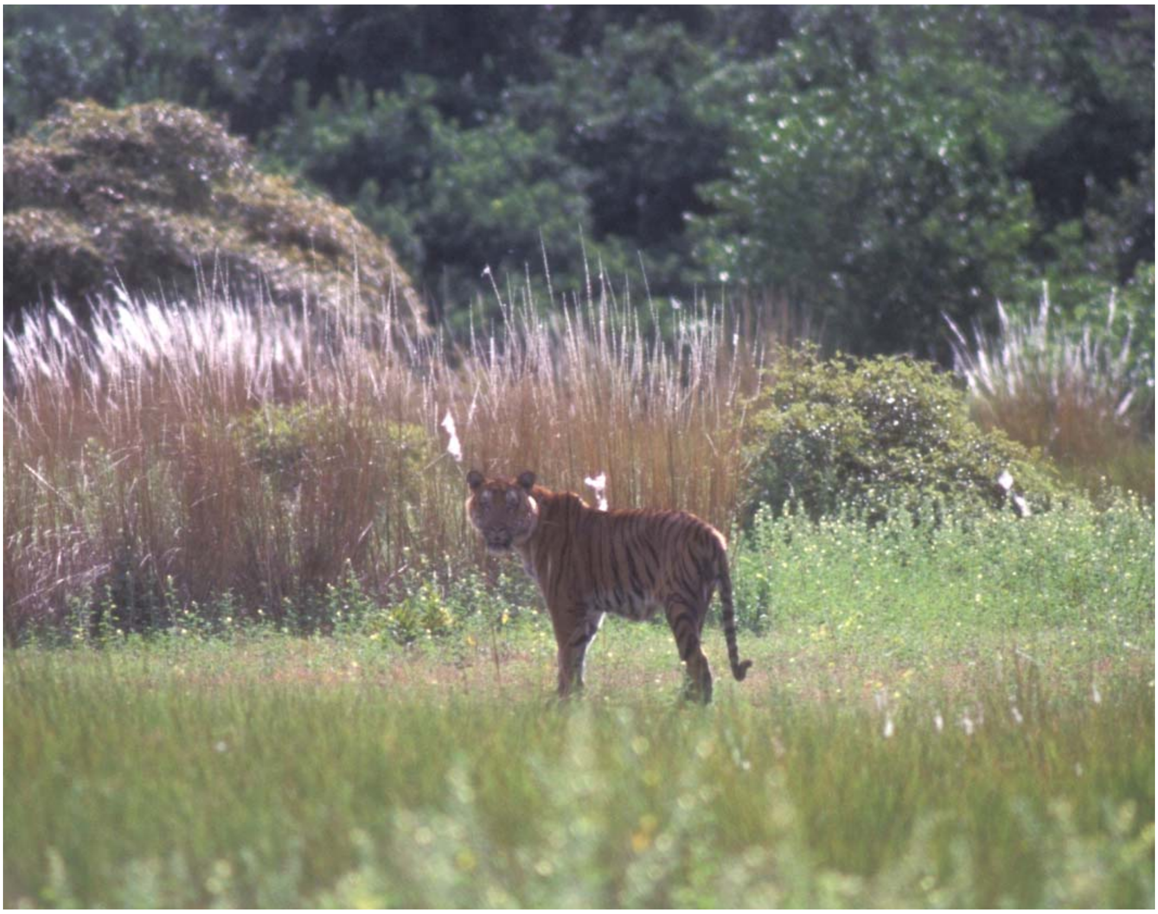
Plate 2



Various landscapes of the Sundarbans: a) aerial view, b) view from a creek, c) view inside the forest, d) view of a grassland in April, and e) view of a grassland in October.

Prey species of tigers in the Sundarbans: a) spotted deer, b) wild boar, c) rhesus macaque, d) lesser adjutant, e) red junglefowl, and f) ring lizard.

Plate 4



An adult male tiger in Jamtala, Sundarbans East Wildlife Sanctuary.

Plate 5

Tiger scat collection and analysis: a) a tiger is defaecating, b) fresh scat, c) sun-drying of scats, d) scat analysis, and e) prey and other remains found in scats.

Plate 6

Kill of the tiger: a half-eaten spotted deer.

Remains of a lesser adjutant killed and eaten by a tiger.

Plate 7

Tiger signs: a) track on the sand, b) scratching in a *Lannea coromandelica* tree, and c) indication of drinking.

A young tiger hidden in dense mangroves of Supati, Sundarbans East Wildlife Sanctuary.

Tracks of a tigress (centre) with two cubs on two sides.

Interviewing local people in Napitkhali in the northern end of Satkhira Range, Sundarbans.

Recording daily protein intake of a local family in Bouddamari in the northern end of Chandpai Range, Sundarbans (note the antler of a spotted deer at the background).

Plate 10

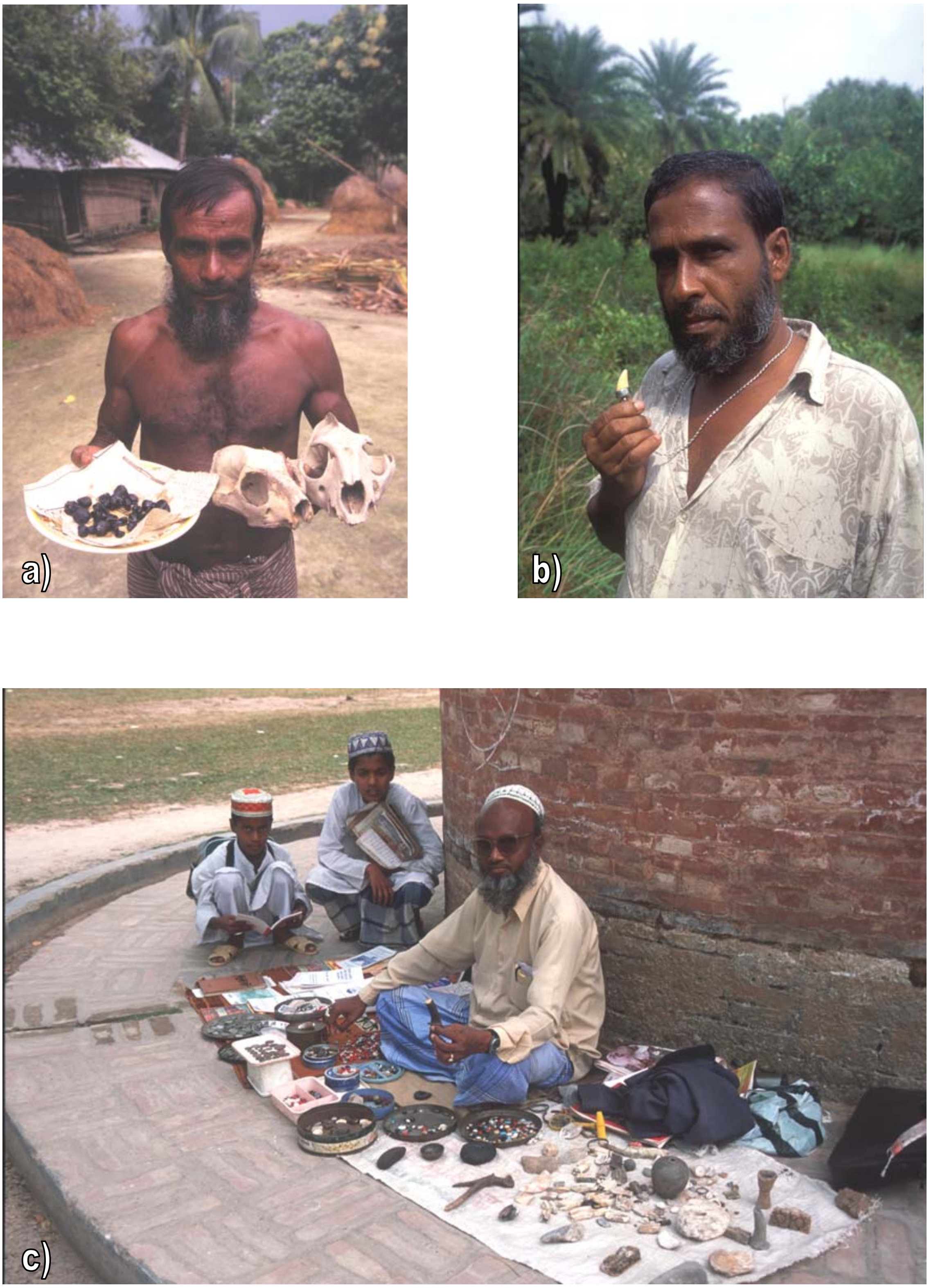
A fresh skin of a tiger that was poached in Chandpai, Sundarbans.

A sub-adult male tiger that was found dead during the fieldwork in Kochikhali, Sundarbans East Wildlife Sanctuary.

Plate 11

People attacked by man-eating tigers: a) Monu Mollah had a paw on the head from the back, b) Ziaul Gazi had a bite on the leg and paws on the body, c) Siddik Ali had a bite on the head, and d) Mostafa Howlader had a paw on the head.

Spiritual protection measures taken by people in the Sundarbans: a) forest deities worshipped before entering the forest so that the deities save people in danger, b) sacred bead is carried in the belief that this will protect the carrier from the tiger, c) spiritual red flag is set in the working area so that the tiger cannot approach, and d) goats are sacrificed by releasing them in the forest in order to please the spirit of the Sundarbans.



Use of tiger parts: a) tiger bones and genital organs are used as medicine, b) tiger canine is used as a locket in the belief that this will increase strength and vigour, and c) wildlife parts are openly sold in Bagerhat, 30 km away from the Sundarbans (this salesman claimed that he had a tiger tooth for sale).

Plate 14

Poaching in the Sundarbans: a) spotted deer hidden on the poachers' boat, b) two poachers arrested with 162 snare traps for deer and a bottle of poison to poison the tiger kill, c) snare traps for the red junglefowl, and d) illegal logging of a timber tree *Heritiera fomes.*